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RESEARCH ARTICLE

ASSESSMENT OF SOLAR ENERGY AND WIND PARAMETERS IN NAIVASHA, KENYA.

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Abstract

Solar energy is one of the most reliable sources of renewable energies (RE) and it contributes to the existence of other renewable energy sources. Due to variation of the Sun temperatures and wind patterns, it influences the availability of hydro power, solar energy and wind regimes which can be harnessed using different technologies. Mainly solar energy is used in drying, cooking, water purification, heating and power generation. Wind energy, though intermittent has been used mainly for water pumping and to a lesser extent for power generation.
In this study the potential of solar energy and wind energy were assessed to depict the suitability of its usage in Naivasha (- 0° 43' 1.8408" S and 36° 25' 51.6936" E) and its environs. Naivasha has tourist attraction sites and therefore energy demand is very high in lodges, restaurants and other public amenities. Irradiance data (kW/m^2) and wind speeds (m/s) were collected and recorded per second for seven hours of sunshine per day and in 24 hours for wind speeds during the sampled period of the study (three months). The results showed that the site had maximum average wind speed of 4 m/s at 10 m height. The recorded insolation varied between a low of 1.21kWh/m^2 to a highest of 6.5kWh/m^2 while the irradiance ranged between 172W/m^2 and 925W/m^2 respectively.

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Introduction:-

Utilization of solar energy in Kenya is very low compared to Europe, Asia and America, Kenya being along the equator has the unique advantage of getting more energy because the irradiance reaching the earth is not affected much by Sun- Earth rotation throughout the year.

In recent years Government of Kenya has introduced guidelines and incentives to promote the renewable energy (RE) uptake; this include tax exemption for RE equipment, funding training in RE etc. Other Government bodies have been introduced such as Energy Regulation Commission (ERC), Rural Electrification Authority (REA) and they are working closely with private institutions. As a result of the government input, the prices of solar equipment has been reducing attracting more investor in RE, However researchers are required to be carried out research to assess the solar energy potential in Kenya for proper implementation of the guidelines(Energy, 2004).

Solar:-

Use of Photovoltaic system to harness solar energy is basically either by an On-grid solar system or Off-grid solar systems. Off grid solar system are suitable for rural areas where there is no access to transmission grids, in such

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systems electricity is generated by Solar PV and stored in batteries to be used at night when there no irradiance. On-grid solar systems are integrated to the grid and power generated by Solar PV is fed to the grid (Solar Direct , 2015).

Solar PV modules are designed to operate at standards test conditions of 1 kW/m^{2,} 25 ^{0}C for the cells to generate maximum current. However it is not practically possible for a module to operate at this conditions, each cell usually has a standard voltage output of between (0.5-0.6V) depending with cell type (monocrystalline or polycrystalline). Monocrystalline cells have higher efficiency than polycrystalline since they are made from high grade silicon, its efficiency rate is typically between 15-20% while the efficiency of polycrystalline is typically between 13-14% (S.Steven & Luque, 2003).

$$\text{Efficiency of module at } 1\text{kW}/m^2(\%) = \frac{power\ output}{Power\ input}\ x\ 100 \ldots\ldots (1)$$

Efficiency of the module is relative to the demission, therefore;

$$\text{Efficiency of module at given irradince}(\%) = \frac{Module\ rating\ (kW)}{Area\ m2\ x\ given\ irradince(\frac{kW}{m2})}\ x\ 100 \ldots\ldots (2)$$

The solar PV power generation is dependent to solar irradiance in a day which is affected by several conditions for instance; cloud, dust, shadow casted on the module and high temperatures of the modules. High temperature reduces the open circuit voltage (Voc) and increases the open circuit current (Isc) slightly while shadow, dust and soiling reduces the system current (Twidell & Weir , 2006).

Kumar & Rosen (2011) noted that efficiency of solar systems is very dependent to the irradiance, choosing solar PV and Solar Thermal Technologies for harnessing solar energy it is very important to consider the available daily irradiance.

The equation (1) below is modified to elaborate the effect of irradiance to the system current.

$$I_{(12V)} = \frac{I_{(sc)STC}\ x\ Irr.daily\ (kW/m^2}{1\ kW/m^2} \ldots\ldots (3)$$

Where *I* is the system current (charging current), *Isc* is the module short circuit current, Irr. Daily is irradiance per day.

