INVESTIGATION OF SOLAR ENERGY POTENTIAL IN NAKURU – KENYA, AND ITS IMPLICATIONS ON KENYA'S ENERGY POLICY

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Abstract

The Kenyan Government is committed to promoting electricity generation from Renewable Energy Sources (RES) with priorities in solar, wind, hydros, biomass and geothermal. In this study, the potential of solar energy as a local source of clean and renewable resource for Nakuru was investigated. Global daily radiation intensity covering period 1986 to 2010 and air temperature records from 1960 to 2008 for Nakuru obtained from archives of the Kenya Metiorological Department (KMD) were subjected to a number of statistical analyses that included: Quality control and Homogeneity tests, temporal, time series as well as empirical statistics. The characteristics examined for the resource include diurnal; seasonal and annual power expectations. Results revealed that Nakuru is a moderate to high solar energy potential region, with an average daily insolation of 6.9kWh/m2. It was also revealed that the energy reaching the surface in this area is season dependant with December-February season receiving the highest amount of 678 kWh/m2 and September-November season receiving the least amount of 602.6kWh/m2. The study concludes that Nakuru is endowed with abundant solar energy resources, favorable for tapping at both small and medium scale levels. These levels are quite convenient, particularly for isolated households in the rural and pre-urban settings of the town. The solar energy potential revealed by the study is bound to go a long way in fulfilling the vision of Kenya energy policy as elaborated in sessional paper No4 of 2004.

Keywords: Solar Energy Potential, Resource Characteristics, Energy Policy, Nakuru.

Introduction

In Kenya, the demand for energy for both industrial and domestic activities continues to rise. The energy for the industries and urban areas is derived largely from petroleum and hydropower. Wood fuel is however the major source of energy for most domestic activities in the rural areas. Use of these energy sources has invariably assumed in-exhaustible stable supplies. In practice, the supplies exhibit a complex structure. Demand for wood for instance impacts the natural ecosystems through fuel harvesting and disruption of the natural nutrient cycling. Indoor air pollution from traditional cooking methods has serious health implications. High levels of wood smoke exposure have been linked to acute respiratory infection (ARI) in particular pneumonia, eye infections and burns (Mbuthi, 1998). There is also a limitation to the future use of wood in Kenya given that over 80% of the country is either arid or semi-arid.

Extreme rainfall events have significant impacts on the available annual petroleum products since they are imported using foreign exchange earned mainly from rain fed agricultural products. On the other hand, environmental pollution associated with the utilization of petroleum products is currently a global issue. Greenhouse gases from the use of fossil fuels have the potential of changing the climate as has been reflected in many global fora such as the United Nation Framework Convention on Climate Change (UNFCCC). Debates in such fora center on how green house gases emission from fossil fuel utilization should be reduced over a specified period.

Hydroelectric power depends on rainfall together with other meteorological and hydrological factors like droughts, floods, stream flow and siltation. Power rationing is common in the country when stream flow falls below certain critical river flow levels (Mbuthi, 1998). Hydro energy sources also require construction of reservoirs which often flood valuable farmland, displace people from their homes and spread water borne as well as water-rated diseases such as malaria, schistosomiasis and bilharzia (Biswas, 1978, Jones and Rogers, 1976, Marigi, 1999).

Due to a ten-fold increase in the prices of imported oil, the cost of oil based energy imports is now putting a crippling burden on Kenya's economy (Asplund, 2008). Further, these fossil based sources are finite and are therefore likely to be depleted with time. The uncertainty regarding the future availability of oil based products (fossil fuels) as well as the negative impacts of their utilization on the environment have therefore led to a growing need to search for cheaper, renewable and environmentally friendly alternative energy sources.

The development and promotion of renewable energy resources, specifically targeting the rural communities, may provide an alternative, sustainable and promising energy option that will alleviate problems related to deforestation, desertification, environmental degradation, green house gas emissions, global warming as well as potential climate alteration and over dependence on fossil based fuels among many other socio-economic problems.

Based on the importance of the Renewable Energy Resources (RES), the Kenya Government National energy policy as enunciated in Session paper No 4 of 2004 and operationalized by energy Act no 12 of 2006 emphasizes implementation of RES (GOK, 2008: GOK, 2004; GOK, 2006; GOK – Ministry of Energy, 2010) to enhance the Country's electricity supply policy in order to achieve the targeted economic growth by 2030 for Kenya to be a "middle – income'' country (Kenya Govt., vision 2030).

With the current population pressure and escalating demand for energy, it is apparent that Kenya is likely to face some energy and environmental crises unless urgent measures are taken to develop and exploit alternative local and clean renewable energy resources.

This paper presents the results of the study carried out to investigate the potential of Solar Energy in Nakuru-Kenya, and its implications on the Country's energy policy. The temporal characteristics of solar energy in Nakuru are also presented in this paper.

Area of Study

This study was undertaken in Nakuru town (figure 1). The town is located between longitudes 35o 28' and 35o 36' East and latitudes 0o 12' and 1o 10' South. Its altitude is 1859m above the sea level and it is within the Great Rift Valley region. The town was founded in 1904 as a railway outpost 160 km from Nairobi. The town lies along the east-west transport route that links the Kenyan Coast with Lake Victoria and Uganda.

