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CHARACTERIZATION OF SOLAR THERMAL ENERGY RADIATION POTENTIAL OF LAKE VICTORIA REGION: A CASE STUDY OF HOMABAY COUNTY, KENYA.

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ABSTRACT

The study sought to determine solar irradiation in Homa Bay County which can be tapped and utilized in improving lives of residents of the region by converting the solar thermal energy in Home Bay to other forms of energy such as electric form, mechanical form and light. The study was done by assessing the local atmospheric conditions which included sunshine duration data and air temperature records for the period of two years and the data obtained subjected to statistical analysis to determine the localized characteristics of the resource. The characteristics that were examined include; seasonal and annual power expectations as well as resource reliability. The solar irradiance of Home County was found to be 768.0W/m^2.

Key words; characterization, thermal radiation

1. Introduction

The key factor considered by investors before establishing any development project in a region is the availability and reliability of power.According to Abhishek Saxena, Nitin A garwal and Ghasyham sirivestava (2013), energy consumption for cooking, water heating, drying, heating and cooling of buildings, and water distillation in the developing world is a major component of total energy consumption in various households and commercial sectors. A major source of this energy is fossil fuels creating upward demand thus increasing the prices. As an alternative fuel, solar energy is a good option to utilize for various heating and cooling applications. Kenya is using solar energy devices for the above mentioned activities through solar cooking, water heating, solar drying, air heater, and solar still. To reduce the dependency on imported fuel and the pressure on natural gas, the present energy application system must be diversified and at the same time indigenous energy resources have to be explored and developed. Concern for environment is now a universal issue and conventional energy gives rise to greenhouse gases with adverse consequences for health and climate [12]

In these perspectives, harnessing of renewable energies and development of relative technologies is a highly important strategic option. In Kenya, communities in rural and remote areas such as Homa Bay County have limited accessibility to the Kenya National grid electricity supply system. Only about 3.3 % of Homa bay populations has access to the National grid electricity supply system [13].Therefore this study sought to determine solar irradiation in Homa Bay so that the irradiation obtained can be utilized in upgrading the life standards of Homabay residence by improving industrialization and agro economic activities essential for sustainable development of the region.

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2. Background

The location for the project was Homa bay County; Homa Bay County, Kenya. It is located in the South-western region and runs along the southern part of Lake Victoria. The county has a population of 963,794 and a Population density of 303 per sq. km, and a total of 206,255 Households. It covers an area of approximately3, 183.3 sq. km. with eight electoral constituencies and 50.2% of the population lives below the poverty line [13]

