ASSESSMENT OF SOLAR ENERGY POTENTIAL AND ITS ECONOMIC FEASIBILITY TO RURAL AREAS ELECTRIFICATION OF AKAKI KALITI,ADDIS ABABA, ETHIOPIA.

MSc. THESIS

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OCT, 2018

ASSESSMENT OF SOLAR ENERGY POTENTIL AND ITS ECONOMIC FEASIBILITY TO RURAL AREAS ELECTRIFICATION OF AKAKI KALITI ADDIS ABABA, ETHIOPIA.

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THE SCHOOL OF NATURAL RESOURCES AND ENVIRONMENTAL STUDIES,

WONDO GENET COLLEGE OF FORESTRY AND NATURAL RESOURCES,

HAWASSA UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE RENEWABLE ENERGY UTILIZATION AND MANAGEMENT

OCT, 2018

WONDOGENET, ETHIOPIA

APPROVAL SHEET I

This is to certify that the thesis entitled “**Assessment of solar energy potential and its economic feasibility to rural areas electrification of akakikalitiaddisababa,** Ethiopia. Submitted in partial fulfillment of the requirement for the degree of Master of Sciences with specialization renewable energy utilization and management the Graduate Program of the school of Graduate studies Hawasa University Wondo Genet College of Forestry and Natural Resources is a record of original research carried out by YOHANNES TSEGAYE MERI ID. No. MSC/REUM/0015/09, under my supervision and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the courses of this investigation have been duly acknowledged. Therefore, I recommended that it was accepted as fulfilling the thesis requirement.

Solomon T/Mariam teferi__________________ _______________

Name Major Advisor signature Date

Approval Sheet II

We, the undersigned, members of the Board of examiners of the final open defense by YohannesTsegaye have read and evaluated his thesis entitled assessment of solar Energy Potential and its Economic feasibility to rural areas electrification of AkakiKaliti,Addis Ababa, Ethiopia and examined the candidate. This is therefore to certify that the thesis is accepted in partial fulfillment of the requirements for the degree of Master of Science.

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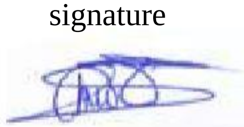
Name of major Advisor	 signature	Date
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DEDICATION

To my Parents

STATEMENT OF AUTHOR

First of all, I declare that this project is my work and that all sources of materials used for this project have been duly acknowledged. This Project has been submitted in partial fulfillment of the requirements for (M.Sc.) degree at the Hawasa University and is deposited at the University Library to be made available to borrowers under rules of the Library.

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School/Department: (NATURAL RESOURCES AND ENVIRONMENTAL STUDIES)

Date of Submission: October 8 2018

ACKNOWLEDGEMENTS

I offer my deepest gratitude first and foremost to my Advisor, Solomon T/mariyam for his unlimited and constructive guidance, advice, suggestions, comments and friendly approach during this research project. His follow up and his consistent support will be in my memory forever.

I am also thankful to my friends for their support, useful discussions and constructive criticism. I want to acknowledge the former National Metrological Agency and akakikality sub-city woreda 10 and 11for their cooperation for providing me the raw data. My special thanks go to my family for their indispensable support. I want to acknowledge the MRV Project for sponsoring my M.Sc. study. I would like to thank Hawasa University Wondogenet College of forestry and natural resource for facilitating the project work. Last, but not least, my thanks also go to all those who have directly or indirectly given me constructive ideas and suggestions for the betterment of my work.

Table of Contents

List of table

List of figure

Abbreviations

C_{bn} Net capacity of the battery (Ah)

C_b Commercial capacity of the battery

E_p Energy supplied or delivered by the solar panel

E_A The array energy available to the load and the battery

E_b Energy that can be stored by the battery

E_u Energy demand of the village

G_{sc} The solar constant =1368 (W/m2)

$\overline{H}$ Monthly averaged daily radiation on horizontal surface (MJ/m2)

o Monthly averaged daily extraterrestrial radiation on a horizontal surface (MJ/m2)

d Monthly average daily diffuse radiation

T Monthly average daily total tilted radiation

I Hourly total or global radiation

I_b Hourly beam radiation

I_d Hourly diffuse radiation

C_T Monthly average daily clearness index

N_s Maximum possible daily hours of bright sunshine

n_s Monthly average daily number of hours of bright sunshine

NASA National Aeronautics and Space Administration

PV Photo Voltaic

P_p Peak power of the solar panel (W)

P_w Power in the wind (W)

R_b Ratio of beam radiation on the PV array to that on the horizontal

r_t Ratio of hourly total radiation to daily total radiation

r_d Ratio of hourly diffuse radiation to daily diffuse radiation

t_L Local solar time in hours.

α_s Solar altitude (^{0})

γ_s Solar azimuth (^{0})

δ Declination angle (^{0})

η_t Overall efficiency of the transmission system/power train of wind turbine

θ_z Zenith angle (^{0})

β Slope of the PV array (100)

$\emptyset$ Latitude (^{0})

ω Solar hour angle (^{0})

ω_s Sunset hour (^{0})

SHS Solar home system

ρ_g ground reflectivity coefficient

Appendix Table Page

Abstract

Many Ethiopians live below the poverty line especially Households in the rural area Because of that used the most extreme traditional energy use for cooking, lighting and heating. In most parts of the country in Ethiopia use kerosene and firewood for lighting. This is the critical problem for rural community lighting the house modern technology's it is extremely important to find the option to solve this problem. According to our country many scholars explain the most abundant energy source or potential was solar energy 13 months of sun shine.

This study was aimed at investigating and estimating the potential of solar PV energy application across rural Ethiopia off-grid solar home system (SHS) for individual solar households and energy demand. The data was collected from nearest part of the study area Akaka kaliti sub-city Addis Ababa bole metrological agencies 8 years global solar energy data was took. Then, using empirical formula and 3 models which is called Leu and Jordan,Koronakis*and*Badescu*calculate average solar energy potential of specific area was analyzes. The calculated result were 5.09Wh/m^2 ,5.08 Wh/m^2 and 5.06Wh/m^2 for each model .To measure the needs of people's energy demand, we took 2 kebeles and 38 households and categorized in to three depend on the energy demand, namely small, medium and large. Then, the average energy demand resulted 111 watt, 327 watt, and 637 watt each of the categorized household. Then, compared the needs of each family's energy demand with traditionally used kerosene and cell battery for payback period and economic benefit the result was it takes pay 1, 2 and 3 years for each categorized energy demand . Therefore, electrifying rural community using SHM was the one and the only solution for sparsely populated Ethiopian farmers and villagers to reduce social, economic and environmental problems.*

Key words: potential, payback, energy demand, solar home system (SHS)

Chapter one

1. Introduction

Background

Diesel engines are commonly used to electrify in remote areas and used as backup in urban areas. Due to their non-renewability, fossil fuel driven power plant are not sustainable. One of the international efforts today to overcome such challenges is to replace the fossil fuel by renewable energy sources. One of these energy sources is of course solar energy.

The total electricity coverage of the country is around 16 % and its coverage is more in the urban areas. Ethiopian rural communities are living far away from the grid and they are sparsely populated as well. Hence, off-grid solar photovoltaic electrification is a good option if properly handled to supply electrical power for individual houses or small community. To a system with a large amount of demand passes major challenge in term of looking at possibility of solar for powering. The whole Ethiopian country need power specially the rural community we need solution for this critical problem one of the best and appropriate one is electrifying by means of solar. Because it is very complex and difficult to powering the whole community using grid connecting electricity and to powering the whole rural community there are a lots of natural, economic and technical problem. It requires money studies, a lot of analysis's, money evaluations to solve the problem. The peoples of Ethiopia suffered a lot for searching of energy can't wait for all of that right now they need solution. we need to look another types of alternative energy out of biomass and fusil fuel very seriously at now. So, we have the possibility to transform appropriate and modern renewable energy which is called solar energy for powering the community.

This study was tray to figure out this solution sustainable for the community through providing full information and used as guide line to transform the community another alternative energy in the fever of privatized solution but, one thing we need to consider or clear is energy have been generated or own by the rural community this was done to clearly understand specific area energy problem solution. Different researchers and estimation tools suggest that the electricity potential of our country on average more than 5MWh/m^2 this indicated that almost all parts of the country can generate electricity annual for household electricity conception of lighting the rural community. According toKebede et.al 2016the annual solar generation potential of Addis Ababa 5.07 KWh/m^2 annually with this capacity we can generate sufficient energy in rural part specific area.

1.2 Statement of the problem

It is difficult to get precise solar data for a particular area in Ethiopia and the different road maps studied by different researches are also showing big variation. Hence, this study will focus more on assessing the solar energy potential in the specified area. This was done by referring the solar data for the given location from different sources taking on field solar insolation and other measurements and comparing the results to find better data which can be used to estimate the solar energy potential in that study area. Moreover, solar PV electrical Power Plant will be proposed.

1.3 Objective

1.3.1 General Objective

The main objective of this thesis work is to assess the solar energy potential of rural parts of AkakiKalitiy as a feasible option to power the village using solar photovoltaic cells.

1.3.2 Specific Objectives

1. Study the solar energy potential of the specified area based on the past information
2. Analyze the current solar energy potential of the site by measuring and taking on sites data. .
3. Assess the economic feasibility of solar photovoltaic electrification for the specified site.

1.4 Research Questions

Based on the stated objectives, the following questions will be used to guide the research process and finally was answered from the findings of the study.

- What is the minimum amount of energy needs in household and small community to electrify themselves?
- Is that possible and affordable to install Solar PV cells to electrify in specific area?

1.5 Significance of the study

The main purpose of the study to know the potential to generate electricity using simple and appropriate way of PV based electrification system for off-grid rural people application the criteria to be follow for designing photovoltaic system for various application such as Solar home system and micro solar energy production for governmental institutions and small business holders in the rural parts of the Addis Ababa and their surroundings. The possibility, affordability and constraint of designing the solar energy in the study area will be evaluated.

1.6 Scope and limitation

This study will focus on developing a small scale solar energy production to electrify rural parts of the country . This system will let users (staff, students or lecturers) to freely interact with the technical support employees who have the ability to answer all problems related to the solar energy potential and there economic feasibility. In addition, investigatesmall scale solar energy appropriate for rural community to electrify individual household using cheap and clean solar technology.