In previous years several studies have been conducted within series of span to show the potential of solar energy in different part of Kenya. Okoola, (1997) observed that insolation reach its peak during the afternoon session. Barman, (2011) analyzed that annual insolation of Nairobi as 2100kWh/m^2. Both researchers conducted the assessment alone but never showed the level of the need in terms of future energy for the purpose of heat or electricity generation and no comparison of available energy sources was done.

Wasike *et al.*, (2014) assessed solar radiation in Thika and Nairobi area to provide information on the solar energy source of the two regions using Gunn-Bellani and Pyranometer to collect data for analysis. From the analysis, it was concluded that the average annual daily insolation ranged from 4-6 kWh/m^2/day and the average monthly daily insolation range from 3-7 kWh/m^2/day, and these shows that the region is endowed with enough insolation for solar energy application.

Omwando *et al.*, (2011) investigated solar energy potential in Nakuru between longitudes 35^{o}28'and 35^{o}36'East and latitudes 0^{o}12'and 1^{o}10'South its altitude is 1859 m above the sea level. From the insolation values as measured for Nakuru municipality, the minimum monthly recorded value is 4.8 kWh/m^2/day. Results revealed that Nakuru has a moderate to high solar energy potential, with an average daily insolation of 6.9 kWh/m^2.

In November, 1997 the maximum value recorded is 9.8 kWh/m^2/day in February the same year, in dry hot seasons a lot of solar radiation penetrates the earth's atmosphere (Okoola, 1997).The researchers did not show any comparison between solar energy and other available energy sources. This study compared the solar and wind parameters in Naivasha-Nakuru country.

Wind:-

Wind turbines converts the energy of moving air into useful mechanical or electrical energy, wind turbine needs more maintenance than Solar PV but with moderate wind speeds greater than 4.5 m/s will often produce more energy than similar priced solar panels. (Riezer*et al.*, 2000).

In the process of producing electrical energy from wind using wind power generators, there is numerous energy losses. At rotor, there is aerodynamic loss of around 60% of wind power input. Furthermore, there are mechanical losses of around 4% as the speed increasers, such as gears. Electrical and mechanical losses of around 6% at generator (Manwell *et al.*, 2012.)

A wind turbine performance is characterized by its power curve which relates wind turbine power output to the hub height and wind speed. Wind turbines produce much more power at higher wind speeds than at lower wind speeds until the wind speed reaches the cut out speed, the power curve below shows the power output of a typical wind turbine operating at lower and steady wind speeds(Riezer *et al.*, 2000).

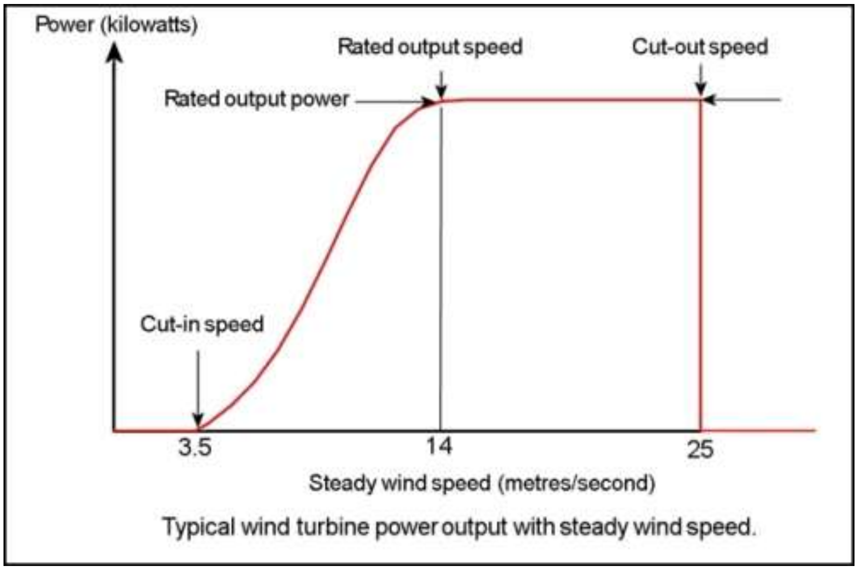

Fig.1:- A typical power curve of a typical wind turbine.

