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MORALITY BEFORE KNOWLEDGE

Solar energy feasibility for power generation in lower shire districts: A case study of Chikwawa District

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ABSTRACT

Background: Electricity availability is an essential part of both economic and non-economic activities in any countries. Malawi being one of the developing nations experiences a lot of challenges both in its economic and non-economic activities due to unlimited levels of electric supply in its country. This inadequacy of limited supply has remained a challenge for a longer period of time to the effect that the country Malawi for a longer period of time has an overwhelming record of blackouts and load shedding. Consequently, this has affected in a negative way the economic activities of this nation such as low productivity in the production of goods and services making livelihood a difficult. Similarly, noneconomic activities such social interactions seem to be challenging due to lack of electricity. In this regard an investigation in determining new innovations towards electricity production remained one of the most important aspects in this county of Malawi. **Method:** This study was conducted in Chikwawa district, Malawi, to assess the feasibility of solar energy production. The methods used include temporal variability, correlation, trend, and spatial analysis to assess solar radiation, sunshine hours, and their distribution in the area. **Result:** As a result, the study was established with the purpose to assess feasible regions within the country of Malawi to innovate solar energy production to boost high level of solar energy production. This study was conducted in the lower shire district and to be specific in Chikwawa district. The objectives of the feasibility in Chikwawa district included; assessing solar radiation and sunshine hours towards solar energy production, the spatial distribution of solar radiation and sunshine hours towards solar energy production, the trend of sunshine and solar radiation towards solar production and at the end to map the areas in Chikwawa District where solar energy production could be harnessed. Through the use of temporal variability, correlation analysis, trend analysis, and spatial analysis, the findings of this investigation established that harnessing solar energy is much more possible in areas of the lower shire which is the among others include Chikwawa district of Malawi as most areas currently in this region has less places with solar energy production but with high availability of solar radiation. **Conclusion:** For the fact that the findings reveal more feasible places to establish solar energy production, this study recommend commitment by government and private sector to greatly establish solar energy production units in this area whilst focusing on identifying other potential areas where solar energy production can be harnessed in Malawi. In this regard, this exposition has achieved it purpose of which is to foster renewable energy production through innovating and investing in solar energy production. **Novelty/Originality of this study:** This detailed spatial and temporal analysis study has identified optimal locations for solar energy production, providing a new approach to renewable energy planning in developing countries.

KEYWORDS: electricity production; solar energy feasibility; malawi energy challenges; solar radiation assessment; renewable energy innovation.

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1. Introduction

Renewable energy is a clean energy that comes from natural source or processes that are constantly sustainable and inexhaustible and can be used in the same pace as they are produced (Milanzi, 2014). These energies are also known as green or alternative energies. Solar energy is a notable example of renewable energy resources. Solar energy involves harvesting the radiant light energy emitted by the sun and converting it into electrical current and the main source of this energy is the sun. The Sun provides heat, light and radiation to the Earth and other planets. Among other uses; solar energy can be used for transportation, lighting, heating, drying and generating electricity.

Malawi is in the south eastern part of the African continent, surrounded by Tanzania to the north, Mozambique to the south and Zambia to the west, relatively small land-mass and being in tropics where intense heating exits on earth can have a great opportunity as far as the utilization of the resource is concerned. Solar energy can supplement the exiting hydro electrical power, which is currently the main source of power in the country Malawi. Currently, the country has a population of 17,563,749 with an estimated growth rate of 2,9% (National Statistical Office (NSO), 2019). The main source of energy used for cooking and lighting in most households in Malawi are hydro-electricity, firewood and charcoal. Approximately, 77,4% of the population use firewood, 18% use charcoal and only 2% use hydroelectricity as main source of energy for cooking. Only 11,4% of population has access to hydroelectricity (National Statistical Office (NSO), 2019). This has exerted significant pressure on the country's forest resources, leading to forest degradation and deforestation due to the use of firewood and charcoal to satisfy thermal energy needs. Inadequate energy supply for some-time had become the major problem confronting Malawi and limiting its social, economic and industrial development. Use of solar energy for power generation presents a solution to reduce the greenhouse gases (GHGs), emitted from burning fuel for lighting and gen set for electricity generation that threaten irreversible climate change for the planet, as well as provide clean, secure and sustainable source of energy (International Energy Agency (IEA), 2011).

Malawi depends mainly on the hydropower electric power, fossil fuels and biomass on its energy sources for social economic and industrial activities. Due to increase in demand, Electricity Supply Corporation of Malawi (ESCOM) has more pressure to supply the power to increased number of industry and domestic use which leads to more frequent blackouts throughout the country. The blackouts have negative impacts on the day-to-day life and the development of Malawi as a Country. Due to climate change which has resulted to the occurrence of drought, power generation had been reduced because of the reduction of water levels in the Lake Malawi, Shire River and Nkula dam. To solve the current power shortage problem-, venturing into renewable energy resources more especially solar energy will increase the power generation and access to clean, secure, sustainable and modern energy which will contribute to reduction of energy poverty and greenhouse gases that threaten irreversible climate change for the planet.

The main objective of this study was to assess the feasibility potential of solar energy for power generation in Nsanje and Chikwawa Districts. The main research question guiding this study was: Is solar energy feasible for power generation in Lower Shire Districts?: Use of solar energy in lower shire Districts could boost the area's power supply. The results of the study provide an effective solution to energy supply problems/challenges that Malawi is facing especially in rural communities which are off-grid. It will also help to address the impacts of climate change issues which most communities in Malawi are still facing by depending on carbon emitting fuels as source of energy for lighting and electricity generation using gen set. The study will also aid in reducing the use of gen sets by Electricity Generation Company (MW) Ltd which aggravate atmospheric pollution which lead to climate change. It is also expected to improve social and economic conditions of people in the study area.