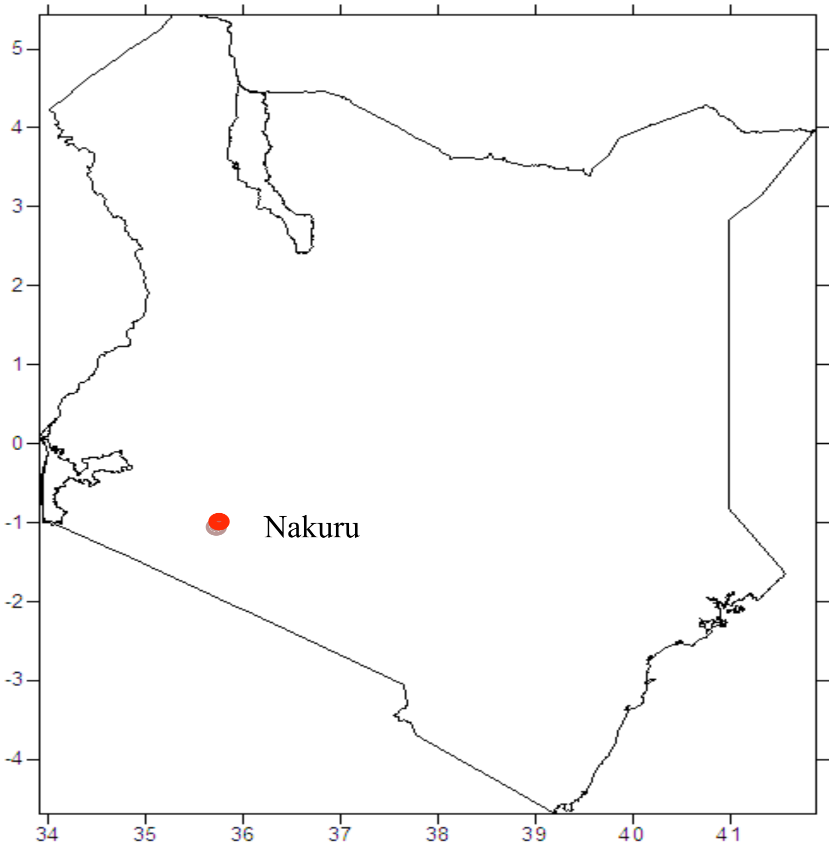

Figure 1

Kenyan map showing location of Nakuru

Nakuru's population has been growing steadily. From a population of 17,625 in 1948, 38,181 in 1962, the population reached 163,927 in 1989; 289,385 in 1999 (GOK, 2005) and 443,424 in 2009. Before Kenya attained independence in 1963, the movement of the indigenous African population into Nakuru, then a *'White Man's'* town was *'restricted'*. After independence, the town was opened up to all, resulting to its steady population increase.

It is, therefore evident that the town is growing at alarming rate while provision of the basic facilities does not expand proportionately. Energy supply is one of such basic facilities required for a decent life, hence the need to investigate Solar Energy potential in the town. The paper utilizes all the available global radiation data to determine the spatial and temporal characteristics of the resource.

Methodology

This research was conducted in Nakuru with assistance of the Kenya Meteorological Department. Most of the dataset was for Nakuru Meteorological station and covered a period of 24 year dating back to the 1980's. This climatolgical dataset was manually extracted from the Kenya Meteorological Department Headquarters' archives.

The methods used to study solar energy potential in Nakuru include those which were used in the determination of the quality of climatological data for Nakuru Meteorological station as well as temporal characteristics of the resource. Highlights of the methods are provided in the sub-sections that follow.

Quality Control Tests

Most of the meteorological elements observations including radiation are collected and recorded manually by trained personnel deployed in all the meteorological observatories spread all over the country. These data is then transmitted in coded form to the Headquarters in Nairobi for decoding and processing to generate required products. There are therefore chances of errors arising in some parts of this chain before the data arrives at the Headquarters. The major sources of error in such data are generally associated with: Instrumentation; Station condition; Observation and recording; Transmission; Coding, entry and decoding.

The instrumentation errors are generally related to the conditions and intrinsic accuracy of the instrument. These errors generally increase with time as the instrument ages. Variation in the station condition like exposure may change the microclimate of the station thereby inducing errors in the observed data. Observation and recording errors are associated with misreading of scales, failure in the sensors and misinterpretation of the standard units of measurements. Transmission errors on the other hand result from the corruption of the telementary data and other errors connected with the transmission systems. Coding errors originate from mistakes arising from the coding and decoding of the records while entry errors are from wrong data inputs.

It is on the basis of the aforementioned that the quality of climatological records including radiation records must be tested before they are used in any study. Quality control is concerned with the detection of errors in the data to ensure that the data sets and archives are error free, complete and have been recorded according to international standards.

Many statistical methods that may be used to test the quality of climatological records exist. These range from the use of simple graphical methods based on mass curves to complex methods involving both parametric and non-parametric methods like the Runs-Test. Details of such methods may be obtained from WMO(1981) and Ogallo (1986, 19991). Brief accounts of the Range validation, Mass curves and one sample runs tests methods that were adopted in this study are given in the next sub-sections.

Range Validation

For any given meteorological observatory, the climatological means, maximums, minimums and the ever recorded extremes (historical highest and lowest values) for each element exist from long term observations dating back to the time each observatory was established in the country. Range validation simply compares the recorded values against the historical largest and lowest values at individual observatories in order to ensure that the records are within the expected physical or logical limits. This is represented by the following expression for good quality records:

$X1 \leq Yi \leq X2$ ……………………………………(1)

Where by X1 and X2 are the historical lowest and highest values respectively ever recorded at the observatory and Yi is the observed value at the station for a given day and year. If the observed Yi values fall outside these limits, the quality is considered questionable and the data interrogated further. The Nakuru observatory radiation data was therefore subjected to this test to ascertain its quality for use in the study. This was accomplished by appropriate manipulation of the data in Microsoft Excel software.