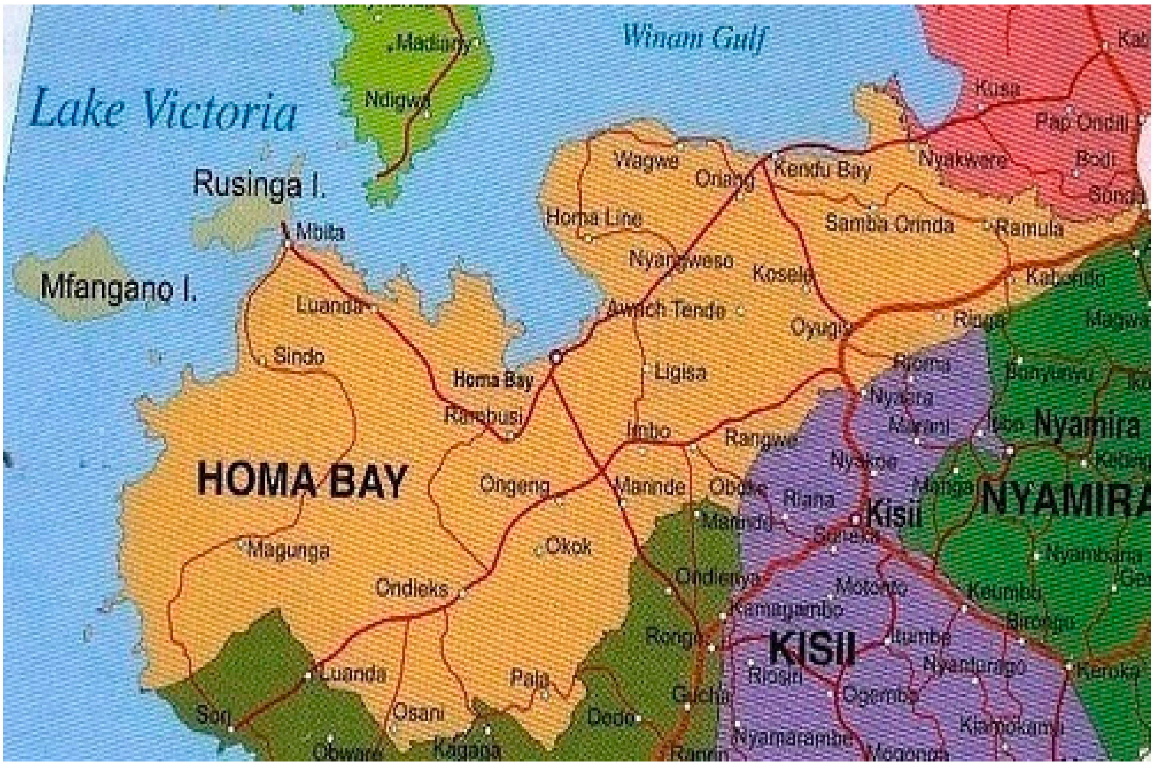

Fig 1. A map of Homa Bay county showing the region of interest in orange [13]

About 14.3% of its area is urbanized. About 3.3% of their population has access to electricity

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3. Conceptual Framework and Governing Equations

3.1. Radiation

Radiation is the mode of transfer of heat energy from the sun to the earth does not require maternal media. It is therefore called radiation. The radiation from the sun falling on the earth outside the atmosphere is 1367 W/m^2 [3] The annual global solar irradiation on the earth depends on the latitude, as the angle of incidence of the solar irradiance results in a lower radiation at higher latitudes. There are two reasons for this occurrence. One is that the distance through which the solar radiation has to travel in the atmosphere is longer at higher latitudes, resulting in increased absorption and reflection before reaching the earth. The other reason is that the higher angle of incidence results in a lower irradiance on the horizontal ground. However, this may be compensated by a tilted surface towards the sun.

When using solar energy integrated in buildings, the optimal conditions for the irradiation on the solar collectors is not always possible to achieve, as the design of the building depends on a large variety of factors. In single family building the most common roof tiles are normally suitable as supporting structures for solar collectors. According to Elisabeth (2009), solar power generating systems converts solar energy to electricity. Every second sun sends about 42 trillion calories of energy to earth surface. [11]

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3.2 Solar power

The rate at which an object radiates energy is proportional to the fourth power of its absolute temperature. This is known as Stefan's law, expressed in equation form as;

$$P = \varepsilon\sigma A T^4 \qquad [1]$$

Where, P is energy, ε is emissivity, σ is Stefans − Boltzman constant, A is the surface area of the body and T is the temperature of the surface of the body [5]

Therefore rate, P at which thermal (heat energy) is radiated from the sun to the earth per unit time in watts, ε is a constant called emisivity of surface of the sun from which the radiant heat origin is temperature of the sun, σ is boltz man's constant ($\sigma = 5.67 \times 10^{-8}\ W/K^4\ M^2$). Bodies that can absorb all the heat reaching it and emit it all are called the black bodies. Such bodies have their values of ε tending to 1.

The amount of heat radiated per second by a body over entire surface is called luminosity. Since the sun radiates about 42 trillion calories per second from its entire surface, this is sun's luminosity;

$$\text{Luminosity} = \varepsilon\sigma\, A[T_s - T_f\ ] \qquad [2]$$

Where T_s is temperature of the sun, T_f is the temperature of the surface onto which heat flow. [5]

When a surface absorbs all of heat energy, reaching it from the sun, then that material is said to be having reflectivity of zero. Reflectivity of a body is called albedo. Albedo of a surface refers to the ratio of the amount of reflected energy to the amount of the heat incited on to the surface.

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Albedo of the earth is approximately 30% [5].This implies that the earth absorbs a proximately 70 % of the heat from the sun i.e. Approximately $^{7}/_{10}$ of 42 trillion calories =29.4 calories per second . The sun is said to be black body and its emissivity is almost equal to 1.Sun emits different spectra of different wave lengths. This relationship between intensity and wavelength is given by Wein's law illustrated graphically as shown below.