Chapter Two

2. LITERATURE REVIEW

2.1 Solar Energy potential

Solar energy

A radiation from the sun that is capable of producing heat causing chemical reaction or generating electricity. That is the largest source of energy received on the earth and solar energy is the ultimate source of all forms of energy

Energy that converted solar energy in to electricity using photovoltaic cell solar cell this converted energy used to provide electricity for different electrical materials cameras, TV, radio, LED bulbs and so on . Solar energy is free the highest cost is collection, conversion and storage has limited the exploitation.

Solar energy potential

Solar radiation can be converted into sustainable produced electricity by using photovoltaic (PV) technology. **Solar** energy **potential** can be **defined** as the physically available **solar** radiation on the earth's surface (Perpiña 2016).

2.1.1 Solar power system

Off-Grid Solar Dependent Systems

For cheap power in remote locations, often these systems are the only choice. They generally consist of a small battery bank, a charge controller, and a solar array. People with these systems choose to use all DC appliances so as to avoid the cost and inefficiency of inverters. These systems have the advantage of lower initial cost. The batteries are still an issue for maintenance cost. And there is no backup power if weather doesn't allow the panels to charge the batteries.

There are also three types of off grid small scale solar system

a) Solar home system (SHS)b) Solar kit c) solar lantern

Fig. 2.1 types of off grid small scale solar systemsa used for all electrical applicant

Solar Home Systems (SHS) are small to mid-size systems using photovoltaic solar energy and battery storage to provide electricity where there is no access to grid connected electricity (Mathur, S et.al, 2001).

Solar kit Most solar systems utilize **solar panels**, a charge controller, a battery bank, an inverter, and all the wiring and appropriate accessories to put it all together (Hankins, M., 2010).

Solar lantern small and very easy types of solar type used to one purpose lighting

Grid-Tied Solar Systems

This is the easiest and most popular way to get started in PV power. These systems simply tie into your existing home power system and the utility grid. If your array generates more energy than you use, the energy is sold back to the power grid and creates a credit for you. The advantages of these systems are the relative simplicity and lower initial cost. A system like this typically requires a few panels, some wiring boxes and disconnects, and an inverter. The inverter converts the electricity from your panels to power that your home and the grid can use.

2.1.2. Photovoltaic Power System

2.1.3. PV Cells

Solar cells, also called photovoltaic (PV) cells by scientists, convert sunlight directly into electricity. PV gets its name from the process of converting light (photons) to electricity (voltage), which is called the *PV effect*. The PV effect was discovered in 1954, when scientists at Bell Telephone discovered that silicon (an element found in sand) created an electric charge when exposed to sunlight. (*national electronics laboratory*). An individual PV cell is usually small, typically producing about 1 or 2 watts of power. To boost the power output of PV cells, they are connected together in chains to form larger units known as modules or panels

2.1.4 Physical characteristics of PV

Solar cells for terrestrial applications are typically made from silicon as single-crystal, polycrystalline or amorphous solids.

• **Single-crystal silicon** is the most efficient because the crystal is free of grain boundaries, which are defects in the crystal structure caused by variations in the lattice that tend to decrease the electrical and thermal conductivity of the material. They can be thought of as barriers to electron flow.

• **Polycrystalline silicon** has obvious grain boundaries; the portions of single crystals are visible to the naked eye.

• **Amorphous silicon** (a-Si) is the non-crystalline form of silicon where the atoms are arranged in a relatively haphazard way. Due to the disordered nature of the material, some atoms have a dangling bond that disrupts the flow of electrons. Amorphous silicon has lowest power conversion efficiencies of the three types, but is the least expensive to produce. (Parimita Mohanty 2012)

Perovskite (Future PV) Future solar panels might rely on perovskite, a promising material that has the potential to make panels cheaper, simpler, and more efficient.Light absorbing capabilities for longer periods.The problem is that perovskite solar cells have the pesky tendency to degrade in sunlight. However, a new study has found both the cause and a solution for this issue, a research breakthrough potentially removing one roadblock to commercialization for this promising technology.(Energy 12 Jul. 2016,)

2.1.5. Major Types of Solar PV Systems

1.***Grid-direct:*** These are primarily used in systems for homes and businesses with utility power present. They don’t provide the user with any energy storage, which means if the utility power isn’t present, the inverter can’t work. In grid direct inverter systems, the PV array is connected to the inverter on the DC side, and the inverter is connected to the utility grid on the AC side.

2.***Battery-based*****:** These require a stable voltage source of power, typically a battery bank, to keep the inverter running. A PV system using this inverter requires more components and is generally more complicated, but it allows the user to have backup power for times when the utility goes out. Battery-based inverters use a PV array and charge controller on the DC side and connect to the utility on the AC side.(Mayfield 2010)

3. *Solar PV hybrid system*: In a hybrid system, another source(s) of energy, such as wind, biomass or diesel, can be hybridized with the solar PV system to

2.1.5 Components of PV system

Introducing PV Components and Systems can be ridiculously simple (connect a module to a load and use the load as you wish), but they can also seem overwhelming when

Yet, despite the differences in the details, the PV systems you connect to homes and small businesses have some specific and very necessary components (all of which have an important role to play in the system).

PV modules: The individual units that you place in the sun to produce electricity from the sun are called PV modules. A number of modules connected together in different configurations form a PV array.

Battery bank: Batteries provide a way of storing the energy produced by the PV array. Individual batteries connected together make up a PV system’s battery bank

Battery types

Lithium batteries

The advantages of Lithium Phosphate batteries (as compared to Lead Acid for example) are that no maintenance is necessary, they can operate at very low temperatures without affecting capacity, and they are much safer.

Flooded lead acid batteries

Flooded lead acid batteries have the longest track record in solar electric use and are still used in the majority of stand-alone alternative energy systems.

Sealed AGM batteries

AGM batteries are seeing more and more use in solar electric systems as their price comes down and as more systems are getting installed that need to be maintenance free.

Sealed gel cell batteries

Gelled lead acid batteries actually predated the AGM type but are losing market share to the AGM's. They have many of the same advantages over flooded lead acid batteries including ease of transportation, as the AGM type, except the gelled electrolyte in these batteries is highly viscous and recombination of the gases generated while charging, occurs at a much slower rate.

Saltwater batteries

Get access to the world’s first green battery! Aquion Energy's new salt-water technology is game changing and makes energy storage safe and sustainable! Very high cycle life at 100% depth of discharge makes this ideal for long duration solar applications.

Desulphators

Battery desulphators electrically shake the sulfate crystals that build up on the lead plates of a flooded lead acid battery over a period of time. Before desulphators batteries with sulfate build up would effectively be considered dead (www.altestore.com).

Inverters: Devices that take power from the PV array or the battery bank and turn it into AC power used to operate loads are inverters.

The inverters in PV applications fall into two major categories:

✓ ***Utility-interactive:***These inverters can connect to a utility and either supply power to the connected loads or send electricity back into the grid, essentially running the meter backward.

✓ ***Stand-alone:*** These inverters aren't designed to interact with the utility and work by supplying power to loads.

Disconnects and overcurrent protection: These components are necessary for ensuring the safety of the system and the people who come into contact with it.

2.2 Current statues of Solar Energy in Ethiopia

The first PV systems were installed in Ethiopia in the mid-1980s these systems were installed for rural home lighting and for school lighting. The largest of these was a 10.5kWp system installed in 1985 in Central Ethiopia which served 300 rural households through a micro grid in the village (This system was later upgraded to 30kWp in 1989 to provide power for the village water pump and grain mill. It is estimated that a total of some 5.3MWp of PV is now in use in Ethiopia. The main area of application for PV is now off-grid telecom systems (particularly for mobile and landline network stations) which account for 87% of total installations. PV systems are also used in social institutions including health stations, schools and for water pumping. Some thirty thousand residential customers are also electrified with PV in rural areas(Gudina Terefe.et.al,2014).

2.3 solar energy importance and generation capacity

Solar energy is clean, unlimited and safe. Even when it is converted into electricity through photovoltaic or thermodynamic plants, it does not produce harmful emissions. That is why this Renewable energy source has assumed a key role in the future of energy policy. Many governments started incentive plans to promote generation and integration of energy into the grid and solar home system by means that minimize the environmental impact . Ethiopia has substantial solar energy resource. However, less than 1% of the potential has been exploited so far. According to the recent data collected by energy information administration and development follow up core process, within the last 6 years, the total generated energy from solar photovoltaic is more than 35 MWh, more than 6MW than the installed capacity. Solar water heating systems with the total energy generation of 299 MWh and ten water pumps with pumping installed capacity of 10 kW have been installed in different parts of the country by governmental and nongovernmental organizations (minister of water and irrigation)

2.4 The energy situation in Ethiopia

"Energy for different countries plays a great role in shaping the economy of the country. According to the energypedia Ethiopia is one of the least developed countries in the world. Approximately 34 % of its over 100 million inhabitants live below poverty line (*International Energy Agency, 2016*). According to the latest national energy balance indicates that Ethiopia consumed 1.3EJ of energy in 2010. This was derived from biomass fuels (92%), hydrocarbons

(7%), and electricity (1%). The main consumers of energy were the residential and service sector (93%) and transport (5%) with the remainder going for industrial and other applications. Rapid economic growth has increased the pace of energy demand growth in Ethiopia: 6% for biomass fuels, 11% for electricity, and 11% for petroleum products.*(Ethio Research Group 2012*). Now a day, the development of the country increase time to time because of world driving force and the country's economy but still the energy demand is very high and the production of energy is very low.More than 70% of Ethiopians depend on fuel based lighting including fossil and solid biomass fuels (*CSA, 2012b*) and a relatively small segment of the population also uses fuel based electricity generators. This contributes to greenhouse gas emissions, air pollution, and local environmental degradation. The green growth strategy seeks to displace fossil and solid biomass fuel use for lighting and other applications by renewable sources of energy including hydro, wind and solar.(*Ethio Research Group 2012*).