Several research has been done in characterizing the wind energy potential, Kamau *et al.*, (2010) had investigated the characteristic of the wind patterns in Marsabit. From the analysis lowest monthly average wind speed of 7.440 m/s was registered in December 2002 while August 2002 recorded the highest average wind speed of 14.490m/s. However the researchers did consider comparison of solar and wind energy.

Saoke *et al.*, (2011) investigated the wind patterns in Juja. In his findings the wind speed frequency distribution at the 20 m was determined and the mean wind speed found to be 5.04 m/s with a standard deviation of 2.59. The average wind speeds at the two heights (13 m and 20 m) were used to calculate the wind shear exponent and the roughness parameter for the selected site in Juja; this was found to be 0.16 and 0.048 m respectively. However the results did not show any comparison of solar irradiance and wind speeds available in Juja.

Maina, *et al*., 2016 compared the wind speeds in Juja JKUAT site and Naivasha, in her results average wind speeds recorded in Naivasha at height of 10m was 3.54 m/s. But the researcher did not show any comparison between solar irradiance and wind spends available in Naivasha.

According to Power law, wind speed depend with the heights due the effects of terrerains, the wind speed near the ground lower as compered to some height above, equation (4) below was be used to determied the wind speed at hieght of h_2 m from 6 m and the power excpected. (Kantar & Usta , 2008); (Manwell *et al.*,2012).

$$v_2 = v_1 \left\{\frac{h_2}{h_i}\right\}^{\alpha} \qquad \ldots\ldots 4$$

Where v_1 (m/s) is the actual wind speed recorded at h_1 (6 m) ,v_2 (m/s) is the wind speed at h_2 (m) and α is roughness exponetial.

According Rayleigh and wellbull wind speed probability can be estimated based on the wind data at the monitoring station or using the model called “Weibull distribution” or “Rayleigh distribution” if wind data is not available at the project site. Weibull distribution determines two parameters k and c which represents wind speed, Rayleigh distribution is a special case of Weibull distribution where only parameter k and average wind speed is needed (Manwell *et al.*,2012),(Kantar & Usta , 2008).

Weibull $$f(V) = \frac{k}{c}\left(\frac{V}{c}\right)^{k-1} \exp[-\left(\frac{V}{c}\right)^{k}] \qquad \ldots\ldots 5$$

Rayleigh $f(V) = \frac{\pi}{2}\frac{V}{\bar{V}^2}\exp[-\frac{\pi}{4}\left(\frac{V}{\bar{V}}\right)^2]$ ……………………………………………… 6

According Rayleigh the average power can be obtained by considering average wind speed as follows

$\bar{P} = \frac{6}{\pi}.\frac{1}{2}\rho A\bar{v}^3$……………………...………………………………………………......7

Where ρ : air density , A: Area, $\bar{v}$: average wind speed, k: shape factor, c: scale factor.

Study site and methodology:-

The data was collected in Naivasha, Nakuru county Kenya, the latitude of Naivasha is -0.717178, and the longitude is *36.431026* with the GPS coordinates of *0° 43'* 1.8408" S and 36° 25' 51.6936" E.

Solar:-

The data used in this study was the mean irradiance per day (W/m^2) in seven hours of sunshine; the irradiance/second data were recorded at the height of 6m by use of a thermopile (Pyranometer) MS-602Sensor. Temperatures were also measured and recorded by Hioki data logging system for the sampled period of time.

Wind:-

Wind speeds (m/s) mean data was recorded 24 hours a day for period of three months; wind sensor kit was installed at height of 6m. However using the power law (equation.4) the wind spends was elevated to a height of 10m.

The statistical analysis of the data using Excel (Microsoft office) and origin software as research tool was done to determine the mean and generating illustration curves.

Fig 3:- Hioki Data logger

Fig.4:- Sensor Kit

Fig. 6 illustrates site experiment setup for data collection procedures. Four solar PV modules, two N70, 12V batteries (connected in series) were used to supply power to the data logging system.