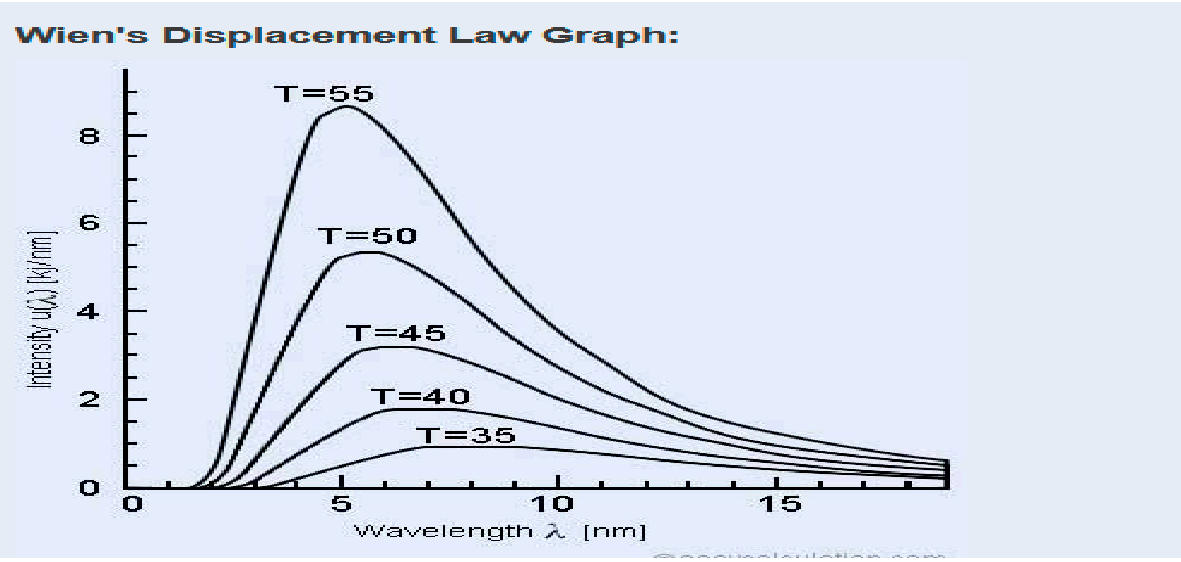

Figure 2. A graph of Intensity of sun's radiation

According to Wein's ; $\lambda_{max}T$= constant = 2.86 x 10^{-3}mk

The light component of radiant energy from the sun propagate in discrete packets called photons tracing paths called rays. The heat component of radiant energy from the sun propagates in discrete packets called quanta. These two components can be used in various applications in life such as heating, lighting or generation

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3. Research Design

The study was carried out in two stages. First stage involved data and instrument sources establishment. This stage involved identification of weather stations with the relevant data and instruments followed by seeking permission to use them from the relevant authorities.

The second stage involved assembling of instruments and materials at specific strategic positions within the selected sites and thereafter carried out tests and measurements.

4. Results and Findings

Table 1 below shows the average monthly radiation for the region for the period of September 2015 to September 2016.These results show that St. william's osodo school its environment experienced maximum average solar radiation of approximately 810.56w/m^2 followed by Homabay school with approximate value of 807.45 w/m^2 these two values are close because the elevation of the two sites are also close ,that is 1281 meters above the sea level for Osodo and 1221 meters above the sea level for Homabay school, Koyoo being at higher elevation above sea level of 1407 meters above sea level has the least average radiation of 649.01w/m^2 for this period. It is also worth noting that all the four sites are at same time zone offset of 180.

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Table 1 Average monthly radiation for the region for the period of September 2015 to September 2016 in watts per square meters.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average
Site1(Osodo)	795.	868.	868.	844.	829.	763.	736.	820.	829.	783.	817.	774.	**810.56**
Site2(HomaBay)	766.	792.	899.	794.	814.	748.	735.	802.	876.	848.	827.	788.	**807.45**
Site 3(Koyo)	734.	812.	833.	707.	701.	660.	663.	726.	725.	706.	604.	590.	**649.01**
Site4 (Urudi)	611.	673.	690.	626.	625.	588.	625.	563.	675.	711.	738.	815.	**665.01**
AVERAGE	**727.**	**786.**	**823.**	**743.**	**742.**	**690.**	**691.**	**728.**	**810.**	**779.**	**749**	**782.**	754.