The transition to an environmentally benign economy will reshape many features of today's society. In developing countries, where rural electrification is embryonic, the applications of photovoltaic (PV) systems are important. Extending power lines from centralized sources to rural areas is often not yet economical, and so, decentralized power sources, such as the PV system, are a promising alternative (Kolhe 2009).

It is anticipated that photovoltaic (PV) systems will experience an enormous increase in the decades to come. However, a successful integration of solar energy technologies into the existing energy structure depends also on a detailed knowledge of the solar resource (Ganguli & Sinha 2010).

In rural areas it is rather difficult to maintain a diesel generator because of the lack of essential spare parts and fuel availability or for maintenance reasons. As a result of this some villages own a generator, but it is out of operation and cannot supply reliable electricity. Another problem is the low voltage connection of the houses. In some cases the villagers cannot afford to connect their house to the central generator. Energy loss in such low voltage distribution networks and low power demand of end-users are significant and worsen the financial performance. Furthermore air and noise pollution of a diesel generator is not negligible (Anon 2007).

2.5 Solar home system payback period

The payback period of a standard 10 Wp SHS is between 2 to 4 years, depending on energy consumptions habits of the users. Families using two kerosene lamps reach break-even of their investment in a 10 Wp SHS in about 3.5 years (Breyer, Ch, et al.2009). After break-even there are only regular replacement costs of some components which add up to a significant monthly reduction of energy cost by about 80% this saved energy spending can be used for increasing the standards of living, e.g. better energy supply, education, medical aid, improved houses and much more(Breyer, Ch, et al.2009).

2.5.1 Financial benefit of *SHS*

Financial benefit for SHS owners is obvious, in particular in respect to an expected system lifetime of 20 years. Profitability of rural off-grid SHS is considerably higher than on-grid PV installations in most developed countries.(W. Short, D.J. Packey, T. Holt, A 1995) Ethiopia is an example that off-grid PV is a highly attractive source of electricity for rural population in developing countries. Very short payback periods for small PV systems offer high financial savings which can be spent for other needs like education (Breyer, Ch, et al.2009).

Energy poverty is defined as inability to cover basic energy cost to keep homes adequately warm, cook food and have light. It can be also defined as the absence of sufficient choices for affordable, reliable, high quality, safe and environmental benign energy services to support economic and human development (Reddy, 2004).

Rural electrification is often considered to be the backbone of the country's economy. It brings tangible social and economic benefits to rural public who contribute growth and development for the population(Annigeri & Ieee 2016).Most of the remote rural areas of Ethiopia are not yet electrified. Electrifying these remote areas by extending grid-system to these rural communities is difficult and costly. As the current international trend in rural electrification is to utilize renewable energy resources solar, wind, biomass, and micro hydro power systems can be seen as alternatives. Among these, solar energy system is thought to be ideal solution for rural electrification due to abundant solar radiation availability nearby the rural community in Ethiopia.(Anon 2012)

2.6 Past studies of solar energy in Ethiopia

According to AkliloDalelo et.al,2003the potential of Ethiopian solar energy Studies indicate that for Ethiopia as a whole, the yearly average daily radiation reaching the ground is 5.26 KWh/m^2 . This varies significantly during the year, ranging from a minimum of 4.55 KWh/m2 in July to a maximum of 5.55 KWh/m^2 in February and March. On regional basis, the yearly average radiation ranges from values as low as 4.25 KWh/m^2 in the areas of Itang in the Gambella regional state (western Ethiopia), to values as high as 6.25 KWh/m^2 around Adigrat in the Tigray regional state (Aklilu Dalelo 2003).when we come to Addis Ababa surrounding and some part away from the city the solar potential also have some difference from the lower latitude like afar gambela and other because of altitude , cloudiness effect, temperature etc. difference.

Local aid agencies, as well as domestic engineers and electric engineers, often use diesel generators in generating electricity. This technology has two major consequences: It is often unreliable and fuel injection at distant places is very difficult. However, spare parts and experienced technicians can be readily available. Of course, due to the high impact of the Dodge technology, most of Ethiopia's regions are very remote, making it impossible to supply electricity to that source.(Sch 2011)

2.7 Past studies of solar energy in Addis Ababa surrounding

According to kasahune the average hourly solar energy Using HOMER software, the daily radiation and clearness index of the proposed site is presented. The annual average daily radiation is 5.07 kWh/m^2 (tilted equal to the latitude), and the average clearness index is 0.513 most parts of the Addis Ababa surrounding ,(Kebede 2015). this indicated that the potential is very high but the economical affordability of the technology is not feasible when we compared to grid based solar electricity generation. In our country Ethiopian context, the energy crisis is believed to be the second most serious problem in these countries next to the food crisis the best solution to solve and control the problem is use of solar technologies. This is unique in Ethiopia 80% of the population live in rural areas where only 1% of the populations have access to electricity.Lighting up the countryside has long been a challenge for Ethiopian governments. Unlike houses in urban areas, villages in rural areas are often difficult to connect to the national electricity grid, (BBC, 2009) .

According to the early studies of grid connected solar production in Addis Ababa surrounding for commercial purpose suggests that a detail feasibility study for a grid-tied 5 MW PV system in Addis Ababa area was also conducted. It was found that 7658 MW can be generated annually from the system and the financial indicators showed that the investment is economically viable but not sufficiently attractive for commercial investors.It requires high initial investment for joining the solar PV market.Not only this, but also when compared to SHS it's not convenient and easy in many ways there are so many things that are hard to deal with some of them are it needs transmission line to distribute, as explained earlier it needs high investment cost, it is difficult to use highly remote areas and so on. if you take the SHS you can use any time any were because it easily portable and cost effective for our rural community. This review provides a detailed overview of the solar energy Problems and challenges, including the current state of SHS's status and operation strategy in rural Addis Ababa surrounding, its successful development and benefits.

The techniques of disseminating the energy through the specific area. In general the study gives hint to electrify the rural community

2.8 Constraints of solar energy in rural Ethiopia

The solar energy price is very expensive at first glance due to the per installment basis. Professional installation’s comparatively high expense is primarily due to the fact that solar energy use is an emerging technology. To make the most of any solar panel installation, energy efficient appliances should be utilized to prolong effectiveness and the lifespan. But now a day solar photovoltaic technology getting chipper very rapidly and its cost price are already comparable with energy from fosil fuels in some countries according to the (enrgpidia, 2017),

The main constraint of solar energy generation in country

- In adequate technical skills,
- Lack of innovative financing mechanism to draw-down up front cost of systems,
- Inadequate awareness among policy makers as well as consumers,
- Lack of clear and coherent policy, and hence, institutional capacity to facilitate commercialization of the technology, and
- Poor linkages between the national level suppliers/dealers and local level retailers and
- technicians etc. (enrgpidia,2017)

Expected outcome for this study

- The technique of the rural community producing their own energy easily and manageable way
- In order to identify rural people producing their own energy how much it is costing
- To understand how much amount of energy sufficient for each house hold, the cost of the total installation and the economic feasibility of the technology.
- To make the study as a reference for researchers and investors for investing and studying further.
- It provides information for technological efficiency problem by providing detail information
- The potential of feasibility and their sustainability for the local community
- The constraint of the technology and their appropriate solution

- This research used as a Gide line who should not know or familiar with solar technology
- It change the quality of life in the rural community it needs alternative energy this indicate solution for it

Chapter Three

3. MATERIALS AND METHODS

This research important to know the low cost solar electricity production for the rural community which have a statues of the poorest of the poor, by developing different alternative use. If you cannot power it has been always poverty. The best way of avoiding poverty electrify the rural community as well as the city and villages by providing easily accessible, reliable and affordable alternative energy this study identify the solution for those critical problems of rural parts of Addis Ababa surroundings.

3.1.2 Description of the study area

Akakikality sub-city is one of the largest sub-cities located in South Eastern part of Addis Ababa. It shares boundary with Bole Sub-city in the North, Kirkos and Nifas Silk LaftoSubcities in the North West and Oromia regional state in the South. The lowest point 2,050 meters in the Southern periphery and the maximum elevation is 2,331 meters above sea level. The Sub city has 11 woredas and covers total area of 156 km^2. (Addis Ababa City Land Information Center, 2014).it is 20 kms far from the city's center and its population is estimated 220,740 with 114,095 female and 106,645 male most of the kebeles/woredas are found at the out skirt of city the number of household 45,751 it have 12 woredas (2007 central static authority)

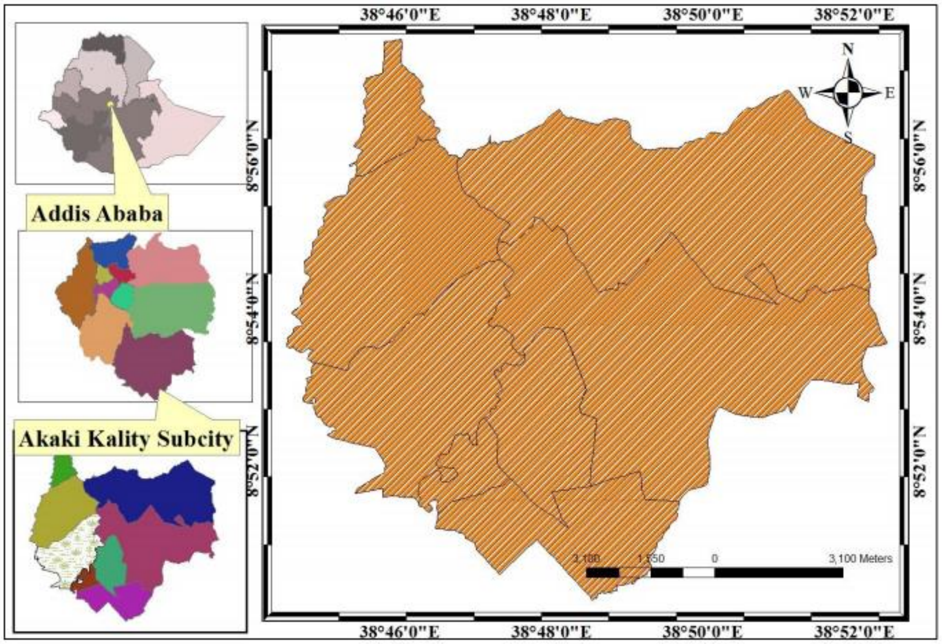


Fig. 3.1Akaki GIS Map

3.2 Method of data collection

3.2.1 Primary data collection

The solar energy assessment was made from data collected at Addis Ababa surrounding station. bole (a village of our interest) is about 3 km from but at comparable altitude with AkakiKaliti , which is the closest station with Meteorological data available. Solar energy potential, there is no accurately measured solar radiation database. Only sunshine hour data was available. Therefore, mathematical models able to incorporate the available sunshine hour data and provide the required solar radiation data were used for determining the potential at the location. In this study, all the data that were used for determining the solar potential of the site were relatively recent (2011 – 2018). The data were recorded every 15 mint over 24 hours using data logger attached to cup anemometer, at a height of 2 meters, for 8 consecutive years.