Station	Correlation Coefficient	Tabulated T-Value at 95% confidence level	Computed T-value	Significance Results
Nchalo	0.104000	2.101	0.33037000	Low
Ngabu	0.617977	2.101	2.48580773461	High

1.1 Concept of solar energy

Solar Energy is radiant (light and heat) energy produced by the Sun that is harnessed using a range of ever-evolving technologies including solar heating, photovoltaics, solar thermal energy (Ahsan et al., 2014). According to previous study, solar energy is the most cleanest and inexhaustible renewable energy source abundantly available especially over Equatorial and Tropical region. Its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic (PV) systems, concentrating solar-thermal power (CSP), and solar heating and cooling (SHC) to harness the energy. Passive solar techniques include orienting a building to the sun, selecting materials with favourable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

Photovoltaics generate electricity directly from sunlight via an electronic process and can be used to power anything from small electronics such as calculators and road signs up to homes and large commercial businesses. Concentrating solar-thermal power systems use mirrors to reflect and concentrate sunlight onto receivers that collect solar energy and convert it to heat, which can then be used to produce electricity or stored for later use. It is used primarily in very large power plants. Solar heating and cooling collect the thermal energy from the sun and use this heat to provide hot water, space heating, cooling, and pool heating for residential, commercial and industrial application. Solar energy technology reduce daily dependence on fuels for energy

1.2 History of solar energy and its modern trends

Solar technology isn't new. Its history spans from the 7th Century B.C. to today. It started out from as simple as concentrating the sun's heat with glass and mirrors to light fires. Today, we have everything from solar-powered buildings to solar powered vehicles. Ultimately, it's clear that even thousands of years before the era of solar panels, the concept of manipulating the power of the sun was a common practice (Gabash & Li, 2012).

According to (Winter, 1991), Sunlight has been used as an energy source by ancient civilizations to ignite fires and burn enemy warships using "burning mirrors". Till the eighteenth century, solar power was used for heating and lighting purposes. During the 1800s, Europeans started to build solar-heated greenhouses and conservatories. In the late 1800s, French scientists powered a steam engine using the heat from a solar collector. This solar-powered steam engine was used for a printing press in Paris in 1882.

A highly efficient solar-powered hot air engine was developed by John Ericsson, a SwedishAmerican inventor. These solar driven engines were used for ships. The first solar boiler was invented by Dr. Charles Greely, who is considered the father of modern solar energy. The first working solar cells were invented in 1883 by Charles Fritts. Selenium was used to build these prototypes, achieving efficiencies of about 1%. Silicon solar cells were developed in 1954 by researchers Calvin Fuller, Daryl Chapin, and Gerald Pearson. This accomplishment was achieved by following the fundamental work of Russel Ohl in the 1940s. This breakthrough marked a fundamental change in the generation of power. The efficiency of solar cells increased from 6% up to 10% after the subsequent development of solar cells during the 1950s (Khaligh & Li, 2010).

Based on expected future direction of solar technology as stated on U. S. Department of Energy website (www.energy.gov) under Office of Energy Efficiency And Renewable Energy, all buildings will be built to combine energy-efficient design and construction practices and renewable energy technologies for a net-zero energy building. In effect, the building will conserve enough and produce its own energy supply to create a new generation of cost-effective buildings that have zero net annual need for non-renewable energy.

2.3 Socio-economic and environmental benefits of solar energy

Solar energy is a renewable resource, and is environmentally friendly unlike fossils that are only found in selected regions of the world (Salima & Chavula, 2012). The use of diesel engine and burning of fossil fuel for generating electricity this has read to increase release of greenhouse gases into the atmosphere, such as carbon dioxide, methane and nitrous oxide. These gases do not just contribute to air pollution, but also contributes to the enhanced greenhouse effect, which is warming up our earth faster than ever before. The increase of this gases has been linked to a number of catastrophic weather events, such as flooding, cyclones, storms, extreme heat and drought (Grover, 2007). Generating electricity from solar panels produce no greenhouse gases, this can help to reduce the effect of climate change.

Inadequate energy supply is the major problem confronting Malawi and limiting its social, economic and industrial development (Taulo et al., 2015). This problem is reading to increase in daily costs which leads to unstable global economy since the price of production depend on the price of fossil fuel. The price of sunlight is zero. Unlike fossil fuels, sunlight is never going away. Coal and natural gas are not free, and they are expensive and unclean. Their price is volatile too and has increased systematically. But there is no fuel cost for sunlight.

Solar energy is becoming more economically attractive as technologies improve and the cost of electricity generated by fossil fuels, which are steadily rising and putting poor people as well as developing country like Malawi to keep on lowering down its economy every month. Solar energy is cheap source of energy since once installed it takes time to repair, hence, lowering daily and monthly utility bills. Local utility rates are probably higher when using other source of energy like Hydro-power, coal, generators and burning of fossil fuels. When you choose to install a home solar system and a battery, you control average electricity costs over a year. Households with the highest electricity rates from their local utilities are the ones who stand to save the most when they convert to power from the sun. But home solar systems can save almost any homeowner thousands of dollars over the life of the product, which is two decades or more.

Energy is one of the basic necessities for the survival of human race (Mwanza et al., 2017). Solar energy helps people as well as National in times of need. We need energy to live our daily lives, but we also need energy to help those less fortunate, some countries around the world are using solar energy to push through power outages caused by storms and other natural disasters that can lead to loss of life and property. Events like floods, wildfires, hurricanes, rising sea levels and hunger related to environmental damage have caused devastation around the world. The costs associated with climate change are growing and include rising health care costs, destruction of property, increased food prices and more. Wide scale adoption of solar energy must continue so that we can address the negative economic impacts of unclean fossil fuel.

1.4 Solar energy in Malawi

Solar resource is one of the renewable energy resources that is available in abundance in Malawi, the country's average solar irradiation per day is 5.8kWh/m2 on a horizontal surface and solar energy's potential ranges from 1642.5 to 2555kWh/m2 per annum on a horizontal surface (Mohan & Ngwira, 2019). According to 2013 study by Gamula and others, Malawi has a quite high levels of solar energy in the range of 1200 W/m2 in the warm months and 900 W/m2 in the cool months that is received in most parts of the country which would enable photovoltaic systems and solar thermal systems to perform well.

Electricity supply in Malawi is much less than demand resulting in deficient and unreliable energy supply. Inadequate energy supply is the major problem confronting

Malawi and limiting its social, economic and industrial development (Taulo et al., 2015). Solar energy prove to be a viable solution to meet the growing energy demand (Kouzmanoff et al., 2016).