Mass Curve Analysis

The method uses cumulative values of observations (in this case, radiation observation) plotted against time as indicated in the table 1

Xt – represents observed radiation values Yt – represents cumulated values of the observations.
The plot of Yt against t gives the mass curves for the location. For homogeneous records (good quality records), all Yt values will cluster about a single straight line. More than one line can be fitted to the Yt scatter diagram if the Xt values are heterogeneous (questionable quality). In this study, mass curves were generated for mean monthly radiation records for the Nakuru Meteorological observatory.

One Sample Runs Test

A run is defined as the persistence of consecutive values above or below a given threshold value; where, the threshold is the median value of a set of ordered (either increasing or decreasing order of magnitudes) observations.

For purposes of generating the runs in this study, any value equal to or above the threshold value was represented by a dummy 1 while any value below the threshold value was represented by a dummy 0. This is clearly illustrated in the chain diagram below:
111111110111000000111100000100001111100011110111110000000000001111111000000
From this chain diagram, it can be observed that there is persistence of 1's seven (7) times and 0's six (6) times.

In the Runs theory, the number of runs above or below the median value of a sample of observations can give some indications of homogeneity (good quality data) or heterogeneity (questionable quality data) in a time series of observations. In this study, a statistic "Z" was calculated from Equation 2 (Marigi, 1999; Kirui, 2006).

Table 1

Mass curve analysis

Time, T(years)	T_1	T_2	T_3	T_4	…………..	T_n
Value, X_t	X_1	X_2	X_3	X_4	…………	X_n
$\sum X_t = Y_t$	X_1	X_1+X_2	$X_1+X_2+X_3$	$X_1+X_2+X_3+X_4$	…………	$X_1+\ldots..+X_n$

Characteristics of the Solar Energy Resource

The characteristics examined in this respect include the diurnal; seasonal and annual power expectations as well as resource reliability.

Diurnal and Seasonal Solar Energy and Power Computations

The values of (x) as collected from the Kenya meteorological Department archives were all in Mega joules per square meter per day (MJ m-2d-1). These were, therefore, converted to the widely used standard units of energy (kWh) for ease of use. The following expression was applied (Duffie and Beckman, 1991; Kirui, 2006):

1 kWh =………………………………………… (3)

$$Z = \frac{- \dfrac{2n_1\, n_2}{n_1 + n_2} + 1}{\sqrt{\dfrac{2n_1n_2\left(2n_1n_2 - n_1 - n_2\right)}{\left(n_1 + n_2\right)^2\left(n_1 + n_2 - 1\right)}}} !$$

Where: r is the total number of observed runs (i.e. n1+ n2), n1 and n2 are the number of runs above or below the median. In this case, n1 represents the total number of runs above the median and n2 the total number of runs below the median for the entire dataset used. In applied statistics, it is always a norm that for large sample sizes (N>40), the Z approximates to a standard normal distribution (mean zero and unit variance). The significance of the calculated Z is determined with reference to a standard normal table. |Z|>1.96 at 5% level of significance indicates heterogeneity (questionable quality) or otherwise in the records. The monthly radiation records for the Nakuru Meteorological observatory were therefore subjected to this test to determine their quality for use in this study.

Once the quality of the radiation data for Nakuru Meteorological observatory had been ascertained, the data was further subjected to various other analyses to determine the potential of the solar energy resource as described in the following subsections.

The mean daily solar energy ($\overline{X}$) available in Nakuru was determined as the ratio of the daily summations of the energy observed to the total number of days in the given month. This is given by the expression:

$\overline{X}$ =(∑di)/n ……………………………………..(4)

whereby di is the radiation observation on day i and n is the total number of days in the month.

The total available solar energy (ET) on a unit area of horizontal surface for Nakuru in a given season was then obtained as a product of the number of days (N) in the season and the daily mean energy ($\overline{X}$) value for the season. The cumulative energy value (AE) for the four seasons represented the annual value. These is given by expressions,

ET = $\overline{X}$ x N and AE = ET x 4 ………………….(5)

respectively.

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Temperature Trends

The annual trends of temperature in Nakuru were investigated through a simple time series plot of the observed data. This was necessary since temperature is an indicator of environmental pollution (global warming) as a result of increased consumption of fuels, and also has implications in installation and operation of solar energy systems.

Results and Discussions

Results from Quality Control Tests

Range validation techniques showed that the radiation records used were consistent and within the logical limits. These observations signified their good quality for use in the analysis. Results from homogeneity tests are discussed in the subsequent subsections.

Results from the Mass Curve Analysis

Figure 2 presents the pattern of the mass curve obtained from the cumulative values of annual average radiation records for the entire period of study. It is evident that only one straight line could be fitted. This indicates that the data samples were from the same statistical pyranometer and therefore homogeneous.

Results from one Sample Runs-Test

A summary of the results of the test is given in the table 2.

It is evident from the table that |Z| values are less than 1.96 at 5% level of significance for all the months thus indicating that the series were all homogeneous, further confirming the high quality of data used.

Temporal Characteristics of Solar Radiation

From the insolation values as measured for Nakuru municipality (table 3), it is observed that the minimum ever recorded monthly value is 4.8kWh/m2/day in November, 1997 and maximum value ever recorded is 9.8kWh/m2/day in February the same year.

