Feasibility Study on Wind Energy in Samoa

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Abstract

Energy is a critical element behind Samoa's strategy for economic growth and social development. The demand for energy in Samoa has risen exponentially making Samoa reliant on fossil fuels such as petroleum. This paper presents a feasibility study of a proposed wind energy system in Samoa. This study is based on year round recorded wind speed data. The data analysis, descriptions and performance of the system are presented in this paper. Two wind masts poles/towers with wind masts attached were constructed at Afulilo (3 masts) and Aleipata (Satitoa) (2 masts). These wind masts recorded wind speed or wind velocity and direction every 10 minutes into a wind vane and anemometer (wind speed measuring device) from the period 2006-2008. The heights of these wind masts ranged from 10m–30m above ground level. It is possible that for the average wind speeds of at least 6 m/s with the exact height could produce electricity. The wind speeds are in the 15-25 m/s range, conditions could be right for a wind mill that might supply 17–18 MW of power per day for this island.

Key Words: renewable energy, wind power, Samoa

Introduction

The use of renewable energy is not new. More than 150 years ago, wood which is one form of biomass, supplied up to 90% of our energy needs. As the use of coal, petroleum and natural gas expanded, few developed countries became less reliant on wood as an energy source. Today, researchers and scientists are looking again at renewable resources to find new ways to use them to help meet our energy needs. In the 1970s, oil shortages pushed the development of alternative energy sources [1]. Renewable energy plays an important role in the supply of energy. When renewable energy sources are used, the demand for fossil fuels is reduced. Unlike fossil fuels, non-biomass renewable sources of energy (hydropower, geochemical, wind and solar) do not directly emit greenhouse gases [2]. In the 1990s, the push came from a renewed concern for the environment in response to scientific studies indicating potential changes to global climate if the use of fossil fuels continues to increase [3]. Renewable energy sources can be replenished in a short period of time. The five renewable sources used most often are: biomass (ethanol and biodiesel), water (hydropower), geothermal, wind and solar [4]. Renewable energy is used for electricity generation, heat in industrial processes, heating and cooling buildings and transportation fuels. Two of the most common types of renewable energy are wind and solar [5]. Wind energy is an economical power resource in many areas of the world. Wind is a clean fuel; wind farms produce no air or water pollution because no fuel is burned. Growing concern about emissions from fossil fuel generation, increased government support and higher costs for fossil fuels (especially natural gas and coal) have helped wind power capacity in developed countries grow substantially over the last 10 years. Wind is a widely distributed energy resource. Between 30ºN and 30ºS, air heated at the equator rises and is replaced by cooler air coming from the south and the north [5]. Samoa is located east of the International Date Line and south of equator about halfway between Hawaii and New Zealand in the Polynesian region of the Pacific

Ocean [6]. It consists of two large islands of Upolu and Savaii which account 99% of the total land area. The main island of Upolu is home to nearly three-quarters of Samoa's population and its capital city is Apia [6]. With Samoa so close to the equator, it could therefore take advantage of this situation to produce wind energy to supply the country's energy needs. The motivation to undertake this research arises from the fact that the price of fossil fuel products such as petrol and diesel among others, has risen exponentially over the last couple of years. Because Samoa has to import these fossil fuel products from overseas, the prices of such necessities as electricity, water and food will also be on the increase [7]. So there is a real need to develop and apply technologies that will enable Samoa to use its renewable energy sources in the most efficient ways Wind is also readily available along the coastal areas of the islands so this can be utilized to produce wind energy, hence the installation of wind turbines at Afulilo and Satitoa to trial this other form of renewable energy. Thus the purpose of this research was to carry out a technical study of wind monitoring masts installation so as to advice the Samoan Government and related agencies to decide whether to proceed to the installation of a wind farm and secure funding for the project.

Methodology

Data for monitoring wind masts at Afulilo and Aleipata (Satitoa) was collected, filed and achieved by the Electric Power Corporation (EPC). Two wind masts with wind masts attached were constructed at Afulilo (3 masts) and Aleipata (2 masts). These wind masts recorded wind speed or wind velocity and direction every 10 minutes into a wind vane and anemometer (wind speed measuring device) from the period 2006-2008. The heights of these wind masts ranged from 10m–30m above ground level. These data is logged onto microchips that EPC downloads onto a laptop for analysis. All the data (wind speed and direction), filed and tabulated using spreadsheets in Microsoft Excel. For our feasibility study, we statistically analyzed these data (wind speed and height of wind masts) to determine the correlation of heights of these wind masts and average wind speed within the 12 month period. It is possible that for the average wind speeds of atleast 6 mph with the exact height could produce electricity. But if the wind speeds are in the 15-25 mph range, conditions could be right for a wind mill that might supplies power for some part of this island. The wind turbine monitoring masts site at Afulilo is located in the Afulilo hydropower storage scheme which is located in the eastern part of the Upolu Island. Aleipata (Satitoa) site is located 13°58′60 S and 171°22′0 W (Fig.1).