World Bank (2017) conducted a Solar Resource Mapping Study in Malawi. Using Solargis solar resource data for Malawi based on the ground measurements collected at three solar meteorological stations, which are Mzuzu, Kasungu and Chileka across the country. These solar meteorological stations were installed and operated by GeoSUN Africa, over years 2016 to 2018. However, the study methodology employed did not cover other meteorological stations to come up with a region Map since climatic parameters varies with location and geographical position.

The livelihood of Likoma and Chizumula Islands will greatly improve with the 24 hour availability of electricity due to a 1,3 Megawatt (MW) Solar Power Plant has recently been commissioned by Electricity Generation Company (Malawi) Limited. This solar power plant is part of a 3,1 MW Hybrid Power plant comprising of 1.8 MW diesel generators and 1,3 MW solar power. This has reduced fuel costs on the generators as well as increase the power supply hours from the previous 14 hours. EGENCO through the government of Malawi plans to install a 20 MW solar power plant in Salima in phases of 10 MW in each to increase the generation capacity and introduce a diverse power mix in the generation system. In future there also plans to develop and install three mini grids one in each region of the country (www.egenco.mw).

Furthermore, JCM has been developing a 60 MW AC (75.6 MW DC) solar photovoltaic project in the Salima district of the Republic of Malawi since mid 2013. JCM has signed a power purchase agreement (PPA) with the Electricity Supply Corporation of Malawi Limited (ESCOM) and has obtained all the permits and Land Agreements. An Implementation Agreement (IA) has also been signed with the Ministry of Finance and the Ministry of Energy. The project is currently in construction Salima (Salima & Chavula, 2012).

According to study done in 2014 by Milanzi on similar subject of Assessing Solar Energy potential in Malawi, his study results shown that there is abundant solar radiation resource which is not being utilized in Malawi. This abundant solar radiation can be harnessed and be put into various uses such as water heating, cooking and electricity generation by the use of PV systems. However his study didn't concentrate on region or district level rather at national level. For this he recommended that further research be done at region and district level.

2. Methods

2.1 Research design/rationale for methodology

This study adopted the quantitative design. Data for sunshine duration and solar radiation was statistically averaged in order to identify suitable area for solar generation in Chikwawa district.

2.2 Study site

The study was conducted in Chikwawa, one of Lower Shire Districts in Southern Malawi. Geographically, Chikwawa lies at latitude and longitude of 16020'S and 34077'E with a surface area of 4,755 km2 and population of 6,114 (National Statistical Office (NSO), 2019).

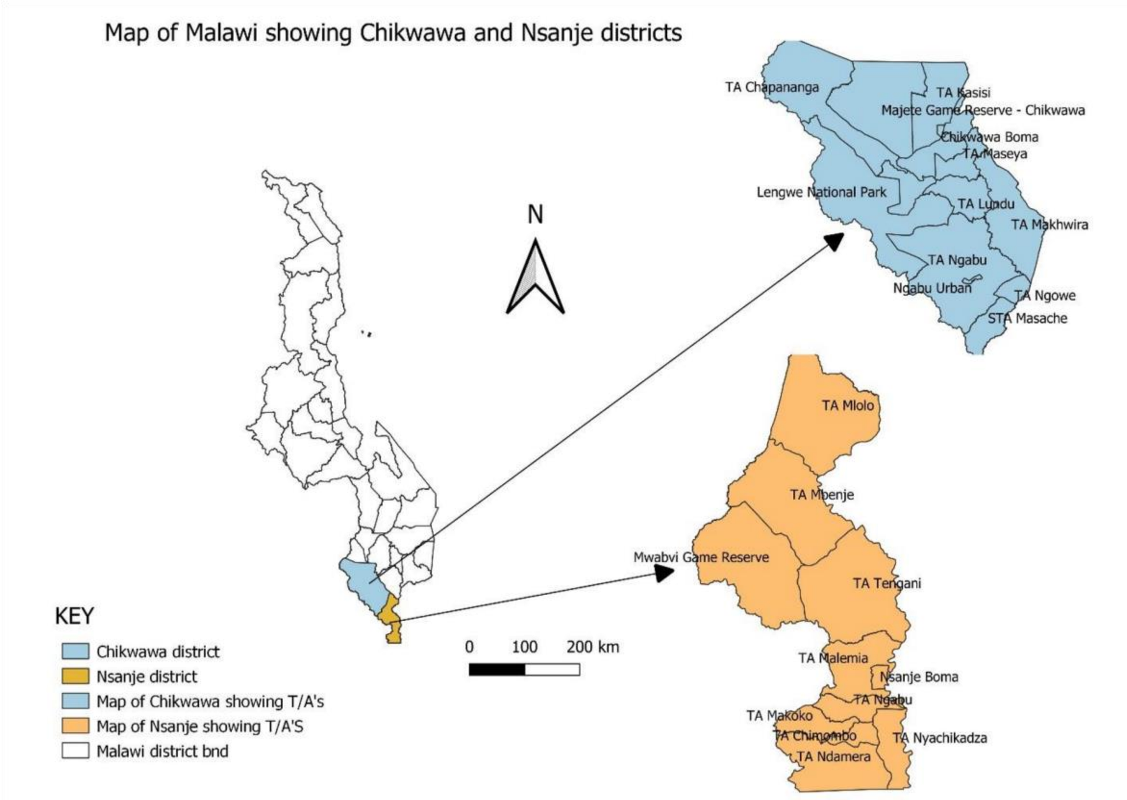


Fig. 1. Map showing the study area of the investigation

2.3 Data collection method

In order to achieve study objectives, this study used secondary (climatology) and meteorological collected from the National Aeronautics and Space Administration (NASA). The data required was for a 19 years period (from 2000 to 2019) covering dry and wet seasons.

2.4 Meteorological data

Meteorology data from 2000 to 2019 was collected from the Department of Climate Change and Meteorology Services (DCCMS). Meteorological variable will include monthly sunshine duration and solar radiation. The meteorological data that was used was from the Malawi Meteorological Headquarters.