It is also noteworthy that December –February season is generally a dry hot season and therefore devoid of any significant clouds. A lot of solar radiation therefore penetrates the earth's atmosphere during this season. On the other hand, September – November season is the short rain season in the region with abundant and significant clouds. The penetration of solar radiation through the earth's atmosphere is therefore partially inhibited. This had been amplified by the EL-Nino phenomena that prevailed during that period, hence the lowest radiation value which was observed during that month (*Okoola et al, 2008)*.
Figure 3 presents the inter-annual variation of global radiation received on a horizontal surface in Nakuru.

Figure 3
From figure 3, it is evident that the amount of global radiation reaching the surface was increasing till 1996 then followed by an exponential drop (1997- Kenya's last El Nino year) in the consecutive years thus leading to an overall gradual decrease. This confirms a Scholarly literature suggesting that the amount of solar radiation reaching the surface of the earth has reduced significantly in the past few decades (Stanhill and Cohen, 2001; Liepert, 2002) and in particular, the period from 1961 to 1990 – the so-called "global dimming" phenomenon. .

Figures 4 and 5 present monthly and seasonal available solar energy trends in Nakuru.

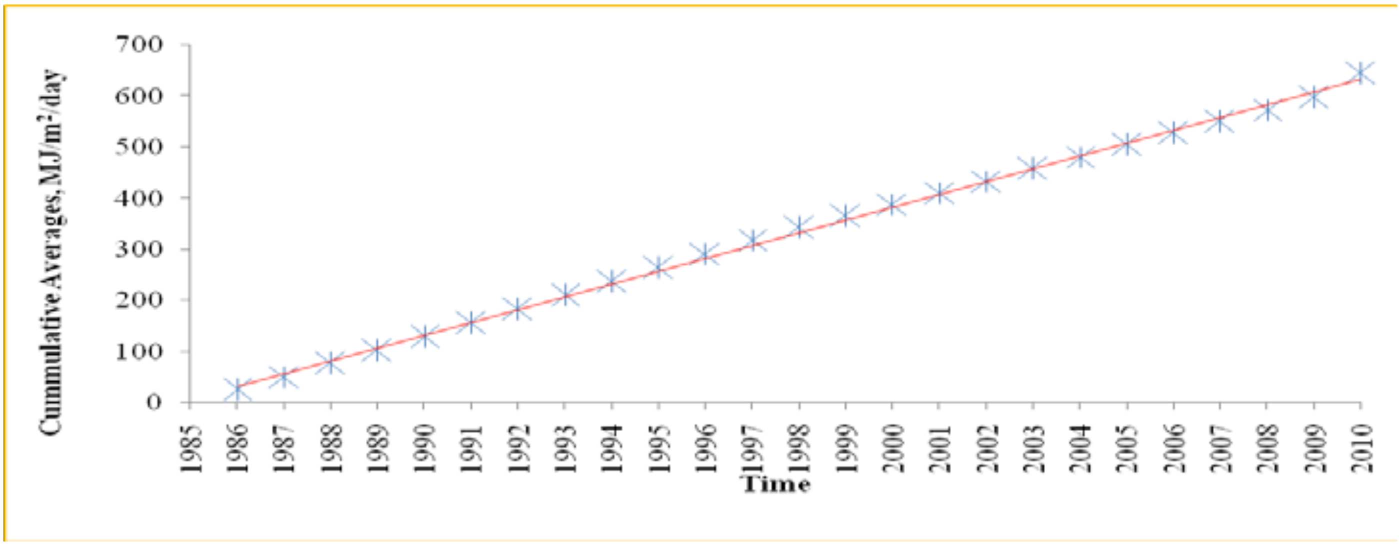

Figure 2
Mass curve for Nakuru radiation d

Table 2

Monthly computed Z-values

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Z - Value	0.9913	0.9923	0.9912	0.9899	1.0125	0.9898
Month	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Z - Value	1.0253	0.9915	0.9899	0.9956	0.9914	0.9913

Both figures are important with regard to the appropriate months to maximally harvest the solar energy resource.

The Kenyan micro-climate is divided into four distinctive seasons that include: December-February, dry hot season; March-May, long rains season; June-August, dry cold season and September-November, short rains season (*Okoola et al, 2008).* It is evident from figures 4 and 5 that the month of January and December-February season receive the highest amount of isolation of 234.4kWh/m2 and 678kWh/m2, respectively. The seasonal values reduce gradually attaining their minimum during the September-November season.

This can also be used to establish relationship between insolation and rainfall in a region, since after any dry spell depending on its magnitude; it is preceded by a proportional rainfall.

Surface Temperatures Trends in Nakuru

Temperature is generally an indicator of environmental pollution (global warming) and also determines the design characteristics of the solar energy capturing devices. In this study, therefore, the annual trends of temperature in Nakuru were investigated through a simple time series plot of the observed data. Figure 6 shows the observed trends in annual temperature.