The economic analysis is collected from interview of personnel involves in assessing the solar home systems energy demand in the study area and the respondents of the systems through questionnaire survey and field observation using bottom up approach. An investigation visit to the study area conducted just prior to the survey. On the contrary, secondary data collected from websites, journals, conference proceedings, and other statistical sources. The specification of the selected systems as follows: The methodology employed in this research is mainly through literature reviews, the use of the online software PVwatt and other supporting tool for analysis.

3.2.2 Sampling

The study used primary data that collected from selecting households for energy demand analysis in the sub-city of Addis Ababa surrounding Akakikaliti. The study employs a central limit theorem to identify data sources. In the first stage of systematic sampling, sub-cities is under Creative common selecting stratified randomly from sub-cities .In the second stage we selected woredas which is more exposed to energy poverty or no access to electricity at all randomly for the purpose of sampling the selecting sub-city categorize in to 3 in the perspective of energy consumption high, medium and low. The determination of sample size used simple formula of central limit theorem.

Using equation 3.1Select 36 households from 800 selected two woredas10 and 11 then, divide the household depend on the energy consumption

We took 18 household from each woredaand divide into high ,medium and low

Take 6 household from each categorized household which is

S_1 from woreda 10

$S_2$from woreda 11

A. Determine Households sample size with the confidence interval of 95%

3.3 Solar energy and their terminology

3.3 .1 solar energy reaching on the earth

The solar radiation reaching per square meter in the outer atmosphere is 1367 W/m². However, some of the sun lights falling on the earth are absorbed and reflected back by the atmosphere and the clouds. Some angles form between the sunlight falling on the earth and the surfaces(Duffie & Beckman 2013). The position of the sun at different periods is determined by the solar angles. Moreover, solar angles are used to track the movement of the sun in a day. The rotation of the sun varies depending on the latitude and longitude of the location.

3.3.2 Solar Radiation terminology

To determine the PV electricity generation potential for a particular site, it is important to assess the average total global solar radiation received over the year. Unfortunately in most developing Countries there is no properly recorded radiation data. What usually available is sunshine duration data. Ethiopia is one of the developing countries which have no properly recorded solar radiation data and, like many other countries, what is available is sunshine duration data. However, given knowledge of the number of sunshine hours and local atmospheric conditions, sunshine duration data can be used to estimate monthly average solar radiation, with the help of empirical equation (Duffie, J. & Beckman,2013).

Solar constant

The solar constant G_{sc} is the energy from the sun per unit time received on a unit area of surface perpendicular to the direction of propagation of the radiation at mean earth-sun distance outside the atmosphere. They resulted in a value of the solar constant G_{sc} of 1353 W/m2 with an estimated error of ±1.5 %.(Thekaekara (1976).

Extra-terrestrial radiation

The radiation that would be received in the absence of the atmosphere G_{on}

Beam Radiation

The solar radiation received from the sun without having been scattered by the atmosphere. (Beam radiation is often referred to as direct solar radiation; to avoid confusion between subscripts for direct and diffuse, we use the term beam radiation.)

Diffuse Radiation

The solar radiation received from the sun after its direction has been changed by scattering by the atmosphere. (Diffuse radiation is referred to in some meteorological literature as sky radiation or solar sky radiation the definition used here will distinguish the diffuse solar radiation from infrared radiation emitted by the atmosphere.)

Total Solar Radiation

The sum of the beam and the diffuse solar radiation on a surface(The most common measurements of solar radiation are total radiation on a horizontal surface, often referred to as global radiation on the surface).

Solar Time

Time based on the apparent angular motion of the sun across the sky with solar noon the time the sun crosses the meridian of the observer.

$$\text{Solar time} - \text{standard time} = 4(L_{st} - L_{loc}) + E$$

3.3.3 Solar angles

Latitude angle, Declination angle and Azimuth angle

Declination angle (δ) is the angle between the sun lights and equator plane. It is positive at north and varies between -23.45º $\leq \delta \leq$ 23.45º. The latitude angle (Ø) is the angle forming according to the equator center. The north of the equator is positive and the south of the equator is negative and it varies between -90º ≤ Ø ≤ 90º. Declination angle is at its highest point on 21th June (23.45º) while it is at its lowest point (-23.45º) on 22nd December in winter. Therefore, Addis Ababa located at the angle between 8.9806º N and 38.7578º E. calculate formula below

$\boldsymbol{\delta = 23.45 sin\left[360o\,\frac{(284+n)}{365}\right]}$ **-----------------------------------(3.2)**

Where n represents the day of the year and 1st January is accepted as the start *.(Duffie &beckman 2013*)The yearly variance of declination angle is drawn in by declination angle formula show in in appendix (table 1).

latitude angle(∅)

The latitude angle calculated according to the equator center the fixed solar plate collector south facing the solar collector location Addis Ababa altitude 8.9806º N and 38.7578º

Calculating Tilt angle

Tilt angle (β) is the angle between the panels and the horizontal plane. This angle is south oriented in the Northern Hemisphere and north oriented in the Southern Hemisphere. Tilt angle varies between 0º ≤ β ≤ 180º. When a plane is rotated about horizontal east-west axis with a single daily adjustment, the tilt angle of the surface will be fixed for each day and is calculate by the following equation.(Karafil et al. 2016)

$\boldsymbol{\beta = /\emptyset - \delta/}$**…………………………………………(3.3)**

∅ latitude angle

δ declination angle

For the rotation of a plane about a horizontal north-south axis with continuous adjustment, the tilt angle of the surface will be calculated by the following equation (Karafil et al. 2016)

$\text{Tan} = \tan\ \beta_z/\cos\ \gamma_s/$

Let say we are using the fixed solar plate collector south facing the solar collector location Addis Ababa altitude 8.9806° N and 38.7578° E(Google earth) should be as follows Tilt angle from the above formula let say we use fixed flat plate solar collector the result as follows . **Yearly Optimum tilt angle** was nearly equal to the latitude of the location where they will conduct the study.The tilt angle of the summer season is found to be minimum and the tilt angle of the winter season is found to be maximum according to the seasonal optimum tilt angle calculation depending on solar angles.(Karafil et al. 2016)

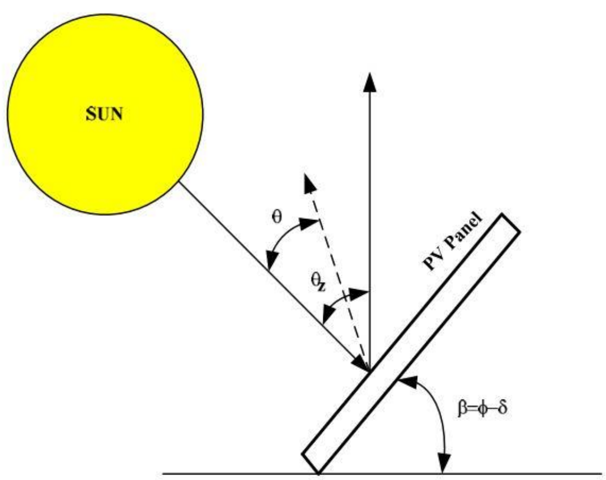


Fig. 3.2Optimum tilt angle

Table 3.1 Tilt Angle using equation(3.3)

12.2	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct	Nov.	Dec.
20.9	**4**	**6.6**	**18.4**	**27.8**	**14**	**12.2**	**4.5**	**6.8**	**0.6**	**27.9**	**32**

The average result 14.642^o or nearly 15 ^{o}

Azimuth angle

Solar azimuth angle (γ_s) is the angle between the north or horizontal east-west axis with continuous adjustment, the tilt south position of the sun and the direct solar radiation. This angle of the surface will be calculated by the following equation. Angle is assumed to be (-) from south to east and to be (+) from south to west. (γ_s)) is 180^o at noon. Azimuth angle is calculated by the following equation.

γ_s= $\cos^{-1}$ [sin(α) .sin α sin(δ) /cos(α).cos($\emptyset$)]……………………….(3.4)

Surface azimuth angle γ,angle of incidence θ, hour angle(ω),day of the year (n), skay clear ness(k_t), cloudiness index(k_d)

The angle of incidence for a surface oriented in any direction can be mathematically expressed by following relation(Duffie, J. & Beckman,2013)

$$\text{Cos } \theta = \sin \boldsymbol{\delta} \sin\emptyset \cos\beta - \sin \boldsymbol{\delta} \cos\emptyset \sin\beta \;\; \cos \delta$$

$$+ \text{Cos } \emptyset \text{ os } \beta \cos \omega + \text{Cos}\delta \sin \emptyset \text{ Sin } \beta \cos \gamma \cos\omega$$

$$+\cos\delta \text{ d} \sin \beta \sin \gamma \sin\omega \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.5)}$$

For a horizontal surface (β=0^0), the angle of incidence (θ) becomes equal to zenith angle (θ_z). Substituting this value in to above equation, zenith angle can be written as:

θ_z= sin$\emptyset$ sin $\boldsymbol{\delta}$ +cos$\emptyset$ cosδ cosω………………………………. (3.6)

Hour angle($\boldsymbol{\omega}$)

ω= 15(12-t_L)…………………………………………………………………………, (3.7)

Table 3.2Local time in hour

7 AM	8 AM	9 AM	10 AM	11 AM	12 AM	1 PM	2 PM	3 PM	4PM	5PM	6PM
-75	-60	-45	-30	-15	0	15	30	45	60	75	90

Sunset hour

ω_s=cos $^{-1}$(-tan$\emptyset$tan $\boldsymbol{\delta}$) ---(3.8)

Table 3.3 Sunset hour

Jan.	Feb.	Mar.	Apr.	May	Jun	July	Aug.	Sept.	Oct.	Nov.	Dec.
86.16	87.9	89.6	91.5	93	93.9	93.5	92.2	90.3	88.46	86.9	86.14

The day length, N, is the maximum possible daily sunshine hour given by

$\frac{2}{15}\omega_s$ or ---(3.8)

Table 3.5 day length

Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun**	**July**	**Aug.**	**Sept**	**Oct.**	**Nov.**	**Dec.**
AM	**AM**	**AM**	**PM**	**PM**	**PM**	**PM**	**PM**	**PM**	**AM**	**AM**	**AM**
11:46	11:72	11:86	12:2	12.4	12:52	12:46	12:29	12:04	11:79	11:58	11:46

The table 3.5 show that average metrological as well as the calculated data show that the maximum solar energy obtained during 12 PM and 11: 50.