2.5 Data analysis and interpretation

In order to interpret data, the use of correlational analysis and spatial analysis was done as these data analysis and interpretation methods has been highlighted below;

2.5.1 Correlation analysis

Correlational analysis was used to investigate the strength of the relationship between the average monthly sunshine and monthly solar irradiance intensity for all the months.

$$r_{xy} = \frac{s_{xy}}{s_x s_y} \qquad \text{. (eq. 1)}$$

r_{xy} was the correlation coefficient
s_{xy} was the covariance (X, Y)

3.5.2 Correlation significance

The correlation significance of the sunshine hours and solar radiation data was tested using the student t-test method as per the formula explained below;

$$t = r\sqrt{\frac{(n-2)}{(1-r2)}} \text{……………………} \quad \text{(eq. 2)}$$

Where t is the computed t value, r is the correction coefficient, n is the number of observation years.

3.5.3 Spatial analysis and mapping

In order to do the mapping, this study used a Qgis software for plotting map to show suitable area that can generate solar energy in Chikwawa district.

3. Results and Discussion

3.1 Results for assessing the temporal variability of solar radiation and sunshine hours over the area of study

The analysis was done to examine the temporal variability of both the sunshine hours and solar radiation over the study area. To achieve this time series analysis was used. In the view of the same, the total monthly average for the period of 19 years; 2000 to 2019 were obtained and being through the plotted graph below (Fig. 2) is the summary of the analysis:

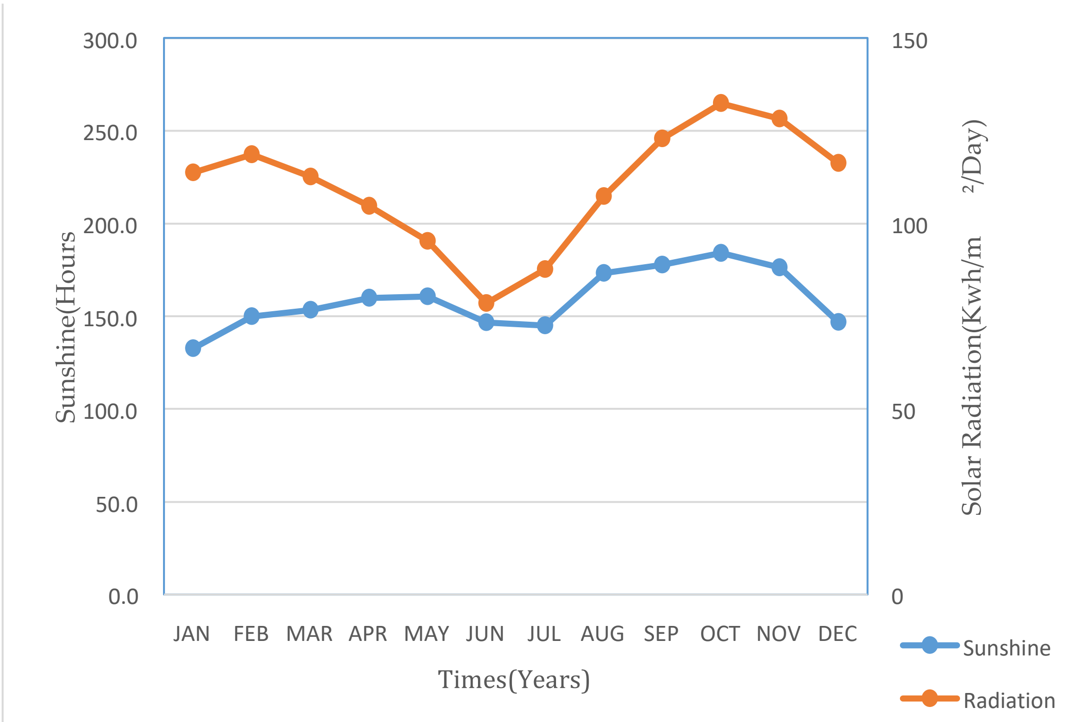


Fig. 2. Sunshine and solar radiation temporal variations for Ngabu.

The Fig 2. above shows that the solar radiation has two picks; the smaller peaks in January to April and the highest pick in August to December. This simply means Ngabu in Chikwawa as an area is likely to have high solar energy production in the months of January to April as well as August to December due high peaks of solar radiation. The graph indicates May, June and July as the period of lower solar radiation. In this context it means that the period of May to July generation of solar energy production could be also lower due to reduced solar radiation. Similarly In terms of sunshine hours December, January, and February have lowest number of sunshine hours and this also means in the same period of time Ngabu in Chikwawa is also likely to experience low solar energy production due the fact that availability of sun is much rare. Conversely, though the feasibility study, it was established that there is an increase in sunshine hours from March to May and this means during this period Ngabu in Chikwawa is when is likely to be able to produce much more solar energy due to the longer period availability of the sun. The graph further shows decrease in sunshine hours In Ngabu in Chikwawa in June and July and during this period it means low solar energy production due reduced number of hours for the availability of the sunshine. Lastly on sun-shine availability it was established that another peak for availability of sunshine was from August to November in Ngabu in Chikwawa and this also meant increased solar energy production due to more hours for the availability of sunshine.

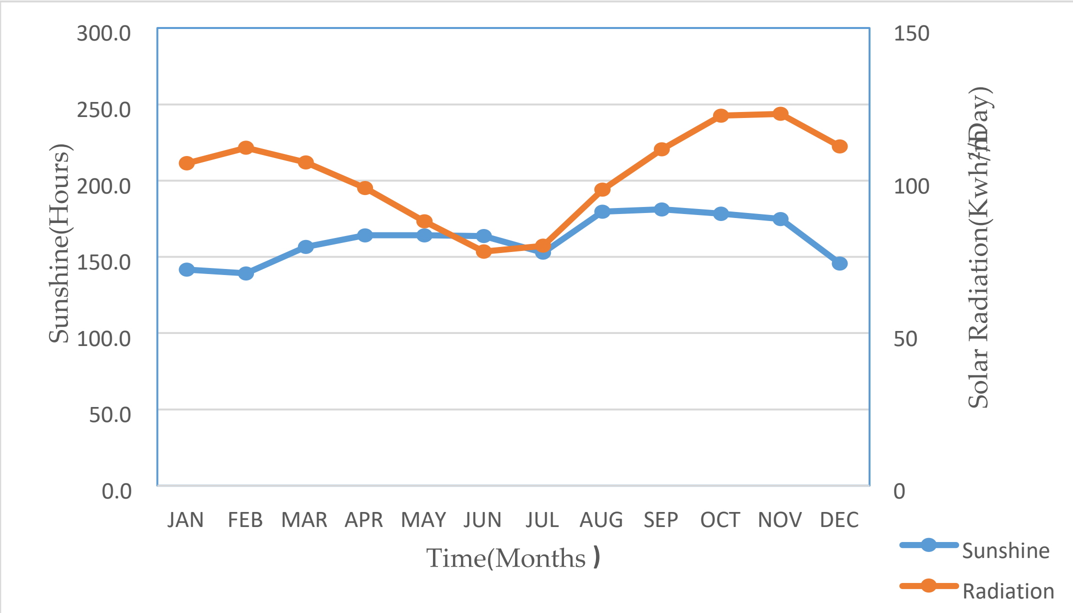


Fig. 3. Sunshine and solar radiation temporal variations for Nchalo.