The figure reveals a general trend of temperature rise

Table 3

Inter-annual insolation value averages

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Yr Av**	Min	Max
1986	7.9	7.8	6.4	5.8	6.5	5.9	6.5	7.0	7.1	7.3	6.2	7.0	**6.8**	5.8	7.9
1987	7.6	8.1	7.6	7.1	6.6	6.6	7.9	7.5	7.9	7.6	6.1	7.9	**7.4**	6.1	8.1
1988	7.5	8.3	7.1	5.7	7.0	7.3	6.4	6.8	6.5	7.5	6.4	7.2	**7.0**	5.7	8.3
1989	8.1	8.5	8.1	6.5	7.0	7.6	6.8	7.3	7.5	6.8	6.2	7.1	**7.3**	6.2	8.5
1990	8.2	7.3	6.7	6.6	7.4	7.8	7.5	7.3	8.0	7.0	6.8	7.5	**7.4**	6.6	8.2
1991	8.7	8.9	7.9	7.1	6.8	7.3	6.3	7.3	8.1	7.2	6.3	7.5	**7.4**	6.3	8.9
1992	8.0	8.7	7.9	7.2	7.3	7.2	7.3	7.1	7.4	6.7	7.2	7.2	**7.4**	6.7	8.7
1993	6.6	8.2	8.5	7.2	7.2	7.0	7.1	8.2	8.2	7.5	7.3	7.6	**7.6**	6.6	8.5
1994	8.7	8.5	8.1	7.2	7.1	7.0	6.9	7.2	8.0	6.9	6.0	7.7	**7.4**	6.0	8.7
1995	9.0	8.5	7.6	7.2	7.4	7.8	6.7	8.0	7.3	6.8	7.3	7.4	**7.6**	6.7	9.0
1996	9.0	8.8	8.0	8.3	7.2	6.5	7.0	7.6	8.0	8.0	6.3	8.8	**7.8**	6.3	9.0
1997	8.8	9.8	7.8	6.7	7.9	7.6	6.9	8.1	8.6	6.4	4.8	6.3	**7.5**	4.8	9.8
1998	5.6	7.4	7.2	6.0	6.2	6.0	5.7	6.0	6.7	6.5	5.8	7.6	**6.4**	5.6	7.6
1999	7.3	7.4	6.4	6.3	6.5	6.6	6.3	6.5	6.7	6.3	5.3	6.2	**6.5**	5.3	7.4
2000	7.7	7.4	6.9	5.9	6.1	6.4	5.8	6.2	6.7	6.3	6.0	6.5	**6.5**	5.8	7.7
2001	6.1	7.4	6.3	5.5	6.3	6.2	6.2	6.5	6.4	6.2	5.4	7.0	**6.3**	5.4	7.4
2002	6.8	7.7	6.8	5.4	6.4	6.5	6.7	6.0	6.2	5.6	5.7	5.7	**6.3**	5.4	7.7
2003	7.4	7.3	6.9	5.8	5.5	6.2	6.2	5.6	6.4	5.8	5.6	6.9	**6.3**	5.5	7.4
2004	7.6	7.9	6.9	6.4	6.6	6.7	6.4	6.9	6.9	6.3	6.1	6.9	**6.8**	6.1	7.9
2005	7.3	7.7	6.7	5.8	6.5	6.6	6.3	6.6	6.1	6.1	6.0	7.2	**6.6**	5.8	7.7
2006	6.9	7.2	6.6	5.8	6.4	6.2	5.8	6.2	7.0	6.1	4.9	5.8	**6.3**	4.9	7.2
2007	7.3	6.9	6.9	6.0	6.4	5.5	5.6	6.0	6.2	6.2	6.1	6.7	**6.3**	5.5	7.3
2008	6.8	7.5	6.5	6.2	6.3	6.2	5.7	6.1	6.3	5.9	6.7	7.3	**6.5**	5.7	7.5
2009	7.0	7.1	7.3	6.5	6.3	6.9	6.6	6.7	6.4	5.6	6.6	6.3	**6.6**	5.6	7.3
2010	7.1	6.7	6.4	6.5	6.3								**6.6**	6.3	7.1
Monthly Av	**7.6**	**7.9**	**7.2**	**6.4**	**6.7**	**6.7**	**6.5**	**6.9**	**7.1**	**6.6**	**6.1**	**7.1**	**6.9**		
Max value	9.0	9.8	8.5	8.3	7.9	7.8	7.9	8.2	8.6	8.0	7.3	8.8			
Min value	5.6	6.7	6.3	5.4	5.5	5.5	5.6	5.6	6.1	5.6	4.8	5.7			

over time. This can be explained in terms of the observed global warming that is majorly attributed to the increasing levels of green house gases such as, among others: water vapor and carbon dioxide, which are mainly by products of industrialization.