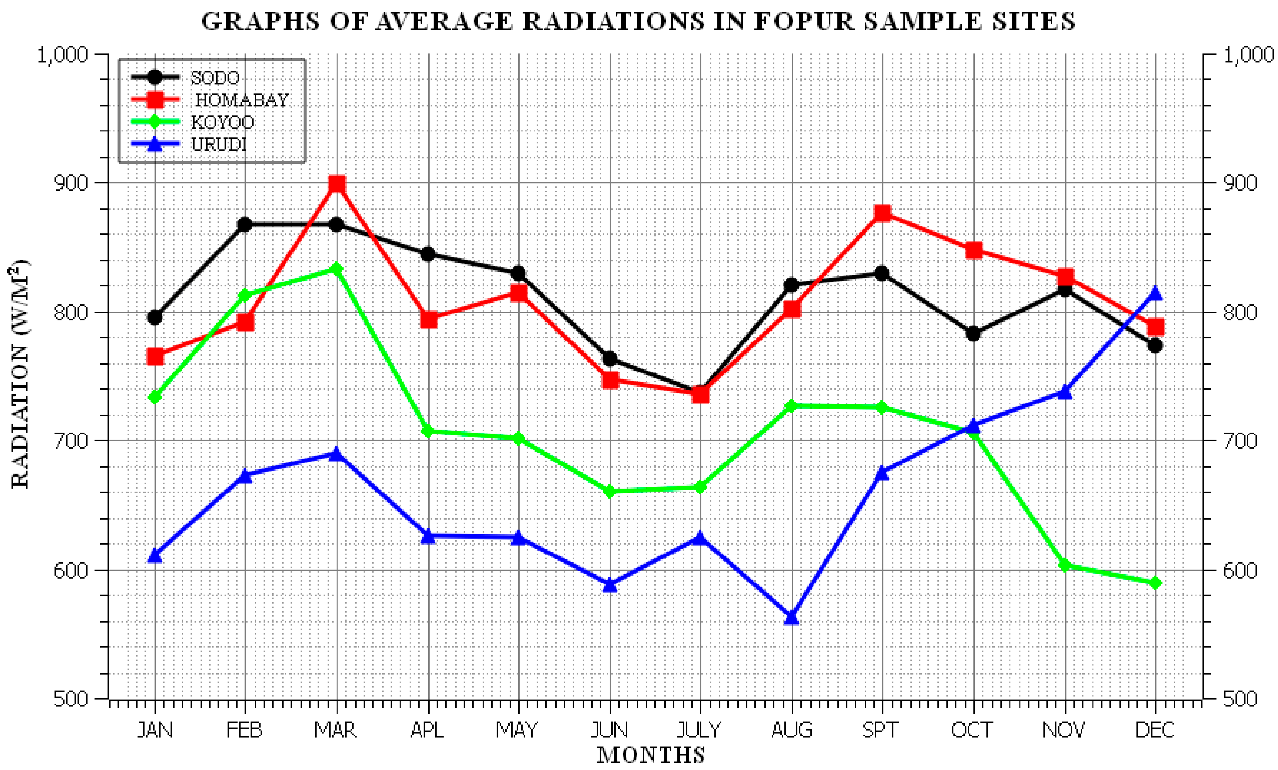

Figure 3. A graph of Radiation for different sites in the for aperiod of sepember 2015 to 2016.

Table 2 below shows the average monthly radiation for the region for the period of September 2016 to September 2017**.**These results show that for this second year, Homabay school st.william's osodo school its environment experienced maximum average solar radiation of approximately 863 **w/m^2** followed by urudi with approximate value of 833 w/m^2 these two values are close because the elevation of the two sites are also close ,that is 1221 meters above the sea level for homabay and 1170 meters above the sea level for urudi, koyoo being at higher elevation above sea level of 1407 meters above sea level has the least average radiation of **649.01w/m^2** for this period. It is also worth noting that all the four sites are at same time zone offset of 180.

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Table 1: Average monthly radiation for the region for the period of September 2016 to September 2017.