The system was installed at a height of above 6m to ensure no shade casted by any tall obstacles, regular maintenance was carried out to ensure the solar radiation sensor (Pyranometer) and other equipment was free from dust.

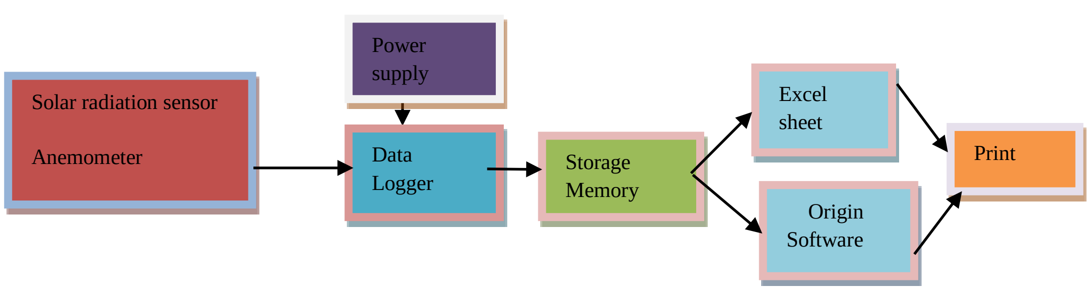

Fig.5:- Schematic experimental setup.

Results and Discussion:-

Fig.6.0 show average daily irradiance for 7 hours in a day, highest irradiance recorded was 925W/m^2 and lowest of 380W/m^2 in February 2016. Highest insolation of 6.475kWh/m^2 and lowest of 2.814kWh/m^2 recorded in February 2016. Fig 6.1 illustrates the wind speed patterns in Naivasha, in February 2016 the highest wind speed recorded was 3.8m/s at hub height of 6m. Power law predicted the wind speed at 10m hub height was 4.06m/s.

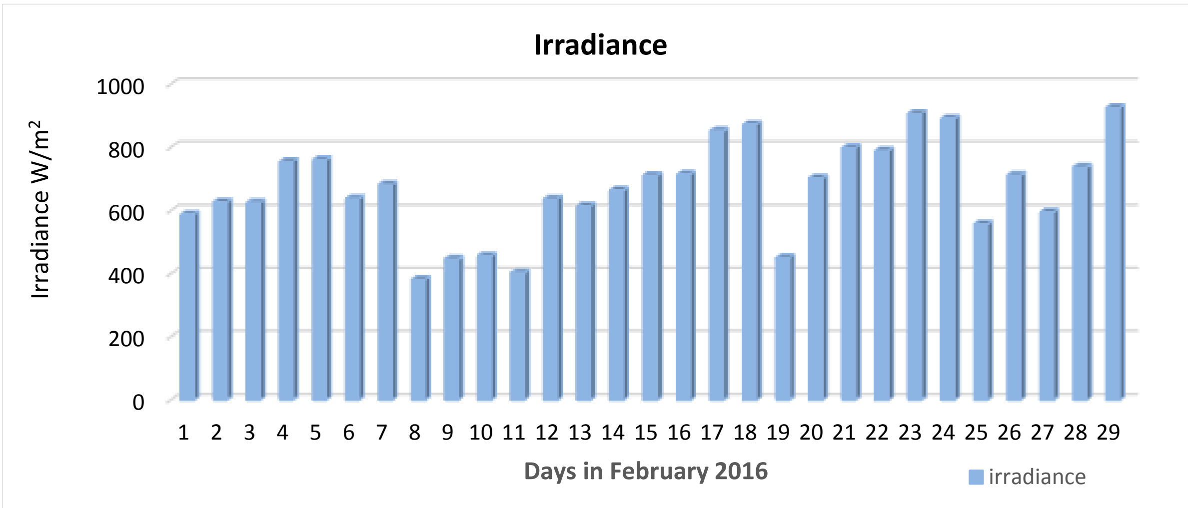

Fig 6.0:- Average daily irradiance in month of February 2016.