3.4 Solar energy data analysis in specific area

In determining the solar potential, the primary aim was to estimate solar radiation and thereby to estimate solar panels for akakikalitiykebeles based on information obtained from on sitepv watt data . For this purpose the following methods were applied.

a) The monthly average daily total and diffuse solar radiations were estimated from the sunshine hours using mathematical methods. Then by subtracting the monthly average daily diffuse solar radiation from the monthly average daily total (global) solar radiation the monthly average daily beam solar radiation was obtained.

b) To analysis the PV power, the following algorithms are used to calculate the radiation on the plane of the PV array:

1. Hourly global and diffuse irradiance on the surface for all hours of an “average day” having the same daily global radiation as the monthly average were determined;
2. Hourly values of global irradiance on the tilted (or tracking) surface for all hours of the day were calculated and then
3. By summing the hourly tilted values average daily irradiance in the plane of the PV array was obtained.

C. Using the value of average daily irradiance in the plane of PV array the power delivered by PV array and the array energy available to the load were determined.

D. The demand load and load required for the village were also estimated.

E. Finally, based on the load required for the village the PV size was estimated.

3.4.1 to calculate extra-terrestrial radiation falling on the earth

Calculate the insolation intensity on a plane perpendicular to sun rays (I^0) on the edge of the atmosphere by correcting I_{SC} for Earth's elliptical orbit.

$$I_{SC} = \text{solar constant} = 1367\ W/m^2$$

$$I_0 = I_{SC}\left[1 + 0.034\cos\left(2\pi\frac{n}{365.25}\right)\right] \text{-- (3.9)}$$

Calculate the extraterrestrial insolation on a plane horizontal to the Earth's surface (I_{0h}) at the site's latitude.

$$I_{0h} = I_0\cos\theta_Z \text{ ---(3.10)}$$

Therefore

$$I_0 = I_{SC}\left[1 + 0.034\cos\left(2\pi\frac{n}{365.25}\right)\right](\cos\phi\cos\delta\sin\omega_S + \omega_S\sin\phi\sin\delta) \text{ (3.11)}$$

θ_z mentioned earlier equation (3.6)

To find the extraterrestrial irradiation energy falling on a plane horizontal to the Earth's surface throughout a whole day, integrate equation (3.10) with respect to time between sunrise ($\omega = -\omega S$) and sunset ($\omega = \omega_S$). The resulting equation is

$$H_{0h} = \frac{86400}{\pi}I_{SC}\left[1 + 0.034\cos\left(2\pi\frac{n}{365.25}\right)\right](\cos\phi\cos\delta\sin\omega_S + \omega_S\sin\phi\sin\delta) \text{----- (3.12)}$$

The above equation gives J/M^2 to convert Wh/m^2 86400/3600 which gives 24 hour the equation become

$$H_{0h} = \frac{24}{\pi}I_{SC}\left[1 + 0.034\cos\left(2\pi\frac{n}{365.25}\right)\right](\cos\phi\cos\delta\sin\omega_S + \omega_S\sin\phi\sin\delta) \text{ (3.13)}$$

To find the extraterrestrial irradiation energy falling on a plane horizontal to the Earth's surface throughout a whole day with respect to time between sunrise ($\omega = -\omega_S$) and sunset ($\omega = \omega_S$). The resulting equation is

$$H_{0h} = \frac{24}{\pi} I_{SC} \left[1 + 0.034 \cos\left(2\pi \frac{n}{365.25}\right)\right] (\cos\phi \cos\delta \sin\omega_S + \omega_S \sin\phi \sin\delta)$$ ---- (3.14)

(Wh/m^2)

If n is set to the 15th of each month (i.e. n = 15 for January and n = 46 for February etc), in the above equation can be used to calculate monthly average daily H_{0h} values. When MAD irradiation values are used the symbol $\overline{H}_{0h}$ replaces H_{0h} to indicate average values.

The average extra-terrestrial radiation of each month shown below **Wh/m^2**in the table

Table 3.4 Extra-terrestrial radiation

Jan.	Feb.	Mar.	April	May	Jun	July	Aug.	Sept.	Oct.	Nov.	Dec.
8611	9492.75	10500	11159	10964	10873	10429	10873	10645.8	10075	9244.8	9792

3.4.2. The Clearness Index

Next the clearness index (K_T) is defined as the ratio of the total irradiation reaching a horizontal plane at the location on the Earth's surface and the extraterrestrial irradiation on a horizontal plane above the location.

$$\overline{K}_T = \frac{\overline{H}}{\overline{H}_{0h}}$$ --- (3.15)

- $\overline{H}$ = the monthly average daily irradiation on a horizontal plane at the Earth's surface. This is the value that can be referenced from weather station data.
- $\overline{H}_{0h}$= the monthly average daily value of extraterrestrial radiation energy falling on a horizontal plane. Calculated from above equation

3.4.3 Defuse radiation

The most widely cited model given by Erbs et al. (1982) was used for the determination of H When the sunset hour angle (ω) for mean day of the month is ≤ 81.4 and a $0.3 \leq K_T \leq 0.8$, and then H_d can be calculated from the following equation

$$\frac{Hd}{H} = 1.391\text{-}3.56K_T + 4.189K_T^2 - 2.137\ K_T^{\ 3} \text{ ------- -------------- -------------------------------}(3.16)$$

If the sun hour angle (ω) is ≤ 81.4 and $0.3 \leq K_T \leq 0.8$, then H_d could be obtained from the following correlation:

$$\frac{Hd}{H} = 1.311\text{-}3.022K_T + 4.189K_T^2 - 1.821\ K_T^{\ 3} \text{-- } (3.17)$$

3.4.4 Beam radiation

$H_b = H - H_d$

The total solar energy received on an inclined surface is the sum of beam and diffuse radiations directly incident on a surface and reflected radiations (reflected by the surroundings). Thus, theMonthly average total solar radiation (in MJ/m2-day) or Wh/m^2.

3.3.5 Total radiation

Which is**G**

Total radiation G intensity W/m^2

I = certain pared of time J/M^2/hr which is J/M^2-(t_1-t_2)

If t_1-t_2 one hour (1hr) I= J/m^2/hr

Terrestrial radiation consists of beam or direct radiation

G = is total radiation it is consists of

$G = G_b + G_d$-- (3.18)

G_b = beam or direct radiation

G_d= diffuse radiation

H = total radiation for the day

$H = H_b + H_d$-- (3.19)

I = total radiation for hour

$I = I_b + I_d$ -- (3.20)

3.5 Estimation of Average Solar Radiation

Data of radiation are the best source of information for estimating average incident radiation. Lacking these or data from nearby locations of similar climate or no metrological agency, it is possible to use empirical relationships to estimate radiation from hours of sunshine or cloudiness

The original Angstrom type regression equation related monthly average daily radiation to clear day radiation at the location in question and average fraction of possible sunshine hours:(Duffie & Beckman 2013)**Where**

$$\frac{\overline{H}}{\overline{H}_c} = a' + b' \frac{\overline{n}}{\overline{N}} \quad \text{--} \quad (3.21)$$

$\overline{H}$= monthly average daily radiation on horizontal surface

$\overline{H}_c$= average clear-sky daily radiation for location and month in question

a',b'= empirical constants n= monthly average daily hours of bright sunshine

N = monthly average of maximum possible daily hours of bright sunshine

(i.e., day length of average day of month)

To calculate monthly average solar radiation () for an inclined surface is expressed as

$H_T = H_B + H_D + H_R$ --- (3.22)

3.5.1 Model used to calculate solar radiation

For the comparison and minimize solar radiation error I used to analyses the collected data Leu and Jordan,Koronakis model and Badescu Model this help to avoid errors all models are isotropic

Leu and Jordan modal

To calculate solar radiation on leu and Jordan modale Solar radiation coming from the sun is attenuated by the atmosphere and the clouds before reaching the surface of the earth. The ratio of solar radiation at the surface of the earth to the extraterrestrial radiation is termed as clearness index (K_T) which is expressed as

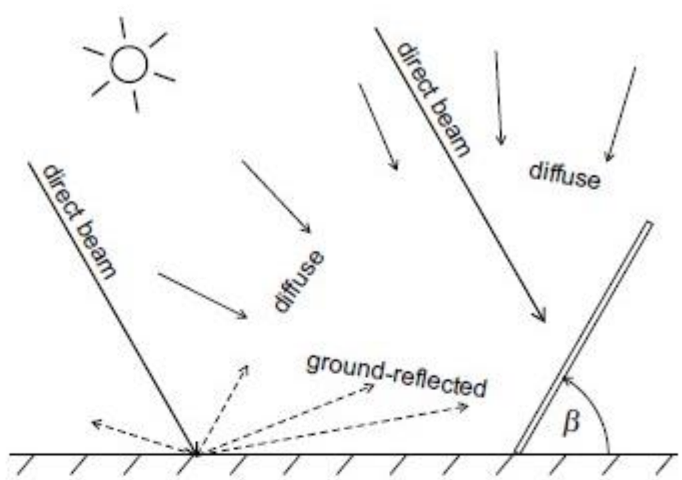


Fig. 3.3beam and diffuse radiation

For purposes of solar process design and performance calculations, it is often necessary to calculate the hourly radiation on a tilted surface of a collector from measurements or estimates of solar radiation on a horizontal surface. The most commonly available data are total radiation for hours or days on the horizontal surface, whereas the need is for beam and diffuse radiation on the plane of a collector. The geometric factor R_b, the ratio of beam radiation on the tilted surface to that horizontal surface