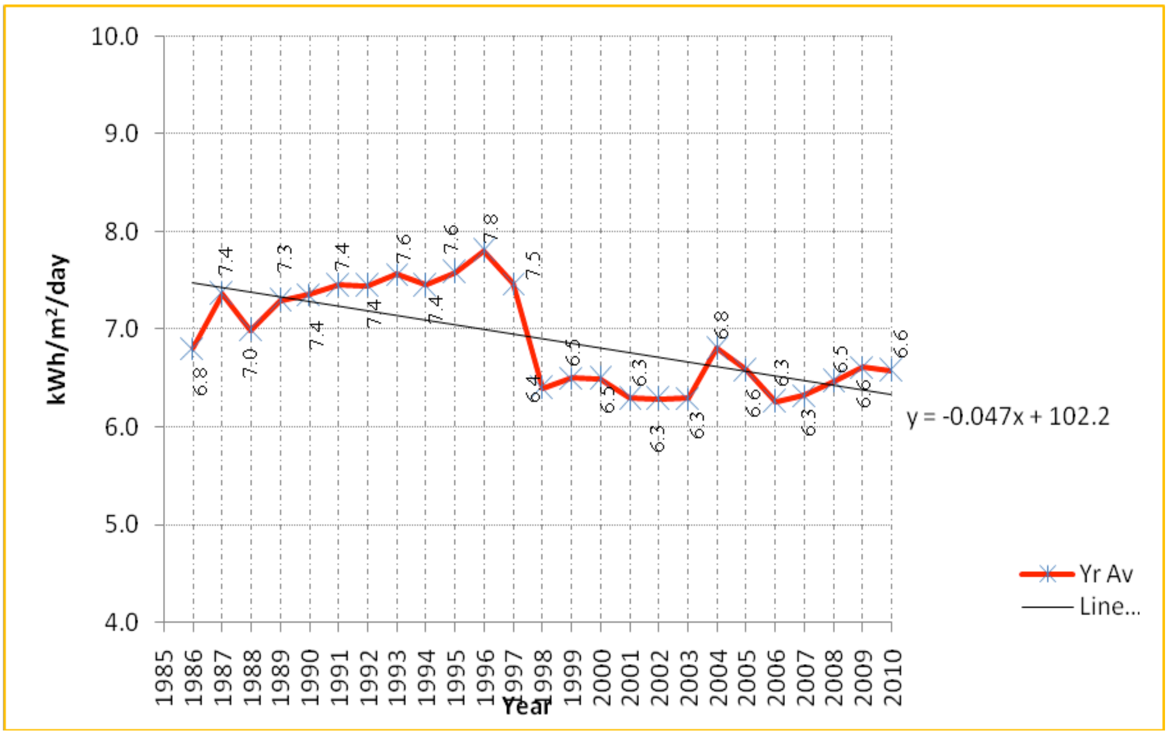

Figure 3

Insolation trend for Nakuru for the period 1986-2010

radiation reaching the surface was increasing till 1996 then followed by an exponential drop (1997- Kenya's last El Nino year) in the consecutive years thus leading to an overall gradual decrease. This confirms a Scholarly literature suggesting that the amount of solar radiation reaching the surface of the earth has reduced significantly in the past few decades (Stanhill and Cohen, 2001; Liepert, 2002) and in particular, the period from 1961 to 1990 – the so-called "global dimming" phenomenon.

In order to curb the fore mentioned, the solar energy which is abundant within the region can be utilized to improve the living standards of people and in the process lead to reduced consumption of fuels thus preserving the environment.

Since the Kenyan Government is committed to promoting electricity generation from Renewable Energy Sources (RES) (GOK, 2008; GOK, 2004; GOK, 2006; GOK-Ministry of Energy, 2010), the results discussed in this paper provides prerequisite information in tandem with accuracy in policy implementation. This means that solar energy projects can be initiated within Nakuru region with the expected power output calculated from month to month and season to season since basic information is now avail-