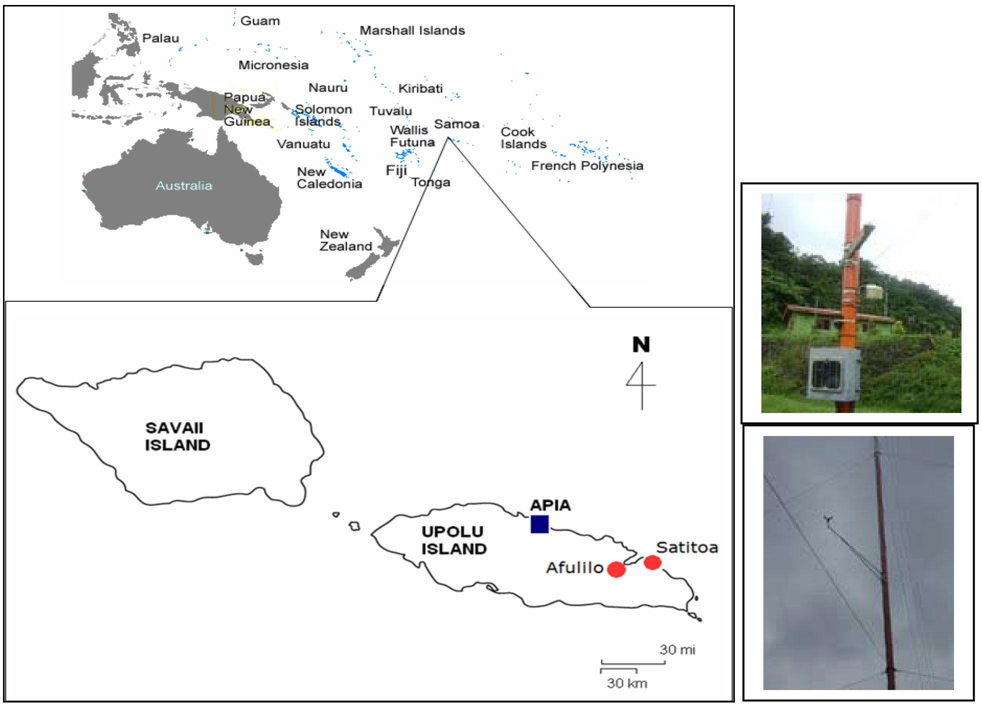

Fig.1. Map showing wind masts

Results and Discussion

Afulilo site

Each calculation has multimode however it has not been included in the analysis because it's meaningless. As seen in Table 1, there is no significant difference in the statistical results thus proper tests are required to show the significant difference.

Table 1: Overall Statistics Results

	(10m)	(20m)	(30m)
MEAN	3.03	3.77	3.79
MEDIAN	2.80	3.60	3.60
VARIANCE	3.64	5.02	5.40

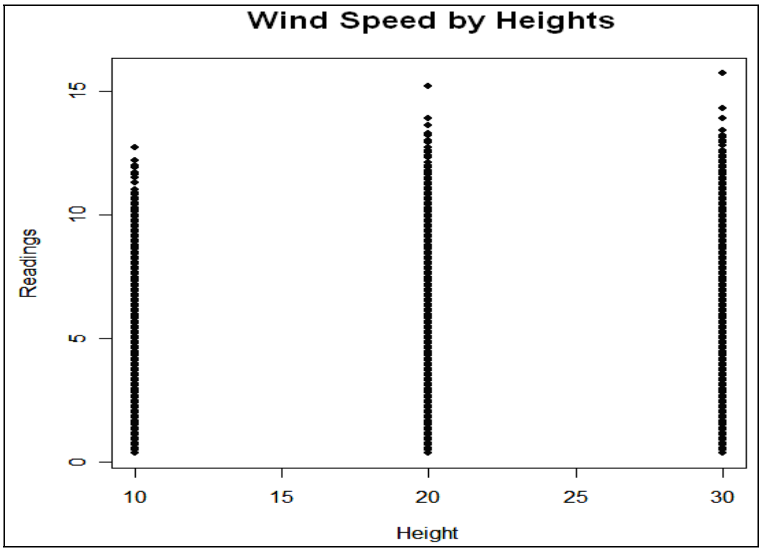

Fig.2. Wind speed by heights

As seen in Fig.2.there may be a significant difference between 10m and the other two. i.e. 10m might be less however there seems to be no difference between 20m and 30m.Hence, from Table 1 we can see that high wind speeds are given by 20m and 30m. However, tests given by ANOVA shows that height is positively correlated with the amount of wind speed. i.e. amount of wind speed increases with an increase in height. Regression model support the above results regarding positive correlation. However, the correlation coefficient of 0.1409255 $\left(\sqrt{0.01986}\right)$ is too small which happens when the correlation is weak (this may be due to unpredictable windspeed at various time of the day. i.e. calm days can give zero readings which in this case are extreme which are treated in regression as high-leverage and influential points).