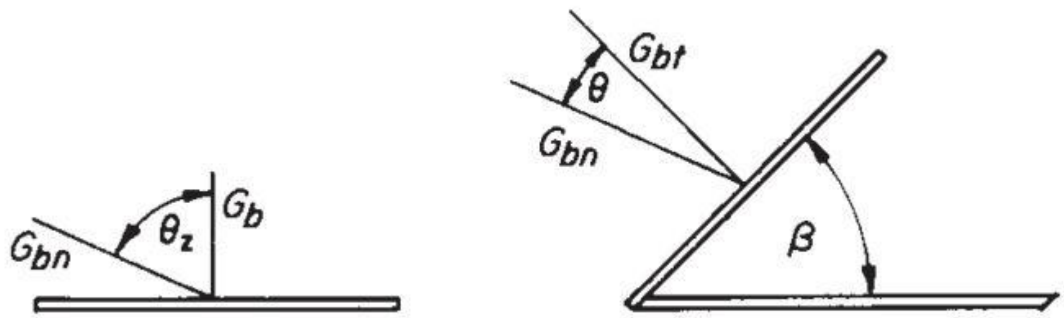


Fig. 3 4Angle of incidence θ and θ_b

The ratio $G_{b,T}/G_b$ is given

$$R_b = \frac{G_{bt}}{G_b} = \frac{G_{b.n} \cos\theta}{G_{b.n} \cos\theta z} = \frac{\cos\theta}{\cos\theta z} \text{ --3.23}$$

According to Liu and Jordan

They classify the radiation received by tilted surface

For horizontal surface

First $G = G_b + G_d$ in equation (3.17)show that

G = Intensity

G_b = Beam radiation

G_d = Diffuse radiation

For tilted surface

$G_T = G_b R_b + F_S G_d + F_g P_g G$---(3.24)

$F_S P_g G$ = Ground reflectance factor as you have seen fig (3.5) --------------------------- (3.25)

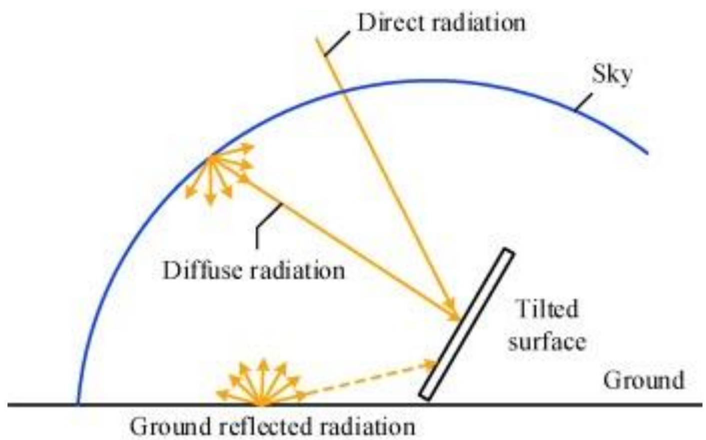


Fig. 3.5ground reflected and albedo on a tilted surface

$F_S = \left[\frac{1+\cos\theta}{2}\right]$ Ground reflected to the tilted surface ---------------------------------- (3.26)

$F_g = \left[\frac{1-\cos\theta}{2}\right]$ From the ground (ground albedo) -------------------------------------- (3.27)

If you put $\beta$is zero which means horizontal surface does not receive reflected radiation

P_g= typically 0.2 for a ground

P_g= is 0.7 for snow covered ground

There for beam radiation horizontal and tilted surface are

$G_b = G_{b.n} \cos\theta_z$-- (3.28)

$G_{b.T} = G_{b.T} \cos\theta$-- (3.29)

Then $R_b = \frac{G_{bt}}{G_b} = \frac{\cos\theta}{\cos\theta z}$--- (3.30)

R_bFor surfaces that are sloped toward the equator in the northern hemisphere, that is, for surfaces with $\gamma = 0^{\circ}$

$$\overline{R}_b = \frac{\cos(\phi-\beta)\ \cos\delta\ \sin\omega_s' + (\pi/180)\ \omega_s'\ \sin(\phi-\beta)\ \sin\delta}{\cos\phi\ \cos\delta\ \sin\omega_s + (\pi/180)\ \omega_s\ \sin\phi\ \sin\delta}$$

For surfaces in the southern hemisphere sloped toward the equator, with $\gamma = 180^{\circ}$, the equations are and

R_b $$\overline{R}_b = \frac{\cos(\phi+\beta)\ \cos\delta\ \sin\omega_s' + (\pi/180)\ \omega_s'\ \sin(\phi+\beta)\ \sin\delta}{\cos\phi\ \cos\delta\ \sin\omega_s + (\pi/180)\ \omega_s\ \sin\phi\ \sin\delta}$$ ---------- (3.32)

$$\omega_s' = \min\begin{bmatrix}\cos^{-1}(-\tan\phi\ \tan\delta) \\ \cos^{-1}(-\tan(\phi+\beta)\ \tan\delta)\end{bmatrix}$$

$GR_b=G_T$--- (3.35)

Then we write R_b= $(\frac{G_b}{G})R_b+\frac{G_d}{G}\left[\frac{1+\cos\theta}{2}\right]+P_g\left[\frac{1-\cos\theta}{2}\right]$---(3.36)

This is also written as $(\frac{G-G_d}{G})R_b+\frac{G_d}{G}\left[\frac{1+\cos\theta}{2}\right]+P_g\left[\frac{1-\cos\theta}{2}\right]$then

R_b= $(1-\frac{G_d}{G})R_b+\frac{G_d}{G}\left[\frac{1+\cos\theta}{2}\right]+P_g\left[\frac{1-\cos\theta}{2}\right]$---(3.37)

A special case of interest is $R_{b,noon}$, the ratio for south-facing surfaces at solar noon.

$R_{.b.noon}$= $\frac{\cos|-\varphi+\delta-\beta|}{\cos|-\varphi+\delta|}$-- (3.38)

3.5.2. Hourly Diffuse Radiation

For each hour of the "average day", diffuse irradiance is given by

$I_d=r_dH_d$

$$r_d = \frac{\pi}{24}\frac{\cos\omega + \cos\omega_s}{\sin\omega_s - \frac{\pi}{180}\omega_s\cos\omega_s} \text{--(3.39)}$$

Where, $r_d$is the ratio of hourly total to daily total diffuse radiation. Using equation (3.30) and (3.37), hourly diffuse radiation of each month for the representative day (mid-month) was determined and the result is given in Appendix C.

3.2.4. Hourly Irradiance in the Plane of the PV Array

Hourly irradiance in the plane of PV array (I_t) can be calculated as

$\mathbf{I_b = I - I_d}$

$$I_t = \left(\frac{I_b}{I}\right)R_b + \frac{I_d}{I}\left[\frac{1+\cos\theta}{2}\right] + I\rho_g\left[\frac{1-\cos\theta}{2}\right] \text{---(3.40)}$$

Monthly average solar radiation on a tilted surface calculated using different empirical models

<u>Liu and Jordan model (1963)</u>

In this model, the solar radiation on tilted surface is considered to be composed of three parts such as beam, reflected from ground and diffuse fraction. It was assumed that the diffuse radiation is isotropic only whereas, circumsolar and horizon brightening were taken as zero.(*Duffie, J. & Beckman*)

$$\overline{H}_t = \left(\frac{\overline{H}_b}{\overline{H}}\right)R_b + \frac{\overline{H}_d}{\overline{H}}\left[\frac{1+\cos\beta}{2}\right] + \overline{H}_d\left[\frac{1-\cos\beta}{2}\right] \text{---(3.42)}$$

<u>Koronakis model (1986)</u>

Koronakis modified the assumption of isotropic sky on diffuse radiation and proposed that the slope β =90^o provides 66.7% of diffuse solar radiation of the total sky dome

$$\overline{H}_t = \left(\frac{\overline{H}_b}{\overline{H}}\right)R_b + \frac{\overline{H}_d}{\overline{H}}\left[\frac{1+\cos 2\beta}{4}\right] + \overline{H}_d\left[\frac{1-\cos\beta}{2}\right] \text{--(3.43)}$$

<u>Badescu Model (2002)</u>

Badescu demonstrated model for the solar diffuse radiation on a tilted surface, and considered the view factor below

$$\overline{H}_t = \left(\frac{\overline{H}_b}{\overline{H}}\right)R_b + \frac{\overline{H}_d}{\overline{H}}\left[\frac{1+\cos 2\beta}{4}\right] + \overline{H}\rho_g\left[\frac{1-\cos\beta}{2}\right] \text{---(3.44)}$$

3.5.2 to calculate the total wattage of the categorized household

For each AC appliance

- Find the wattage of the product, $\boldsymbol{Wi}$
- Estimate the number of hours per day an appliance runs, $\boldsymbol{hi}$
- Find the daily energy consumption per each appliance, $\boldsymbol{Ei} = \boldsymbol{Wi} * \boldsymbol{hi}$
- Sum all the daily energy consumption by each appliances

$$(E_{daily})_{AC} = \sum_{i=1}^{N} E(i) \text{ ---------------------------(3.44)}$$

Where N is number of electron needed load

3.5.3Calculate the required material

Finally after calculating potential of solar energy using metrological information we can calculate the required material to electrify the household of the specific area. Three main factors characterize the potential electricity production in a site of interest: solar irradiation, total area of the solar cells and total efficiency. The latter steps from a combination of partial efficiencies. More specifically, the total efficiency$\boldsymbol{\eta_{tot}}$,is given by the product of PV modules $\boldsymbol{\eta_{mod}}$ installation $\boldsymbol{\eta_{inst}}$ temperature $\boldsymbol{\eta_T}$ and reflectance $\boldsymbol{\eta_R}$ efficiencies, namely

$$\boldsymbol{\eta_{tot} = \eta_{mod} \cdot \eta_{inst} \cdot \eta_T \cdot \eta_R} \text{..(3.45)}$$