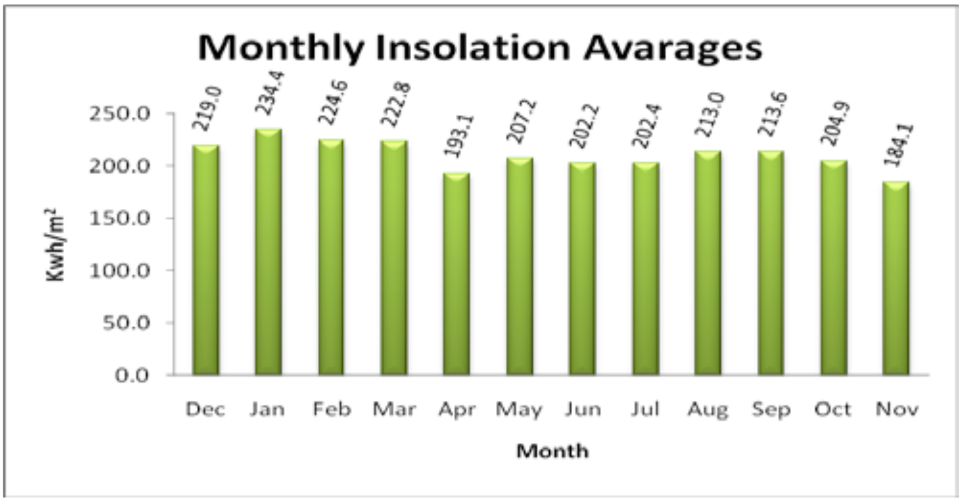

Figure 4
Monthly solar energy availability in Nakuru

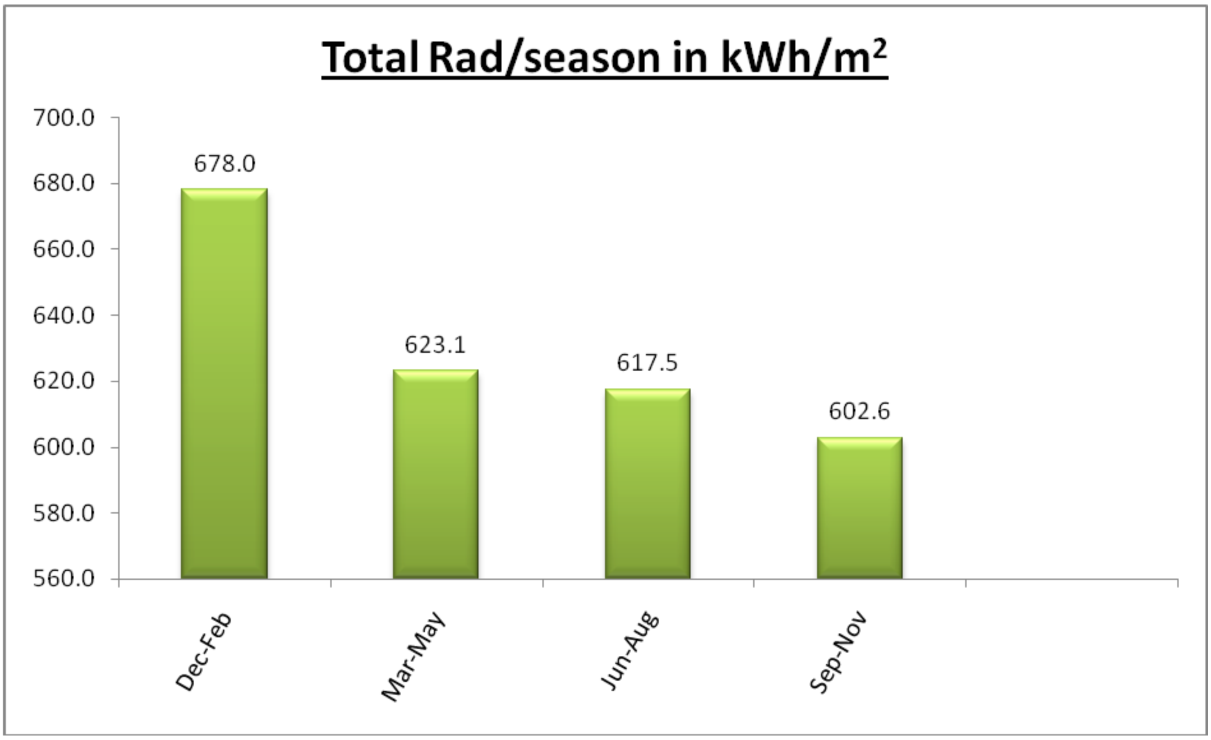

Figure 5
Seasonal solar energy availability in Nakuru 1986 to 2010 averages.

able from the research reported in this paper. Due to the time which was available for the study, other RES like wind, biomass, small hydros, geothermal, biogas and municipal waste energy were not investigated but priority will be given to them in future.

The Government is currently setting up a Green Energy Fund Facility to ensure Accelerated Development of Green Energy and whose purpose is to lend funds to viable Renewable Energy projects at concessional rates.

To encourage wider adoption and use of renewable energy technologies and thereby enhancing their role in the country's energy supply matrix, Government is also designing incentive packages to promote private sector investments in renewable energy and other off-grid generation. Government is also providing requisite support for research and development in emerging technologies like cogeneration, solar and wind energy generation. Cogeneration in the country's sugar belt will be promoted through an attractive bulk tariff regime that recognizes the need to reduce oil based thermal generation to tap the current potential.

Conclusion

From results of this study, Nakuru is endowed with abundant energy resources from the sun, which can favor both large scale as well medium and small scale tapping of the resource. This is very convenient particularly for isolated single and stand alone utilities such as households in the rural and pre-urban setting which in general consume substantial amounts of wood fuel for their energy requirements.

The solar energy potential revealed by the study is bound to go a long way in fulfilling the vision of Kenya energy policy as elaborated in sessional paper No4 of 2004.

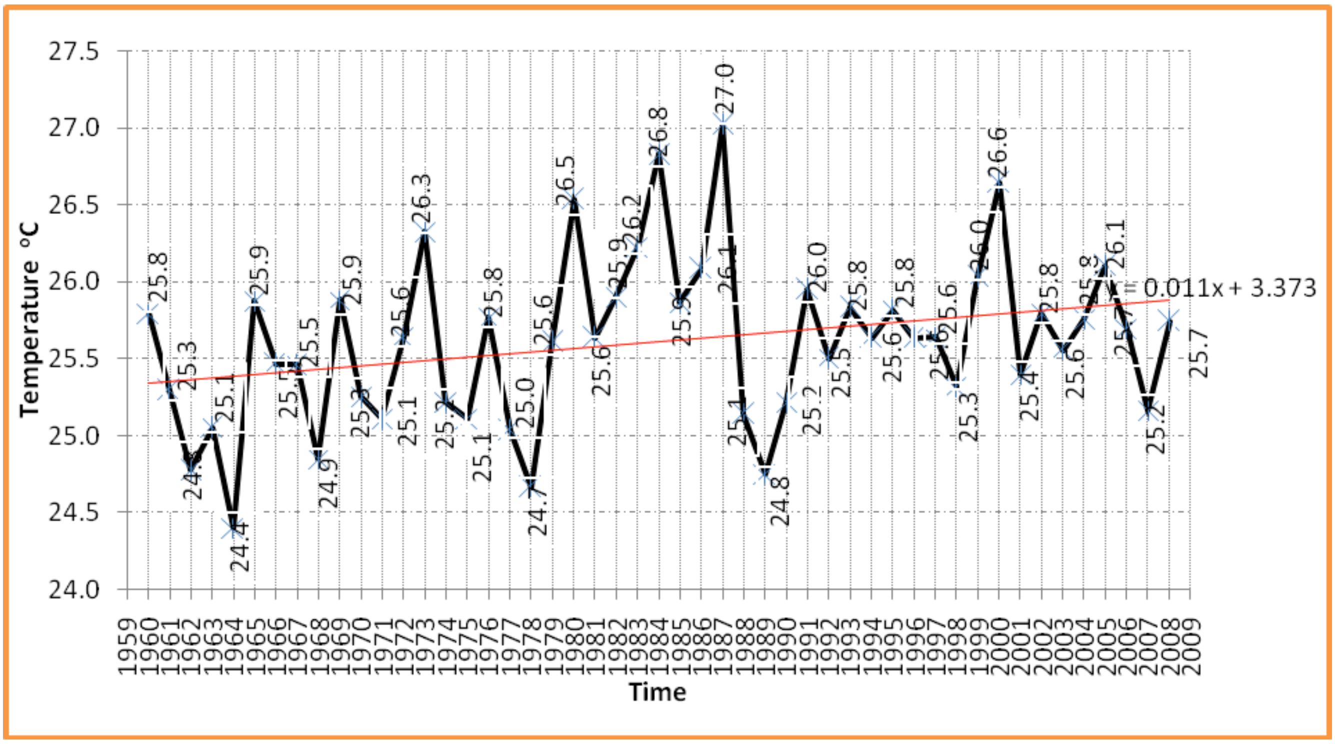

Figure 6

Observed annual temperature trends for Nakuru 1960-2008

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References

Abate, K. , 1998: Identification of rainfall regions over parts of Ethiopia. *J. Afr. Met Soc., 3* (1), 103 – 113.