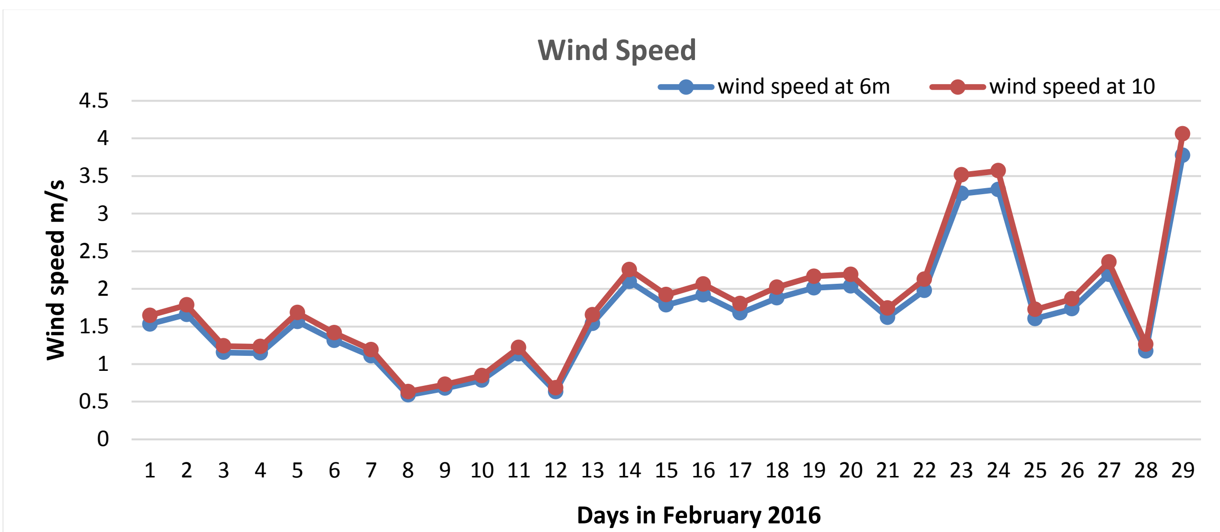

Fig 6.1:- Average wind speed in month of February 2016.

Fig.7 illustrates the irradiance in March 2016, daily average irradiance was and the average 606.4W/m^2 in 7 hours of sunshine. The maximum irradiance attained was 855W/m^2 and a minimum of 352W/m^2 was recorded, the highest insolation attained in this particular month was 5.985kWh/m^2. Fig 7.1 illustrates the pattern of the wind speeds in month of March 2016, 4.2m/s was recorded as the highest average wind speed at 6m hub height. Using the power law (equ.3) to predict the wind speed at hub height of 10m, the height predicted average wind speed was 4.53m/s.

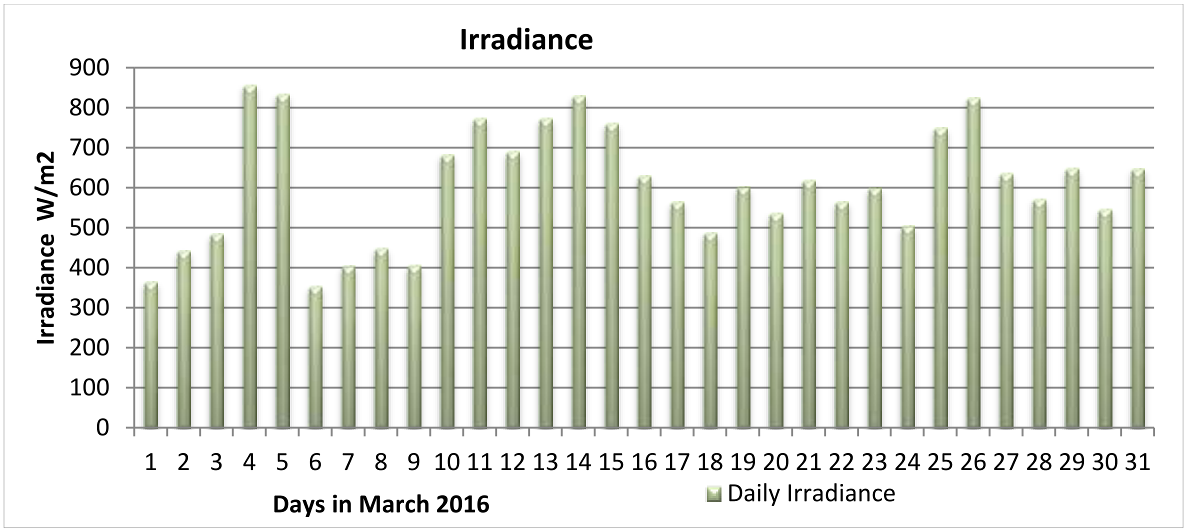

Fig.7.0:- Average daily irradiance in March 2016.