The Fig. 3 above shows that the solar radiation has two picks; the smaller peaks in January to April and the highest pick in August to December. This simply meant that during a period of January to April as well as August to December is when Nchalo in Chikwawa is likely to have the capacity to produce more solar energy due to increase in solar radiation.

Conversely, the graph indicates May, June and July as the period of lower solar radiation. This means that during the period of May, June up to July, Nchalo in Chikwawa is likely to experience reduced solar energy production due to decrease in solar radiation. In terms of sunshine hours December, January, and February have lowest number of sunshine hours. This means that Nchalo in Chikwawa in the months of December, January and February is likely to have low solar energy production as the number of hours for the shining of the sun will also have been reduced. On the other hand, there is an increase in sunshine hours from March to May and this is likely to also increase solar energy due to the longer presence in the shining of the sun for Nchalo in Chikwawa. The graph further shows decrease in sunshine hours in June and July and pick up from August to November and during this period Nchalo in Chikwawa is also likely going to experience reduced solar energy production due to the reduced levels hours for the presence of sunshine in that area.

4.2 Correlation analysis

Correlation was done to determine the degree of relationship between Sunshine hours and solar radiation.

4.2.1 Correlation analysis for the stations

The correlation analysis for sunshine hours and solar radiation was done in all the stations namely, Ngabu and Nchalo in all the months. Below is the bar graph showing the stations with their correction coefficient.

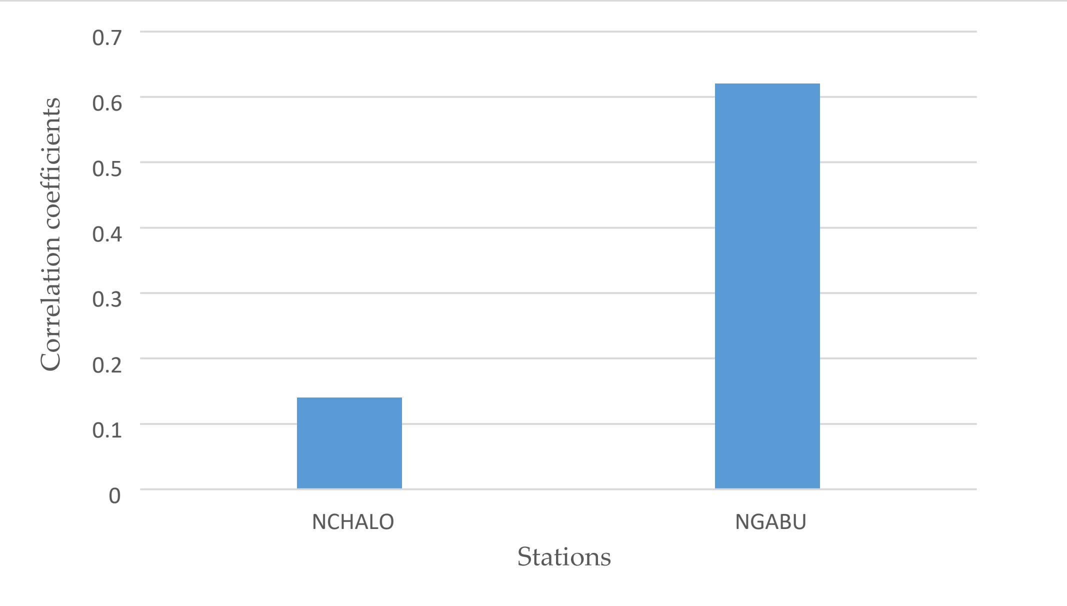


Fig. 4. Correlation analysis of sunshine and solar radiation for all stations.

The Fig 4. above shows how the sunshine hours and solar radiation correlates per station. To interpret the correlation significance, the t-Test was used and below is the results.

Table 2. t-Test results of correlation significance of sunshine and solar radiation over years

Station	Correlation Coefficient	Tabulated T-Value at 95% confidence level	Computed T-value	Significance Results
Nchalo	0.104000	2.101	0.33037000	Low
Ngabu	0.617977	2.101	2.48580773461	High

It can be seen that the significance of correlation is high in Ngabu station while low correlation in Nchalo station. The results clearly show that sunshine correlated highly with solar radiation in Ngabu station than in Nchalo. By using both figure 4 above and table 1, it demonstrates that there is a positive correlation between sunshine hours and solar radiation for all the stations. In this context, it means the increase in sunshine hours is associated with increase in the solar radiation. Conversely, it then also be inferred that the decrease in the sunshine hours could also lead to decrease in the solar radiation. However, by comparing the two stations, it could be established that Ngabu had a strong positive correlation. By having a strong positive correlation, it means that a significant increase in solar sunshine could also lead to a significant increase in the solar radiation. Conversely, for Ngabu it meant that a significant decrease in the sunshine in Ngabu could also lead to a significant decrease solar radiation. The findings also revealed however that Nchalo had a weak positive correlation such that a substantial increase of sunshine only had to lead to a smaller change in solar radiation in this station. Conversely it also means that a substantial decrease of sunshine in Nchalo could lead to smaller increase in solar radiation. In this context, it would also be important to note that for the purpose of correlation the sunshine was viewed as an independent variable (x) and the solar radiation was viewed as the dependent variable (y).