Asplund, W. R., (2008). Profiting From Clean Ener gy. John Willey and Sons Publications, Hobo ken, New Jersey.

Basalirwa, C. P. K., Ogallo L. and Mutua F., 1993: The design of a regional minimum rain gauge network. *Water resources development 9* (4), 411 – 424.

Biswas, A. K., (1978). Environmental implications of water development for developing countries. Water Supply and Management 2 (4), 283 – 297

Burt, C., 1952: Tests of significance in factor analy sis. *Br. J. Physics (5), 109* – 133.

Child, D., 1978: *Essentials of factor analysis.* Hot, Rinehart and winston billing and Sons Publication, London.

Dyer, T. G. J., 1977: The assignment of rainfall stations into homogeneous groups on application of principal component analysis. *Quart.J. R .Met Soc. 103,* 1005 – 1013.

Duffie, J.A., Beckman, W.A. (1991). *Solar Engineer ing of Thermal Processes*, John Wiley and Sons, New York.

GOK (Government of Kenya). *(2005)*. Nakuru dis trict, District Strategic Plan *2005 -2010.*

GOK (Government of Kenya). *(2009)*. Energy Regu latory Commission Magazine, 08/09 Annual report and financial statement.

GOK (Government of Kenya). *(2010).* Census Results 2009 Population & Housing

GOK (Government of Kenya). *(2004).* Sessional Paper No. 4 of *2004* on Energy. Government Printer, Nairobi.

GOK (Government of Kenya). *(2006*). Energy Act. Government Printer, Nairobi.

GOK (Government of Kenya). *(2008)*. The Kenya Vision 2030. Government Printer, Nairobi.

GOK (Government of Kenya)-Ministry of Energy. *(2010)*. Feed-in-Tariffs policy for wind, bio mass, small hydros, geothermal, biogas and solar. Government Printer, Nairobi.

GOK (Government of Kenya). *(2011).* Scaling-Up Renewable Energy Program (SREP): Investment Plan for Kenya. Government Printer, Nairobi.

Gregory, S., 1975: On the delineation of regional patterns of recent climatic fluctuations. *Weather, 30,* 276 – 287.

Herman, H. H., 1967: *Modern factor analysis*, University of Chicago press

Jones, J. O. and Rogers, P., 1976: *Human ecology and Development of Settlemen*t. Plenum press, New York.

Kaiser, H. F., 1958; The Varimax Criterion for analytical rotation in factor analysis. *Psyhromet., 23,* 187-200

Kirui, H. W. (2006). *Assessment of Solar and Wind Energy Potential in the Central Rift Valley of Kenya. M.Sc Thesis. Egerton University, Kenya*.

Kuhnke, K., Reuber, M. and Schwefel, 1990: *Solar cookers in the third World.* Vieweg and Sohn.

Liepert, B.G., (2002). Observed reductions of solar radiation at sites in the United States and worldwide from 1961 to 1990. *Geophysical Research Letters 29*(10), 61-1 – 61-4.

KIPPRA., (2010): Comprehensive Study and Analysis on Energy Consumption Patterns in Kenya. *Report Submitted By the Infrastructure and Economic Services Division*, Kenya Institute for Public Policy Research and Analysis, Nairobi, Kenya.

Marigi, S. N., (1999). *An Assessment of Solar Energy Resource in Kenya*. Ph.D. Thesis, Moi University, Kenya.

Marigi,S.N., Oludhe,C., Ogana, W. and Kimani, D., 2001: An assessment of the potential benefits of seasonal rainfall prediction in relation to hydroelectric power generation in Kenya. *First series of DMCN pilot application reports.*

Mbuthi, P. N., (1998). Hydropower, meteorology and sustainable development in Kenya. *Proceeding of the 4th Kenya Meteorological Society workshop on meteorological research, applications and services, Mombasa, Kenya, 7th – 11th September 1998.*

Mwampamba, H.T., (2007). Has the woodfuel crisis returned? Urban charcoal consumption in Tanzania and its implications to present and future forest availability. *Department of*

*Environmental Science and Policy, University of California Davis, One Shields Avenu*e, Davis CA 95616, USA.

Neville, R. C., (1995). Solar Energy Conversion. *El sevier Science B. V. Publishers, Netherlands. Pp 5-43.*

Stanhill, G., Cohen, S., (2001). Global dimming: A review of the evidence for a widespread and significant reduction in global radiation with discussion of its probable causes and possible agricultural consequences. A*gricultural and Forest Meteo rology 107(4)*, 255278.

Ogallo. L.J., Runanu, K. (1998). *Space time charac teristics of the maximum and minimum solar power expectation in Kenya.* In: First National conference on meteorological applications, Nairobi, Kenya.

Okoola R. E., Camberlin P., & Ininda J.M. (2008). Wet periods along the East Africa Coast and the extreme wet spell event of October 1997. Journal of Kenya Meteorological Society, 2(1), 67-83.

WMO (world meteorological organization), (1981). *Meteorological aspects of the utilization of solar radiation as an energy source.* In: WMO Technical Note no. 172, Geneva.