Station	J	F	M	A	M	J	J	A	S	O	N	D	Average
RS2. (Osodo)	875	886	879	876.	774	700.	699	700	756	745	777	821.	790.8
RS 1 (Homa Bay)	888	929	968	895	902	937	740	780	824	854	818	854	863
RS3(Koyo)	705	720	729	688	637	613	568	629	654	678	672	701	666
RS 4 (Urudi)	818	864	935	807	813	820	758	819	843	870	782	792	833
Average	822	850	878	817	741	768	669	732	769	787	762	792	788

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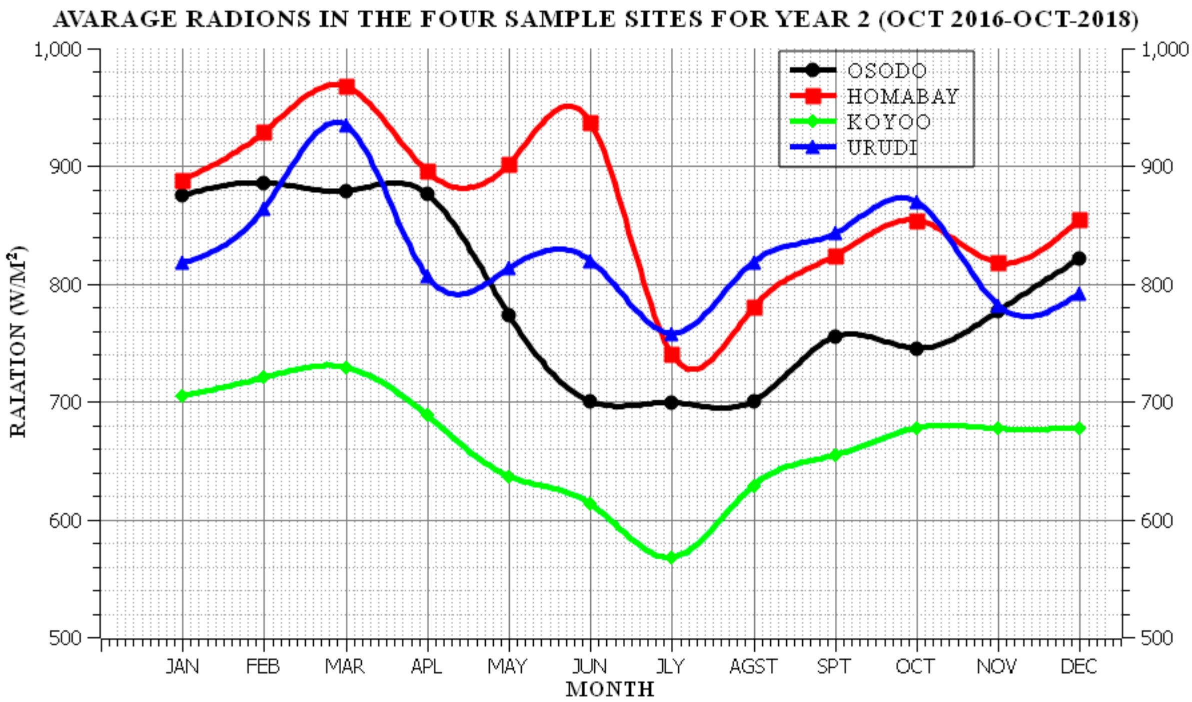

Figure 4. A graph of Radiation for different months in the for the year September 2016 to September 2017.

This implies that in the second set of 12 months we can conclude that Homa Bay central region within a radius of 15KM around Homa Bay High Schools has the highest radiation followed by Osodo, Urudi and Koyoo respectively.

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Table 3 below shows the overall daily average radiations for Homa Bay in watts per square metres.

It shows that the overall daily average radiations for Homa Bay in watts per square metres. we therefore deduce that Solar radiation in Homabay county is at it's maximum in the month of march thereafter it deteriorate to its minimum at the month of july. It again gradually rises to it's second maximum in the months of September October periods.

Table 3 : overall daily average radiations for Homa Bay in watts per square meters.

Months	J	F	M	A	M	J	J	A	S	O	N	D
Radiation	774	818	850	780	741	729	680	730	790	783	756	787