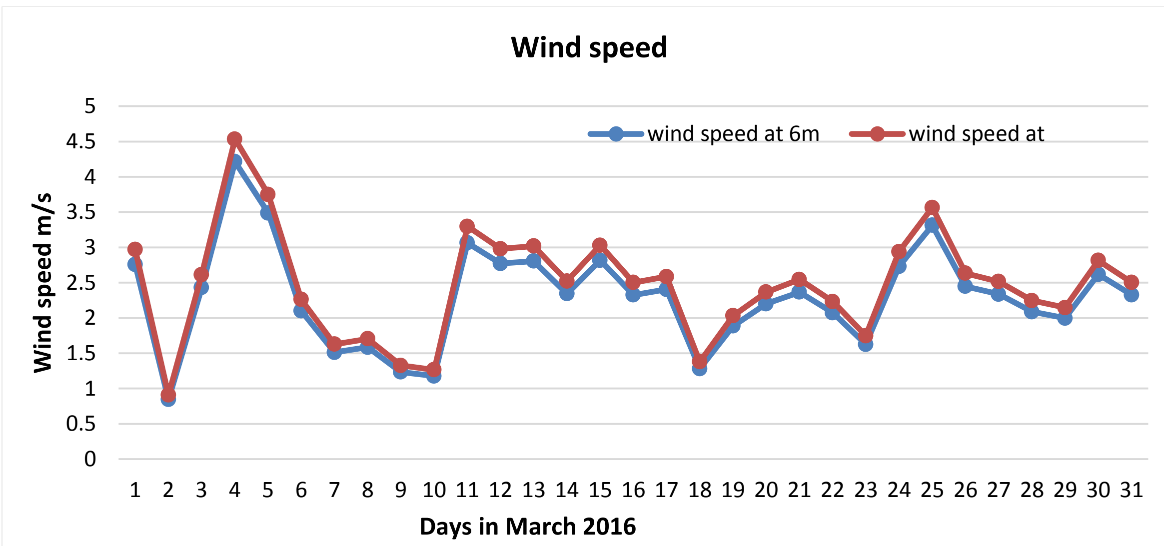

Fig 7.1:- Monthly average wind speed in March 2016

Fig. 8.0 illustrates irradiance recorded in April 2016, highest recorded insolation was 6.11kWh/m^2 at irradiance of 872.85W/m^2 and the lowest was 1.21kWh/m^2 at irradiance of 172.86W/m^2. Fig 8.1 shows that the average wind speed per day pattern in same location as the solar irradiance, the maximum attained average wind speed in month of April was 3.4m/s at hub height of 6m.However using power law (equation.3), the monthly maximum wind speed attained was 3.62m/s at hub height of 10m.