4.3 Results for assessing the trend of both sunshine hours and solar radiation over the area of study

This is the general pattern that the sunshine and solar radiation appears to follow over a long period of time. The analysis focuses the period of 19 years from 2000 to 2019.

4.3.1 Trend analysis of sunshine and solar radiation

The graph below show sunshine hours and solar radiation trend of annual totals for Ngabu station In Chikwawa.

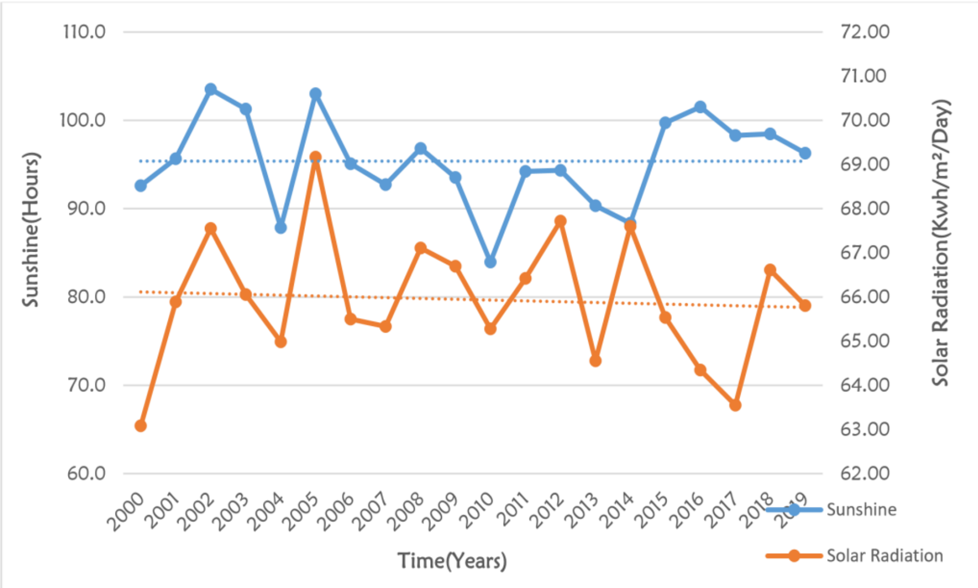


Fig. 5. Trend analysis for sunshine and radiation for Ngabu

To interpret the trends, the t-test was used, and the results are in the Table 2 below. From the t-Test results it can be seen that the trend was significant for both sunshine and solar radiation. The graphs below show sunshine hours and solar radiation trend of annual totals for Nchalo station in Chikwawa.

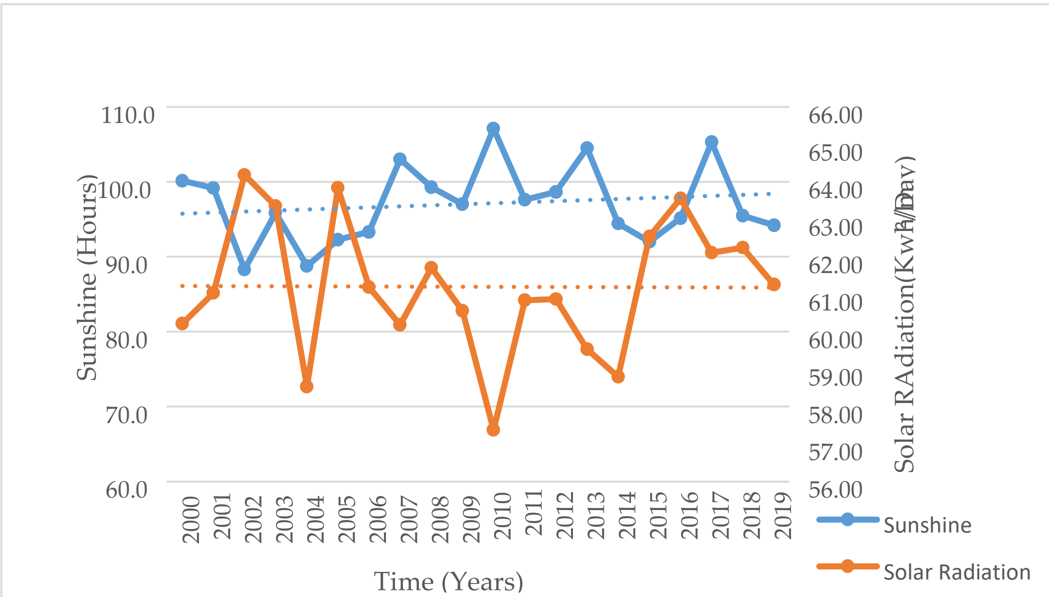


Fig. 6. Trend Analysis for sunshine and radiation for Nchalo

To interpret the trends, the t-test was used, and the results are in the Table 3 below. From the t-Test results it can be seen that the trend was significant for both sunshine and solar radiation.

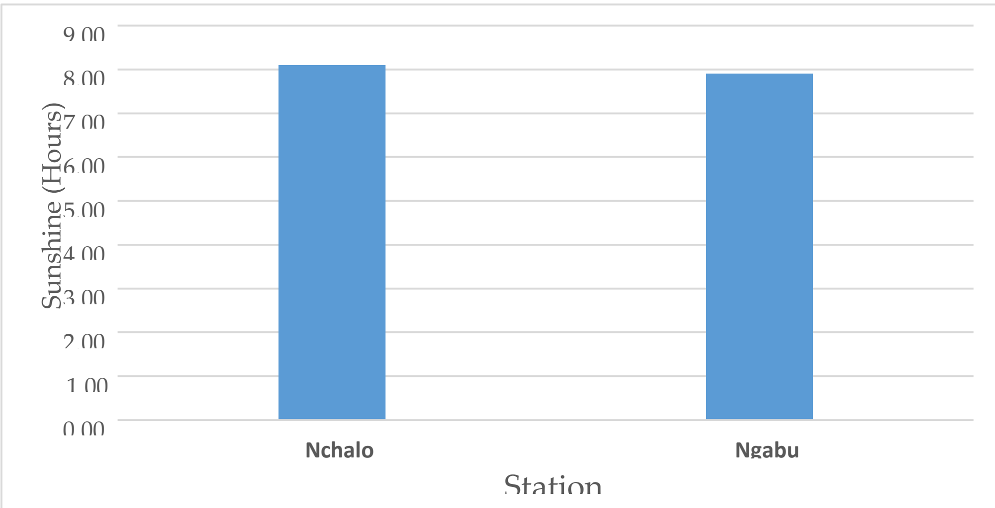
Table 3. t-Test results on the trend of sunshine and solar radiation over years