Table 2. Monthly Statistics for the three channels

MONTHS	10m MEANS	10m Variance	20m MEANS	20m Variance	30m MEANS	30m Variance
Nov.06	3.56	3.822	4.27	4.561	4.45	4.629
Dec.06	2.28	2.793	2.76	3.604	2.81	3.827
Jan.07	3.44	4.082	3.99	5.351	4.00	5.785
Feb.07	2.06	2.703	2.60	3.770	2.58	4.067
Mar.07	2.10	2.595	2.82	4.082	2.77	4.205
Apr.07	2.52	2.754	3.12	3.416	3.12	3.619
May.07	2.87	3.670	3.50	4.486	3.42	5.044
Jun.07	4.08	3.395	4.88	4.184	4.95	4.540
Jul.07	3.86	3.653	4.69	4.420	4.70	4.937
Aug.07	4.47	3.300	5.44	4.131	5.49	4.613
Sep.07	3.74	4.127	4.59	5.553	4.58	6.140
Oct.07	2.81	2.875	3.36	4.081	3.31	4.534
Nov.07	2.52	2.539	3.37	4.107	3.41	4.438
Dec.07	2.74	2.722	3.49	5.037	3.56	5.344
Jan.08	3.03	2.923	4.04	5.365	4.11	5.777
Feb.08	2.68	2.573	3.61	3.799	3.69	3.964

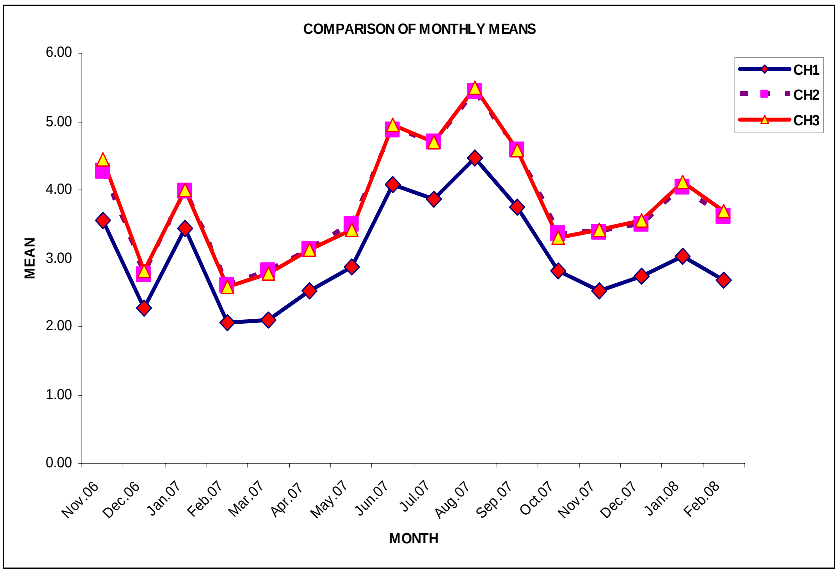

Fig.3. Comparison of means

In Fig.3 confirms that there is no significant difference between 20m and 30m. Also 10m output is less than 20m and 30m not just the overall but monthly.