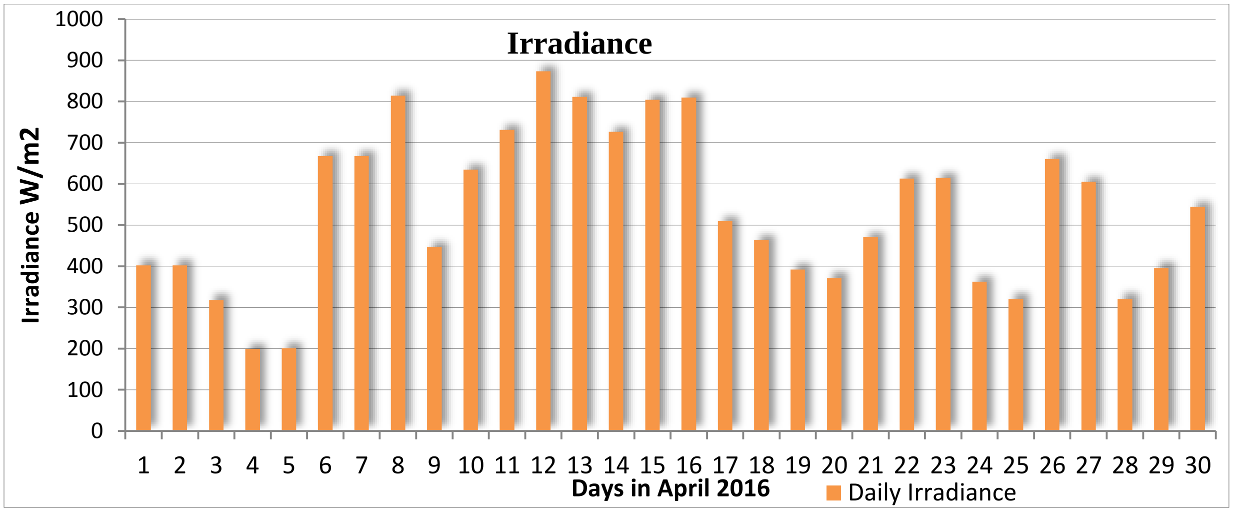

Fig. 8.0:- Average daily irradiance in April 2016

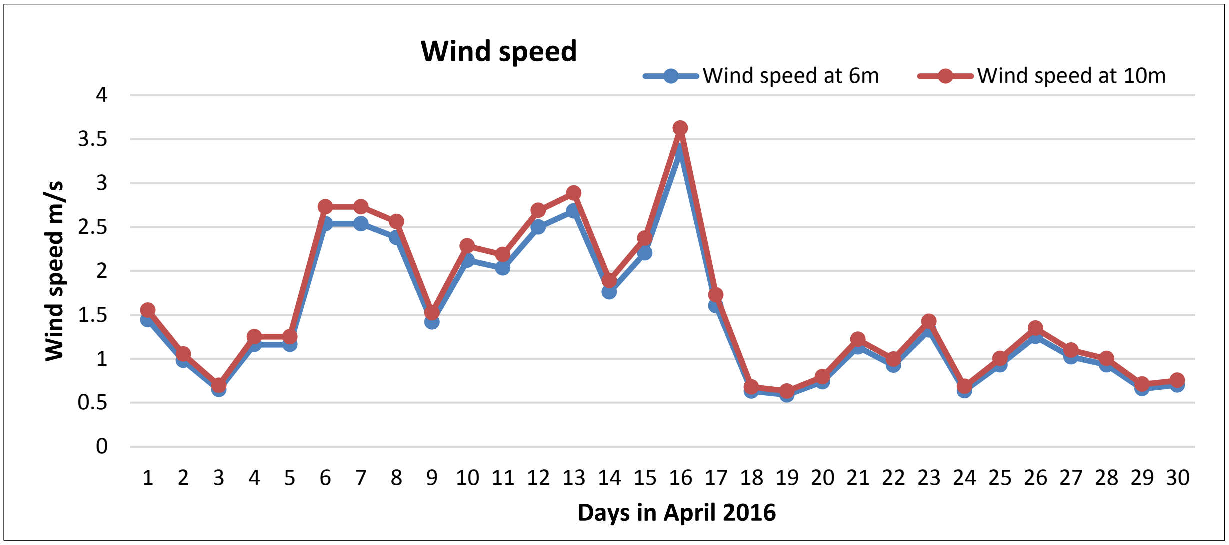

Fig. 8.1:- Monthly wind speeds in April 2016.

Conclusion and Recommendation:-

Naivasha was observed to be potentially viable site for solar systems installation, the result illustrated that the minimum insolation recorded every day for 90 days. A total 18.58kWh/m^2 was available per day during sampled period of this study, this is technically viable for power generation for a home system and for commercial use. The insolation reported by (Omwando *et.al*, 2014) for Nakuru county was lower as compered with the findings of this study. Using solar PV as well as solar water heater for domestic/commercial use will be one of the environmental conservation remedy.

Wind parameters were not so impressive at height of 10m, and only small wind turbine with cut in wind speed (2-2.5m/s) may be considered for power generation. Windmills would be a bit appropriate to pumping water for commercial and for domestic use. Naivasha is semi-arid and water is quite scarce in particular sessions. Wind speed results were comparable with the findings by (Maina, *et al.*, 2016). However due to wind turbines mechanical challenges and regular maintenance, the results of this study found solar PV module would be ideal for power generation in this particular site.