Station	Weather Element	Mean	T Critical one-tail	Trend Results
Nchalo	Sunshine	8.09	2.101	No significant
	Radiation	5.10	2.101	No significant
Ngabu	Sunshine	7.95	2.101	No significant
	Radiation	5.49	2.101	No significant

In relation to Fig. 5 and Fig. 6, as well as table 2, at both stations namely; Nchalo and Ngabu it was discovered that the trend for both sunshine hours and solar radiation were not significant. This meant that the differences between sunshine hours and solar radiation for the stations mentioned above had minimal differences for each respective station or to say it was hard to distinguish the rate of sun-shining hours for each station in relation to its corresponding solar radiation.

4.4 Results for assessing spatial distribution of solar radiation and sunshine hours over the area of study

The spatial analysis was done in order to find out which area have more in terms of yearly average of sunshine hours and solar radiation in the period of study; from 2000 to 2019. All the 2 stations involved in this study were analysed. The Results are shown as below



4.4.1 Spatial distribution for sunshine hours

The figure below shows the spatial distribution in terms of sunshine hours in the area of study Fig. 7: Spatial Distribution of Sunshine hours for Ngabu and Nchalo. As Fig. 7 above demonstrates, in terms of geographical analysis in terms sunshine distribution, it can be established that Nchalo experiences more sunshine that Ngabu but with a minimum difference of sunshine hours. In this regard, it means by assessing the availability of sunshine both Ngabu and Nchalo has the capacity to uphold the harnessing of solar energy production. This follows as both the areas geographically receives a better capacity or substantial amount of sunshine.

4.4.2 Spatial distribution for solar radiation

The figure below shows the spatial distribution in terms of sunshine hours in the area of study.

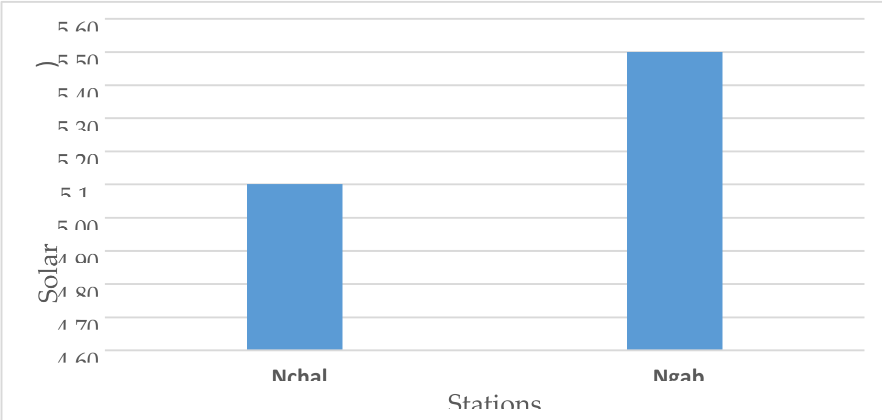


Fig. 8. Spatial distribution of solar radiation for Ngabu and Nchalo

As Fig. 8 above demonstrates, in terms of geographical analysis in terms solar radiation distribution, it can be established that Ngabu experiences more solar radiation than Ngabu but with a substantial difference of the amount that each station can receive. In relation to this it means that Ngabu is more potential for generation or harnessing of solar energy than Nchalo by comparing the amount of solar radiation each station can receive. Despite that Ngabu seems to be much better on this category, still both of the stations can still be used for production of solar energy as both has the access to some amount of solar radiation.

4.5 Map of potential areas where the solar energy can be harnessed over the area of study.

The analysis using QGIS 3.4.4 was done to determine the potential area where solar energy can be harnessed over the study area. The results come from the spatial distribution in the section 4.4.2 above. The map of Lower Shire Districts of Malawi below shows the spatial distribution of solar radiation.

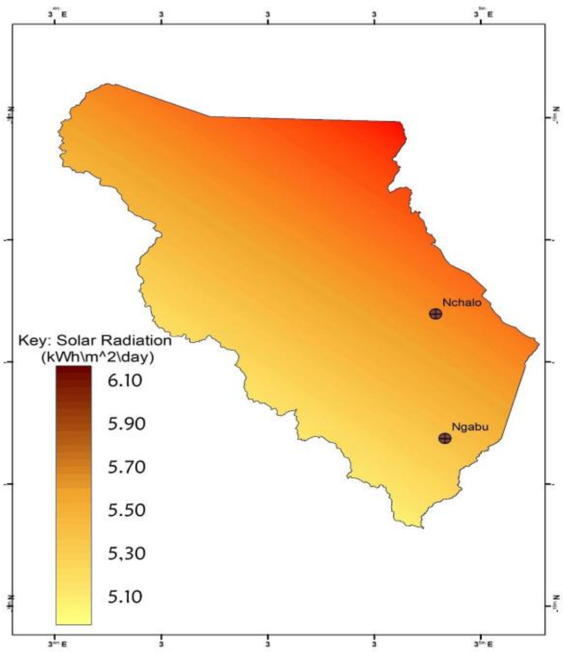


Fig. 9. Map of Malawi showing areas where the solar energy can be harnessed

The Fig. 9 above shows that other areas have more potential in solar energy comparing to other areas. North-Eastern part of the study area has the highest potential seconded by shire river shorelines. The map also shown that most of the areas in the Western region of the study area have lower solar energy potential. However, the minimum average of 5.10 kWh\m2\day is very good as far the utilization of the solar energy is concerned as most of the PV systems accommodate up to the minimum of 3.8 kWh\m2\day.