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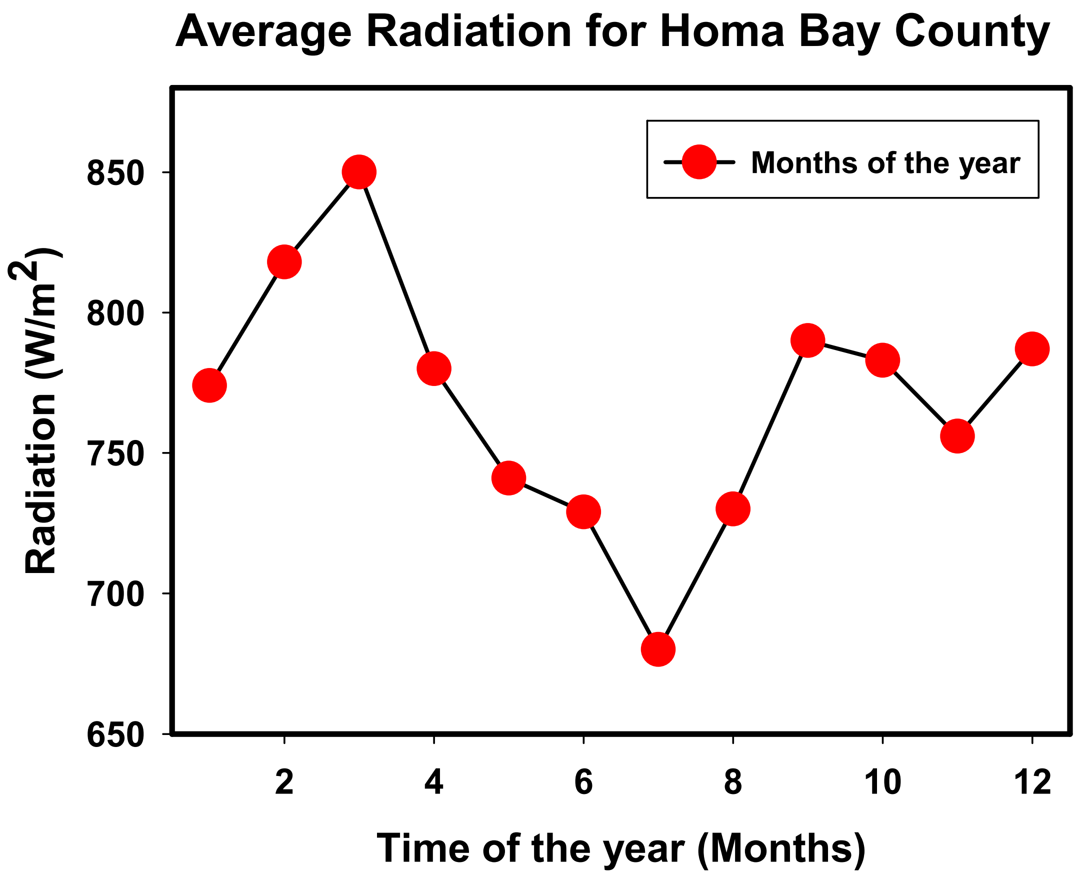
.Fig 4. A graph of overall Radiation for in the for the two years combined.



Conclusion

From the two sets of 12 months data obtain we can conclude that Homa Bay central region within a radius of 15KM around Homa Bay High Schools has the highest radiation This implies that in Homa Bay County, sunshine radiation is at its maximum in the month of March and minimum in the month of July. And following the analysis per station, Homa Bay central region experience the highest radiation and therefore highest solar potential site within the county.

The Final Daily Radiation Statistics for Homa Bay Region

		Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Total months	Statistic	Statistic	Statistic	Statistc	Std. Error	Statistic	Statistic
Overall statistical values	12	170.3	679.8	850.1	768.0	12.9	44.8	2006.8

Results of the study proves that Homa Bay is substantially high solar energy of values ranging from a minimum of 679.8w/m^2 to a maximum value of 850.1 w/m^2 and an average solar Irradiance of 768.10Wm^{2} ., Average daily solar sunshine duration of 8.5 Hours, Minimum Peak Sun Hour (PSH) of 5.774 kWh, Maximum peak sun hour (PSH) of 7.226 kWh and an average of approximately 6.529 kWh

Any region experiencing an average PSH of more than 4.5 kWh is said to be solar potential region Therefore the hypothesis in 5.1.2 is null, and so this research declares Homa Bay a solar potential region because 6.529 >4.5.This high Irradiation in Homa Bay implies that the region can support solar energy converting devices.The best month for testing the performance of solar device is in the month of July when the irradiance is at it's minimum.

RECOMMENDATIONS

1. Homabay county is a high potential solar energy resource site and so investors both governmental and nongovernmental organizations to establish projects that can utilize the resource in improving the living standards of its residents and those of interested parties.

2. More research should be done to see this resource can be substantially harnessed.

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Appendix 1: Field photos

Complete research station