η_{mod} Depends on the solar cell technology and should be provided by the manufacturer of PV modules; whereas, η_{inst} encompasses the efficiency losses from the Balance Of System (BOS) of the whole photovoltaic system (e.g. inverter, wiring, switches, battery bank, battery charger, etc.), will be calculate in the feasibility production π from the PV system can be estimated as Therefor, the production of estimated as

$$\pi = H_y . Area . \eta_{tot} \quad (3.46)$$

Where: A = module area ($1m^2$)

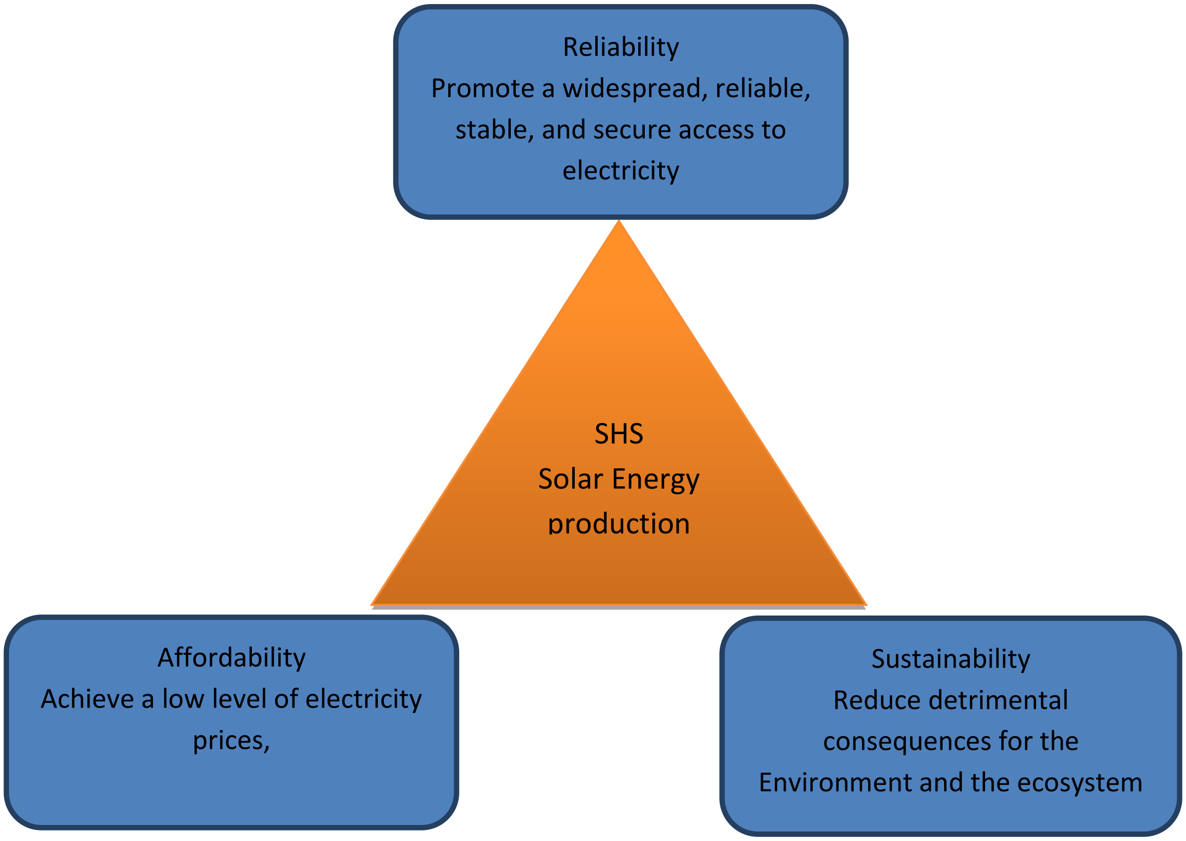
η_P = Efficiency of PV Module (for this study 18%)

from the collected data categorize the household in to 3 and collect energy demand from the selected kebeles and take the average of the 3 categories of rural households low ,medium and high energy demand for electrifying the household

3.5.3 Calculate the pay back and compared with traditional HHs electrification system

3.5.4 The carbon accounting of

3.6Conceptual frame work



Chapter Four

4Result and discussion

4.1 Result

The solar energy assessment of the specific area By using equations, (3.13), the solar radiation of the village is estimated and the result is given in (13. 20) and 22 are measured values at Addis Ababa meteorological station. the value as shown table (4.1)below.

Table 4.1 Average global solar radiation

Month	W/M2	Wh/m^2	Extra t.rad
January.	492.64	5911.73	**8611.00**
February.	531.32	6375.89	**9492.75**
March.	513.19	6158.23	**10500.00**
April.	395.10	4741.20	**11159.00**
May.	462.95	5555.36	**10964.00**
June.	360.66	4327.92	**10873.00**
July.	329.09	3949.10	**10429.00**
August.	267.13	3205.51	**10873.00**
September.	345.39	4144.72	**10645.80**
October.	447.23	5366.71	**10075.00**
November.	424.67	5096.01	**9244.80**
December.	407.54	4890.52	**9792.00**

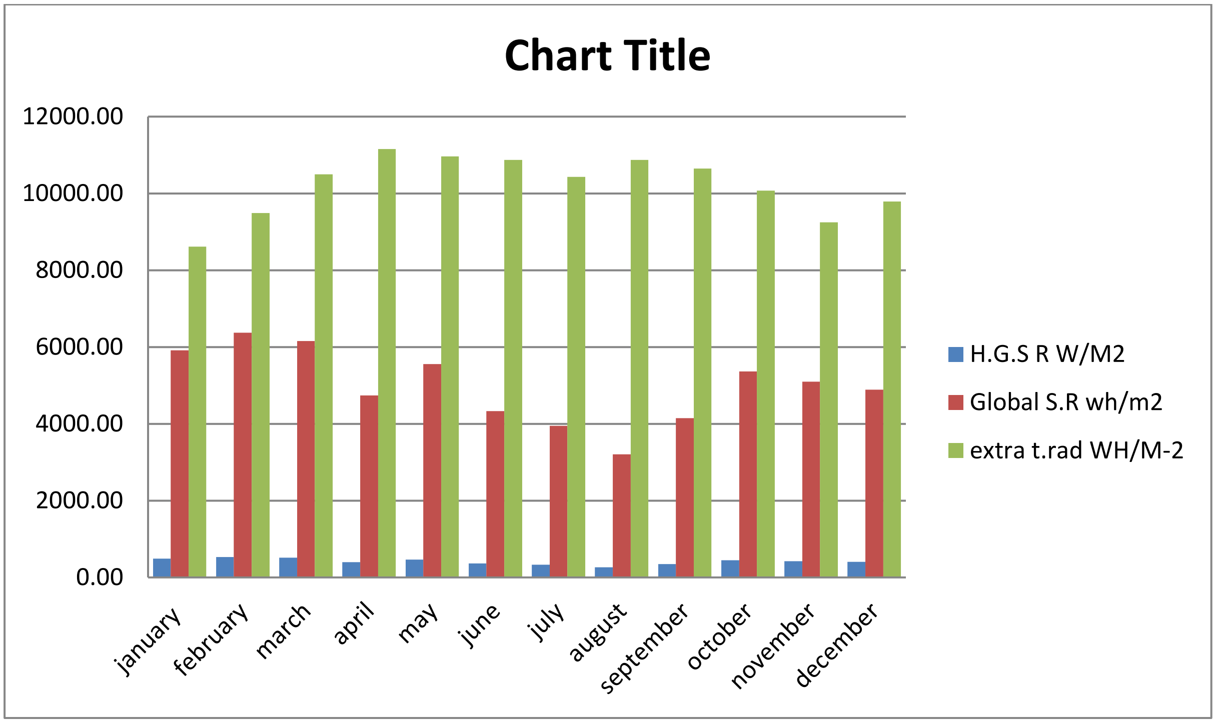


Fig. 4.1 show that the average hourly global solar radiation and extra terrestrial

Table 4.2Below show that the value$\boldsymbol{\cos\theta}$,$\boldsymbol{\cos\theta z}$,$R_b = \frac{\boldsymbol{\cos\theta}}{\boldsymbol{\cos\theta z}}$ using equation 3.5,6 and 31

Month	$\cos\theta$	$\cos\theta z$	$R_b = \frac{\cos\theta}{\cos\theta z}$
Jan	0.973171	0.814033	1.195493
Feb	1.004913	0.907177	1.107736
mar	0.999957	0.976723	1.023788
apr	0.952928	1.009071	0.944362
May	0.872542	1.003693	0.869332
Jun	0.846218	1.007842	0.839634
July	0.863649	1.011195	0.854088
Aug	0.926971	1.012188	0.915809
Sept	0.960318	0.96882	0.991224
Oct	1.00712	0.932521	1.079998
Nov	0.983738	0.853797	1.152192
Des	0.96803	0.814906	1.187903

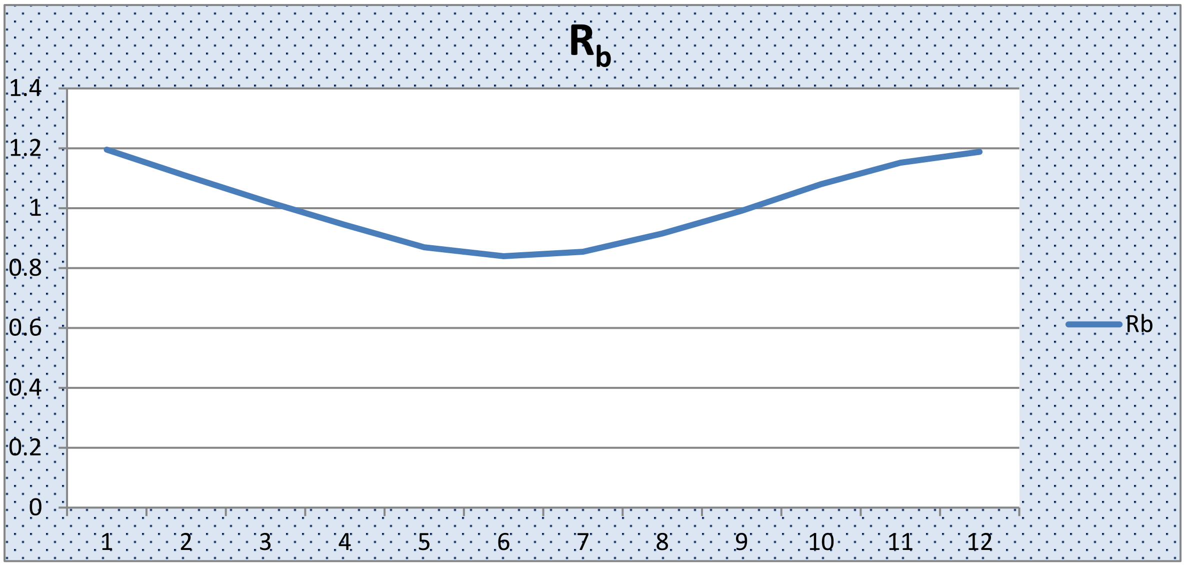


Fig. 3.6 The value of R_b

Fig 4.3 Hourly global solar radiation from metrological data. The average hourly solar radiation will be obtain hourly average solar radiation first obtain after that using the equation (3.15) calculate H_b and H_d then calculate using the empirical formula equation(3.16) mention above and then obtain the following result below .