5. Conclusions

Based on the analyses of this study, it has been shown that the solar energy utilization is feasible in Lower Shire Districts. The 19-year average indicates the minimum of 5.10 kWh\m2\day of solar radiation which is very good as far the utilization of the resource is concerned. The climatologically base map created by solar GIS has shown the parts of the study area which have high potential of solar energy utilization. The analysis has shown that there are higher solar energy potentials in the North-Eastern areas of Chikwawa District and most of Eastern part of Nsanje District. The analysis has also shown that most of the areas covered by Ngabu Meteorological station have slightly higher solar energy potential than areas covered by Nchalo Meteorological station. The study further show that there is seasonal variation of solar radiation within the season of the year; March, April, May, August, September, October and November being the months of highest solar radiation utilization while December, January, June and July has lower solar radiation utilization potentials. The relationship between sunshine hours and solar radiation has been shown to be significant.

The research assessed the solar energy feasibility for power generation in lower shire Districts. The study intended to find solutions to climate change which is brought by use of unclean and exhaustible energy sources used in the study area. After the study was carried out, it has been shown from the results that there is abundant solar radiation resource which is not being utilized in Lower Shire Districts. This abundant solar radiation can be harnessed and be put into various uses such as water heating, lighting and electricity generation by the use of PV systems. In a nutshell, areas such as Ngabu and Nchalo in Chikwawa can be well utilized for solar energy production as they have the access to both a better amount of sunshine and solar radiation. Thus the fact that these areas are not being utilized it means country of Malawi is losing the ability to create more of solar energy by not utilizing such important areas such as Ngabu and Nchalo for energy production. Hence establishing solar energy production units in Nchalo and in Ngabu could help to reduce inadequacy levels of access to source of power in Malawi as long as the energy sector is concerned.

This research recommends the people in the area of study to put into consideration in this form of energy. They should invest and use solar energy as a reliable source of energy more especially in the rural areas where only 2% of the population has access to Electricity. The energy sector should take the utilization of the resource seriously as it real and possible in Lower Shire Districts. The sector should sensitize people on this readily available source of energy. Further detailed research need to be done to carry out full feasibility study more especially at regional and national levels. The study should be given enough and long period of time for data collection as well sufficient resources. There is need to install more solar Meteorological stations especially at district level for easy collection of solar resource data since climatic parameters varies with location and geographical position.

In the view of the above remarks, it also means the government of Malawi in conjunction with the private sector can greatly focus on ensuring on enacting more informed policy towards innovating the production of the solar energy. Among others to increase the capacity of such innovations it also means that both the government of Malawi and the private sector should invest more of its finances in the production of solar energy. This would help much energy sector in Malawi to attain more of the clean and friendly source of energy and at the end both economic and non-economic activities that depend on energy in Malawi would be improved.

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Author Contribution

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References

Ahsan, A., Imteaz, M., Thomas, U. A., Azmi, M., Rahman, A., & Daud, N. N. (2014). Parameters affecting the performance of a low cost solar still. *Applied energy*, *114*, 924-930. https://doi.org/10.1016/j.apenergy.2013.08.066 ,

Arefin, A., & Hossan, M. (2014). Solar Power as Renewable Energy for Home Systems in Bangladesh. *Dhaka, Bangladesh*.

Gabash, A., & Li, P. (2012). Active-reactive optimal power flow in distribution networks with embedded generation and battery storage. *IEEE Transactions on Power Systems*, *27*(4), 2026-2035. https://doi.org/10.1109/TPWRS.2012.2187315

Grover, S. (2007). *Energy, economic, and environmental benefits of the Solar America Initiative* (No. NREL/SR-640-41998). National Renewable Energy Lab.(NREL), Golden, CO (United States). https://doi.org/10.2172/914650

International Energy Agency (IEA). (2011). Solar Energy Perspetives. Paris: IEA. https://www.iea.org/reports/solar-energy-perspectives

Khaligh, A., & Li, Z. (2010). Battery, ultracapacitor, fuel cell, and hybrid energy storage systems for electric, hybrid electric, fuel cell, and plug-in hybrid electric vehicles: State of the art. *IEEE transactions on Vehicular Technology*, *59*(6), 2806-2814. https://doi.org/10.1109/TVT.2010.2047877

Kouzmanoff, J., Magyari, S., Oost, S., & Versteeg, K. (2016). Facts & Figures: Solar Energy. November, 67. http://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/Solar_Facts___Figures_Africa.pdf

Milanzi, H. C. (2014). Assessing the Potential for Solar Energy Utilization in Malawi. http://erepository.uonbi.ac.ke/handle/11295/95243

Mohan, A., & Ngwira, M. (2019). Monthly average irradiation forecasting for Malawi's solar resources. *International Journal of Innovative Technology and Exploring Engineering, 8*(8), 1049–1060.

Mwanza, M., Chachak, J., Çetin, N. S., & Ülgen, K. (2017). Assessment of solar energy source distribution and potential in Zambia. *Periodicals of Engineering and Natural Sciences, 5*(2), 103–116. https://doi.org/10.21533/pen.v5i2.71

National Statistical Office (NSO). (2019). 2018 Malawi Population and Housing. Census. Main Report. https://malawi.unfpa.org/sites/default/files/resource-pdf/2018%20Malawi%20Population%20and%20Housing%20Census%20Main%20Report%20%281%29.pdf

Salima, G., & M. S. Chavula, G. (2012). Determining Angstrom Constants for EstimatingSolar Radiation in Malawi. International Journal of Geosciences, 03(02), 391–397. https://doi.org/10.4236/ijg.2012.32043

Shiitzeichel H. (2007). Rural electrification with Photovoltaics. Altenburg: Solar Energy Foundation. https://iea-pvps.org/wp-content/uploads/2020/01/Rural_Electrification_with_PV_Hybrid_systems_-_T9_-_11072013_-_Updated_Feb2014.pdf

Sukhatme K., S. P. (1996). Principle of Thermal Collection and Storage. Tata McGraw-Hill Publishing Company Limited. https://books.google.com/books/about/Solar_Energy.html?id=l-XHcwZo9XwC

Taulo, J. L., Gondwe, K. J., & Sebitosi, A. Ben. (2015). Energy supply in Malawi: Options and issues. Journal of Energy in Southern Africa, 26(2), 19–32. https://doi.org/10.17159/2413-3051/2015/v26i2a2192

Winter, C. J. (1991). Solar hydrogen energy trade. *Energy policy*, *19*(5), 494-502. https://doi.org/10.1016/0301-4215(91)90027-L

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