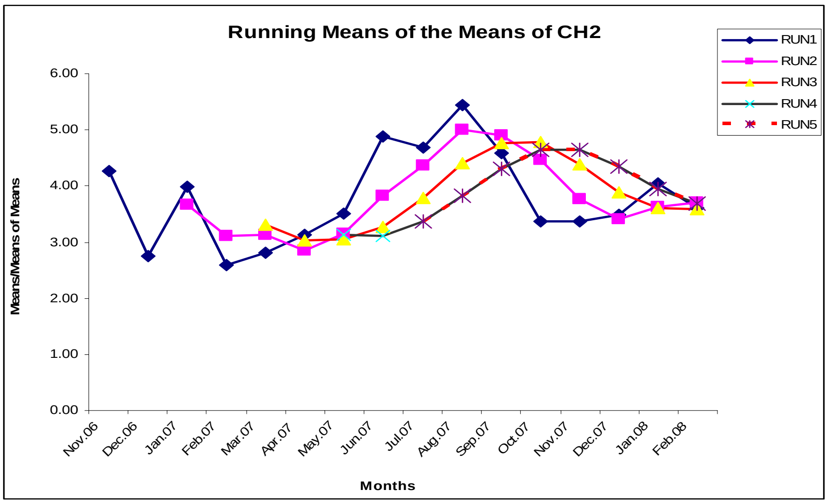

Fig.4. Running Means of the Means of 20m

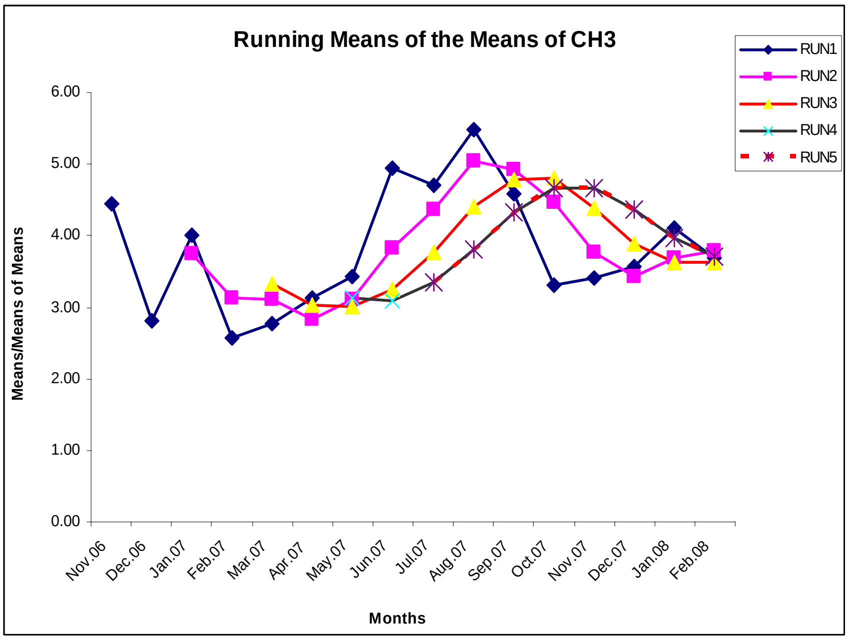

Fig.5. Running Means of the Means of 30m

In Fig.4 and Fig.5 shows that it is not possible to smooth the curve of the output due to the yearly average or even a seasonal average is not possible to predict and wind speed is unpredictable (as described in Fig.2).

Aleipata site

Each calculation has multimode however it has not been included in the analysis because it's meaningless. There is a significant difference between the two channels. Variability however is similar for both heights which means the difference between individual readings from the same height is totally attributed to the difference in the condition (excluding the difference in height) of the time readings were taken.

Table 3. Overall Statistics Results

	(10m)	(30m)
MEAN	2.44	4.61
MEDIAN	1.50	4.60
VARIANCE	5.30	5.55

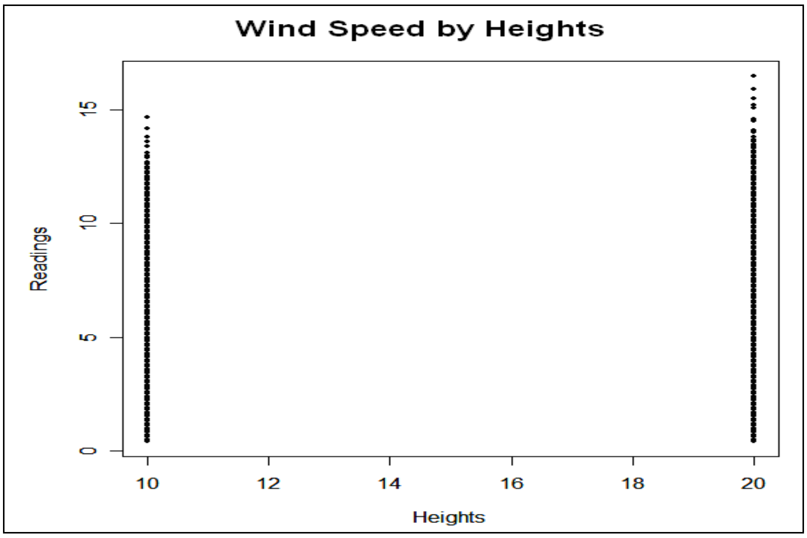

Fig.6. Wind speed by heights

There is a difference spotted as we have seen from the statistics results in Table 4.The p-value of 2.2×10^{-16} confirm that the difference alluded above is statistically significance. Note that although the p-value are similar, the F-test statistics is much larger because means square variation is large. This indicates, as comparison, that the difference here is much stronger than that given by the results of Afulilo. The regression model support the results above regarding positive correlation. Again, the correlation coefficient of 0.4215 $\left(\sqrt{0.1777}\right)$, (similar reasons as stated for Afulilo site). This shows a stronger correlation regards to heights.