This research would recommend the investors in hotels, lodges restaurants, learning institutions and hospitals to install solar systems i.e solar PV for power generation and solar water heating system and utilize them as remedy to save energy and reduce the electricity bill nearly by 60%. The researchers also recommend for more research to be carried out particularly for assessing solar and wind energy potential in all parts of Kenya in order to have a reliable data for designing solar or wind energy systems.

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References:-

1. Barman, J., Pihl, E., & Ahgren, E. (2011). *Design and feasbility study of PV systems in Kenya.* Sweden: Chalmer University of Technology .
2. Commsison, E. R. (2016, 12 1). *Google.* Retrieved from Solar water heating Regulation: http://www.climacento.co.ke/PDF/ERC.pdf
3. Energy, M. o. (2004, MAY). Energy policy . *SESSIONAL PAPER NO. 4 ON ENERGY*, p. 31.
4. Kamau, J. N., Kinyua , R., & Gathua, J. K. (2010). "6 years of wind data for Marsabit, Kenya average over 14 m/s at 100 m hub height; an analysis of the wind energy potential". *Renewable Energy* , 35 (6) pg 1300.
5. Kantar, Y. M., & Usta , I. (2008). Analysis of wind speed distributions function derived from minimum cross entropy principles as better alternative to Weibull function. *Energy conversion management*, 49: 962-973.
6. Khennas, S., Dunnett, , S., & Piggott, H. (2003). *Small Wind Systems for Rural Energy Services.* India : Dorwyn Ltd.
7. Kumar, R., & Rosen, M. A. (2011). A Critical Review of Photovoltaic-Thermal Solar Collectors. *Applied Energy*, pg 306-3614.
8. Maina, A. W., Kamau, J. N., Timonah, N., Nishizawa, Y., & Saoke, C. (2016). Wind Power Potential Analysis Based on Different Methods fitted in Weibull and Rayleigh models for Wind patterns in Juja and Naivasha. *International Journal of Innovative Research in Science Engineering and Technology.*, 5 (1) pg 24.
9. Manwell, J., McGowan, J. G., & Rogers, ,. A. (2012). *Wind Energy Explained; Theory, Design and Application* . Washington: John Wiley and sons Ltd.
10. Okoola , R. E., Camberlin, P., & Ininda, J. M. (1997). Wet periods along the East Africa Coast and Etreme Wet Spell Event of october. *Journal of Kenya Meteorological society*, pg 97-83.
11. Omwando L.M et.al. (2014). Investigation of Solar Energy Potential in Nakuru – Kenya,. *Baraton Interdisciplinary Research Journal*, 29-40.
12. Rahul, K. K., Mohammad, Z. A., & Neelu, K. M. (n.d.). *Scalling up of Wind Energy Development Plans in Kenya.* Ministry of Energy and petroleum Kenya.
13. S.Steven, H., & Luque, A. (2003). *Handbook of Photovoltaic Science and Engineering.* West Sussex, England : John Wiley & Sons Ltd, .
14. Saoke, C., Kamau, J. N., & Kinyua, R. (2011). Analysis of wind speeds based on the Weilbull model and data coreection for wind pattern description for a selected site in Juja, kenya. *JomoKenyatta Unvervisty of Agriculture and Technology journals*.
15. Solar Direct . (2015, December 25). *Bringing Renewable Technology Down to Earth* . Retrieved from http://www.solardirect.com/pv/batteries/batteries.htm
16. Twidell, J., & Weir , T. (2006). *Renewable Energy Resources* . New York: Taylor &Francis.
17. Wasike, N., Soitah, T., Waweru, M., & Kariuki, F. (2015, April 22). *Assessment of the Solar Radiation Potential of the Thika-Nairobi Area, Panel.* Retrieved from google: http://ir.jkuat.ac.ke:8080/bitstream/handle/123456789/1643/wasike
18. WinDForce Ltd. (2013, September). *Wind Secotor prospectus -Kenya*. Retrieved from http://www.renewableenergy.go.ke/asset_uplds/files/Wind%20Sector%20Prospectus%20Kenya.pdf