Table 4. Monthly Statistics results for the two channels

MONTHS	10m MEANS	10m Variance	20m MEANS	20m Variance
Jun-07	0.40	0.000	6.38	6.756
Jul-07	0.40	0.000	5.55	4.577
Aug-07	0.40	0.000	6.29	3.457
Sep-07	0.40	0.000	4.91	5.120
Oct-07	1.09	2.785	3.91	5.090
Nov-07	3.32	3.755	3.88	4.313
Dec-07	3.76	4.485	4.27	5.114
Jan-08	4.15	5.974	5.01	7.004
Feb-08	3.41	3.960	3.90	4.062
Mar-08	3.33	3.430	3.91	3.526
Apr-08	3.30	3.716	3.80	3.814
May-08	3.24	4.411	3.82	4.360
Jun-08	5.33	5.373	5.86	6.426

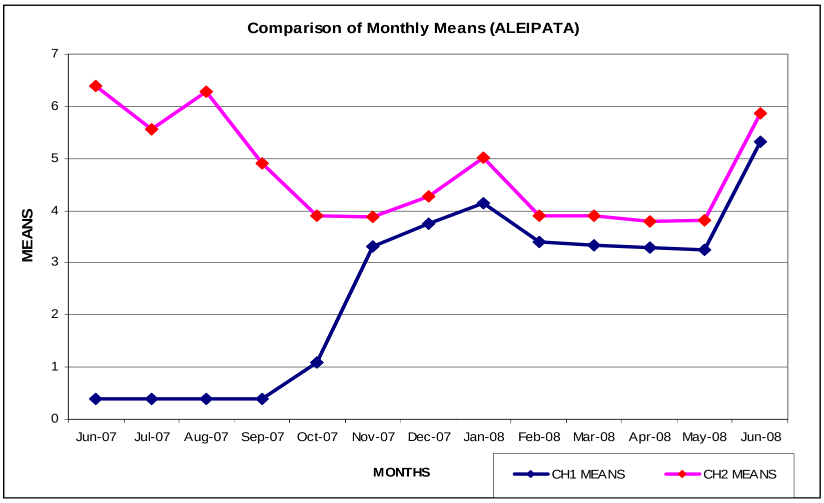

Fig.7. Comparison of the means (Aleipata)

In Fig.7 confirms the difference shown above however from this readings on 10m in the first four months seem unrealistic, this maybe due to technical problems with the measuring device. However, readings recorded afterwards still confirm that wind speed from 20m is greater than that of 10m.

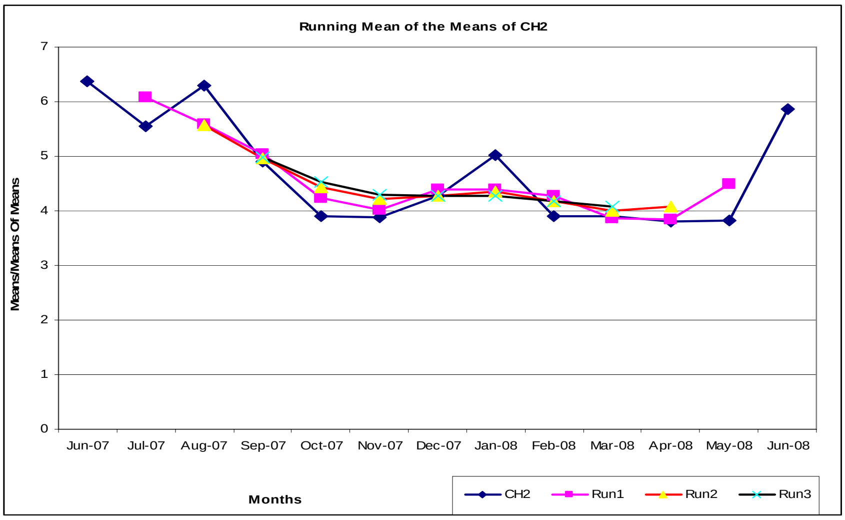

Fig.8. Running Means of the Means of 20m

In Fig.8 gives a near perfect smooth curve thus gives an estimate average for 20m is possible. However, how meaningful it could be in our context is questionable.

Comparison of Afulilo & Aleipata

The analysis here is done only for the month's common in both June 2007 – February 2008.
In Fig.10 suggests that the weather condition are the same (i.e) if the wind speed for 20m (Aleipata) increases so as wind speed recorded in 20m (Afulilo). The results showed that the wind speed in Aleipata is higher compared to Afulilo.

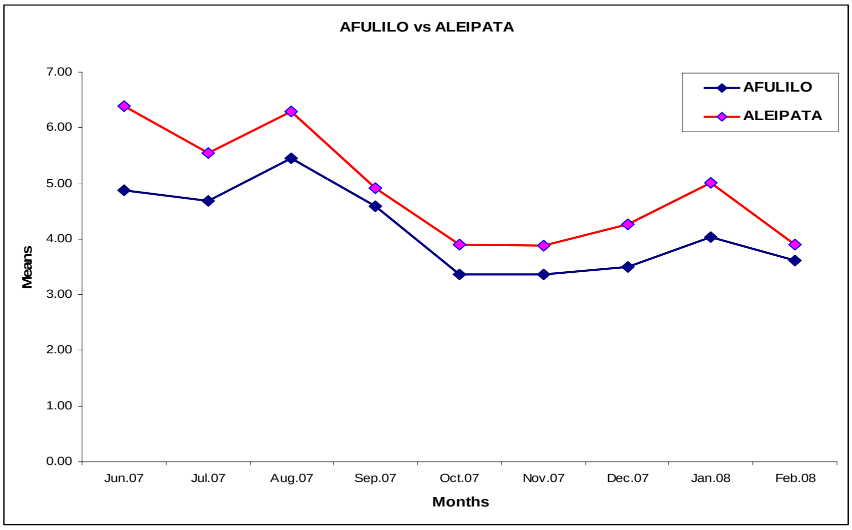

Fig.9. (Afulilo) 20m vs (Aleipata) 20m

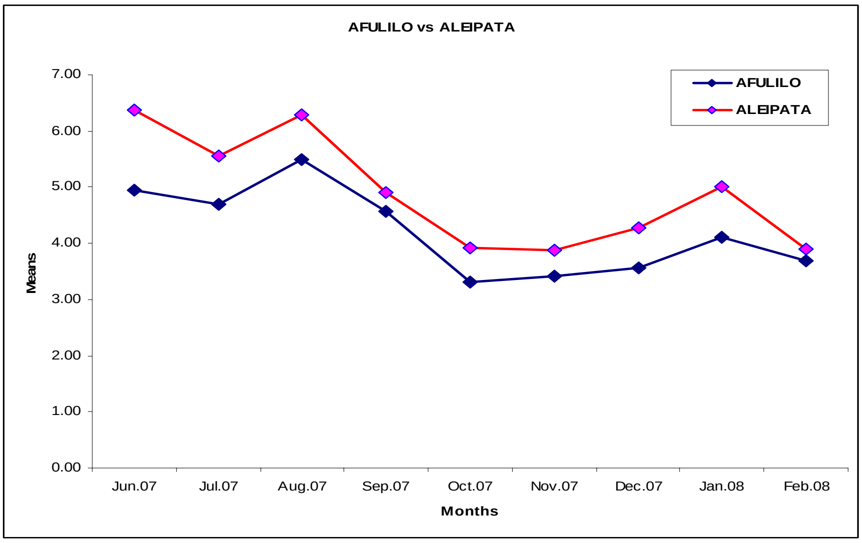

Fig.10. (Afulilo) 30m vs (Aleipata) 20m

Afulilo site

The mean and median are very similar (see Table 4) thus the wind speed readings distribution is approximately normal. However, the distribution skewed slightly to the left which is understandable in this situation. There are two causes; upper extreme happens rarely when there is strong wind and most days are calms or almost calm, readings will be very low (or zero).

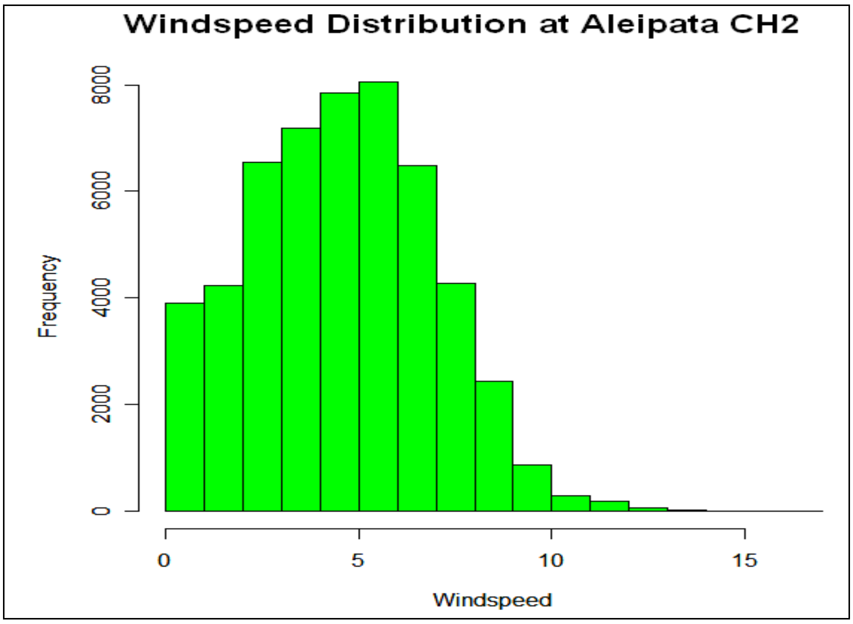

Fig.11. Distribution of windspeed at Aleipata (20m)

The general estimate is 4.61 with a 95% margin of error of 0.031. i.e. General estimate is that windspeed is between 4.579 and 4.641. Fig.12 concludes that all months are feasible. There is a good chance that these values are under-estimate.

Table 5. Monthly estimates

MONTHS	Monthly Interval Estimates
Jun-07	6.273 - 8.397
Jul-07	5.488 - 7.330
Aug-07	6.236 - 7.743
Sep-07	4.843 - 6.911
Oct-07	3.844 - 6.146
Nov-07	3.818 - 5.946
Dec-07	4.204 - 6.415
Jan-08	4.933 - 7.327
Feb-08	3.839 - 5.900
Mar-08	3.855 - 5.771
Apr-08	3.742 - 5.764
May-08	3.759 - 5.914
Jun-08	5.744 - 7.912

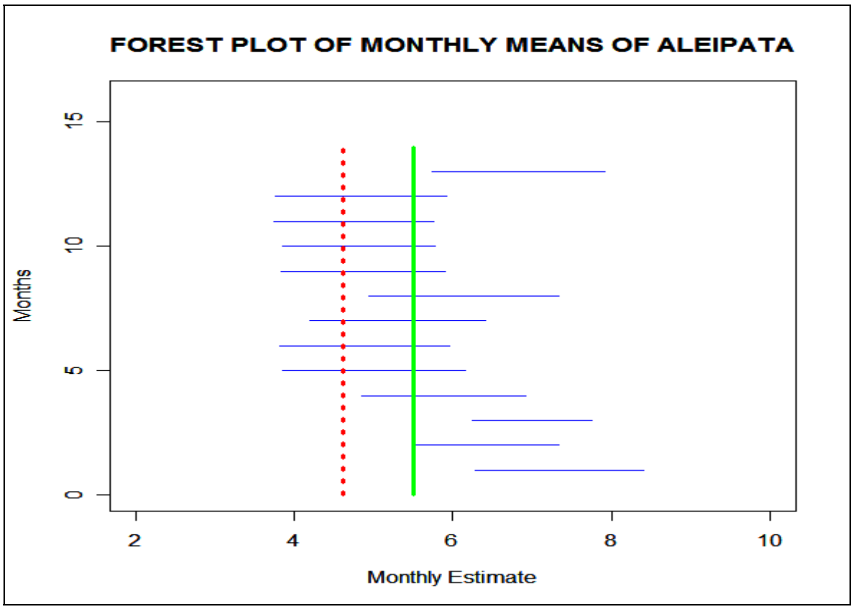

Fig.12. FOREST Plot of monthly means of Aleipata

Afulilo Site

For both 20m and 30m, means and medians are very similar (see Table 2) thus the wind speed readings distribution may be approximately normal. However, the distribution skewed to the left and thus it can be considered non-normal. Explanations are similar to the Aleipata estimates.

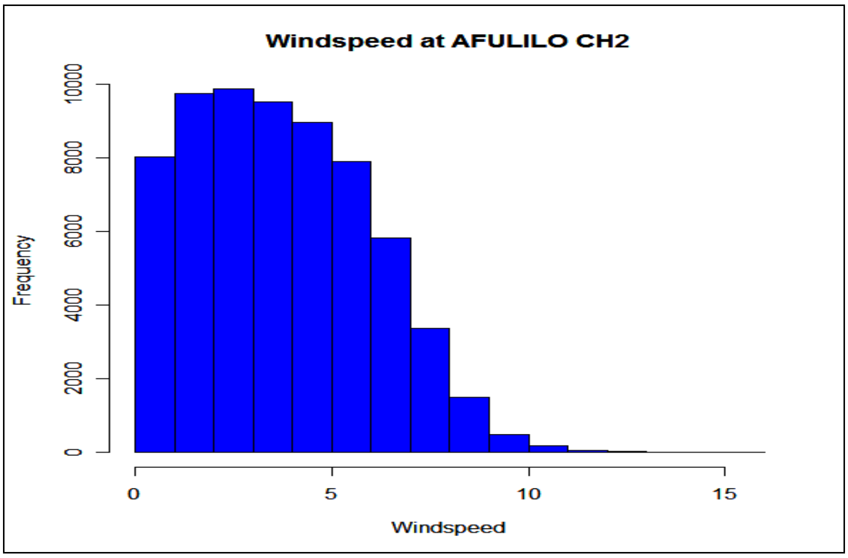

Fig.13. Distribution of windspeed at Afulilo (20m)

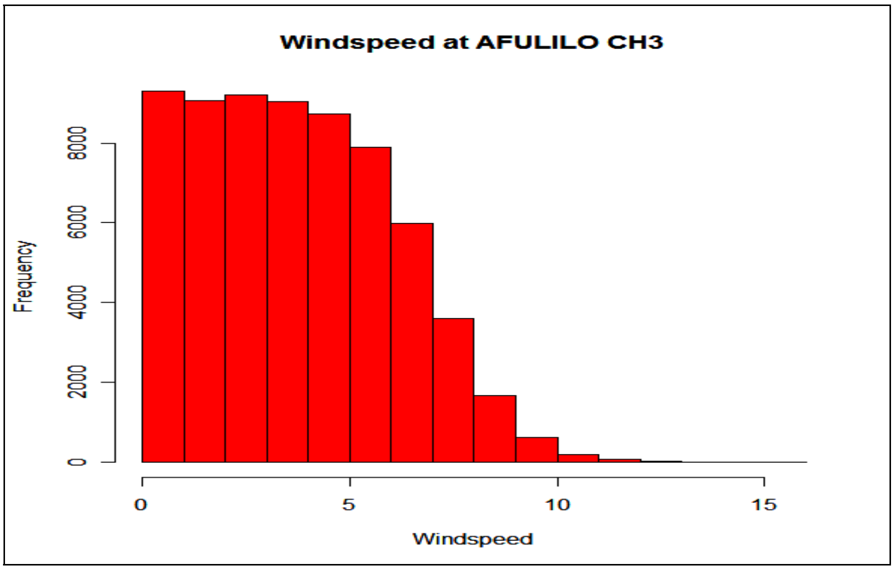

Fig.14. Distribution of windspeed at Afulilo (30m)

General estimate is 3.77 and 3.79 for 20m and 30m respectively. Their respective 95% margin of errors are 0.017 and 0.018.

Table 6. Monthly estimates

MONTHS	20m	30m
Nov.06	4.181 - 4.358	4.361 - 4.539
Dec.06	2.704 - 2.815	2.753 - 2.867
Jan.07	3.922 - 4.058	3.929 - 4.071
Feb.07	2.519 - 2.680	2.496 - 2.664
Mar.07	2.761 - 2.879	2.710 - 2.830
Apr.07	3.066 - 3.174	3.064 - 3.176
May.07	3.437 - 3.563	3.353 - 3.487
Jun.07	4.820 - 4.940	4.887 - 5.013
Jul.07	4.627 - 4.752	4.634 - 4.766
Aug.07	5.380 - 5.499	5.427 - 5.553
Sep.07	4.521 - 4.659	4.507 - 4.653
Oct.07	3.299 - 3.421	3.245 - 3.375
Nov.07	3.311 - 3.429	3.348 - 3.472
Dec.07	3.423 - 3.557	3.491 - 3.629
Jan.08	3.972 - 4.108	4.039 - 4.181
Feb.08	3.520 - 3.699	3.598 - 3.782

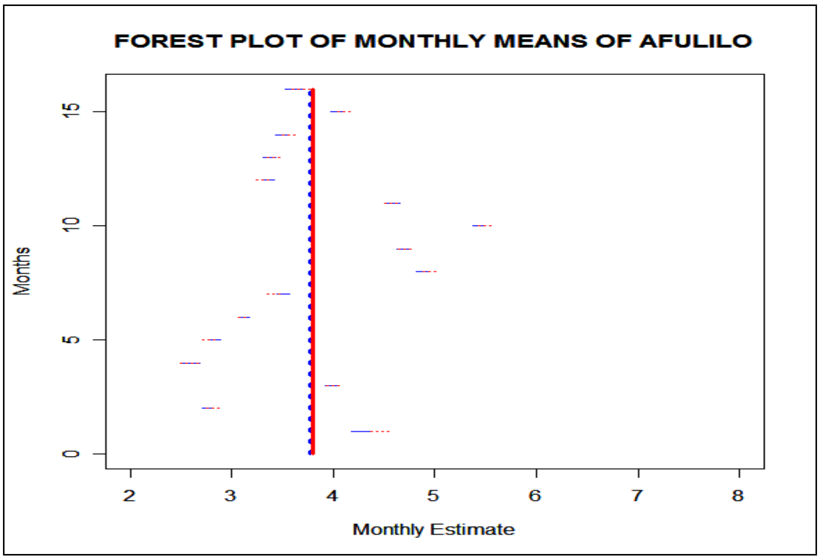

Fig.15. FOREST Plot of monthly means of Afulilo

Fig.15 concludes that not all months are feasible. There is a less variance variability of wind speed within a given month is small in both heights. This is confirmed by the FOREST plot shown above.

Conclusion

A feasibility study looks at different on-site renewable energy technologies available to see which, if any, could be used. In regard to feasible sites, both sites considered the best sites based on all factors considered in this analysis. Since wind resources in Satitoa are expected to be marginally feasible, it will be important to monitor the wind for an eighteen month period to verify that the wind resources used in this analysis are representative of conditions at the project site. As with Afulilo site specific monitoring data should be obtained prior to design and installation of the turbine. The actual site selected for turbine installation will be dependent upon the results of the EPC site survey.

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