Table 4.3Average daily global solar radiation from 8 years metrological stationdata

Hourly global average solar radiation												
Time	7:00AM	8:00AM	9:00AM	10:00AM	11:00AM	12:00AM	1:00PM	2:00PM	3:00PM	4:00PM	5:00PM	6:00PM
W/M^2	**98.21**	**262.8**	**375.0**	**539.77**	**637.89**	**672.6**	**660.14**	**573.56**	**437.5**	**319.8**	**184.5**	**77.08**

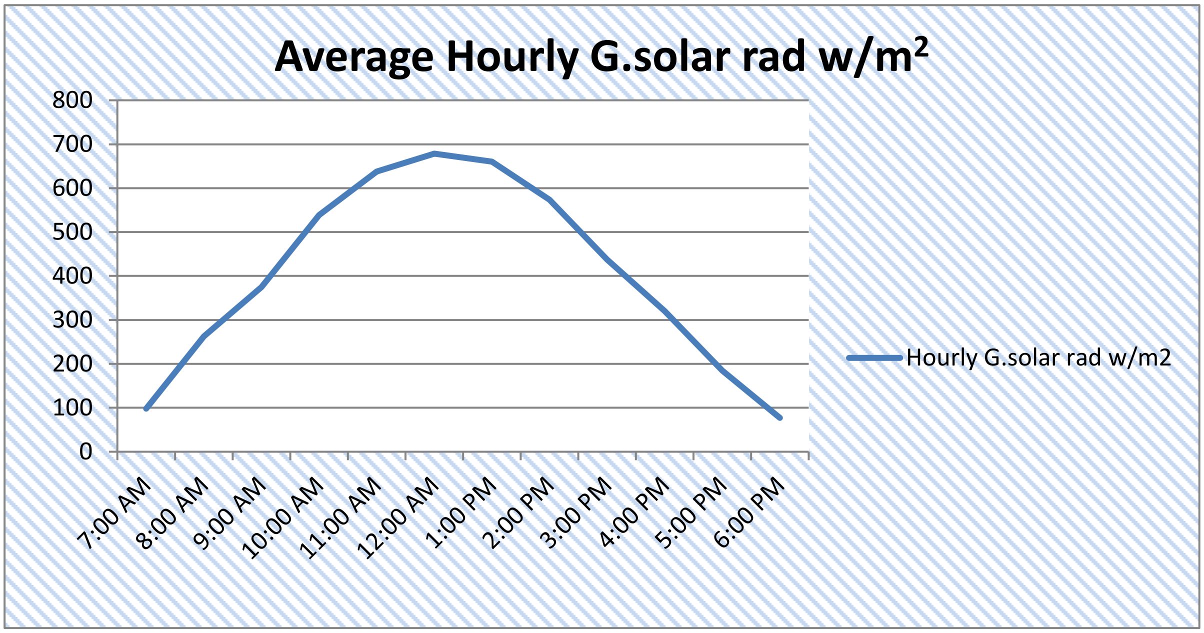


Fig.4.7 Average global solar radiation from 8 years metrological data

The figure 4.7 show that average Hourly global maximum value from metrological data at 12 AM and 1PM and minimum 7 AM (in morning) and 6 PM in the afternoon. It can be assumed [as suggested by Hottel and Woertz (1942)] that the combination of diffuse and ground reflected radiation is isotropic. With this assumption, the sum of the diffuse from the sky and the ground reflected radiation on the tilted surface is the same regardless of orientation, and the total radiation on the tilted surface is the sum of the beam contribution calculated as $I_b R_b$ and the diffuse on a horizontal surface, I_d. This represents an improvement over the assumption that all radiation can be treated as beam, but better methods are available the other thing must be calculate as shown below.

Table 4.4 The average beam and defuse radiation using above formula (3.16) and (3.17)

Month	**H_d/H**	**H_d**	**H_B**
January	0.258996	127.5928	365.0514
February	0.272329	144.6949	386.6294
March	0.347639	178.4035	334.7821
April	0.504733	199.42	195.6801
May	0.42093	194.8683	268.0786
June	0.535131	193.0003	167.6596
July	0.558186	183.6943	145.3972
August	0.670663	179.1512	87.97435
September	0.545378	188.3699	157.0233
October	0.396424	177.2913	269.9348
November	0.379359	161.1015	263.5659
December	0.427916	174.3945	233.149
Average			

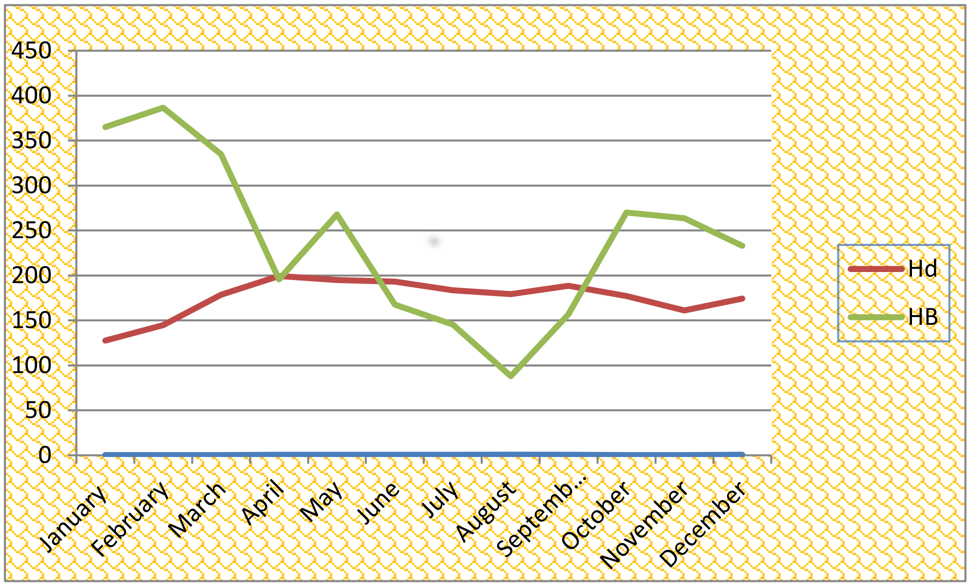


Fig 4.4 show that monthly average beam, diffuse and clearness index of solar radiation

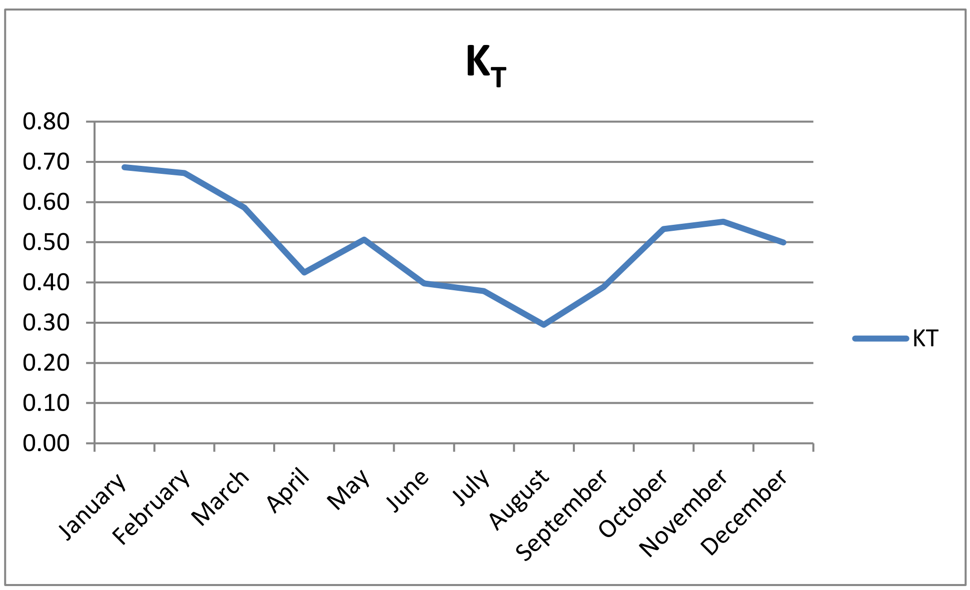


Fig 4.5 show that the K_T value calculated using formula (3.15)

4.1 Determination of solar radiation on tilted surface

4.1.1. Daily Total Tilted Irradiances ($\overline{H}t$)

Once tilted irradiances for all hours of the day are computed, the daily total t is obtained by summing values for individual hours.

Table 4.5 total tilted radiation using 3 models KWh/m^2

month	Liu and Jordan model (1963)	Koronakis model (1986)	Badescu Model (2002)
Jan.	6.76	6.77	6.74
Feb.	6.87	6.88	6.84
Mar.	6.24	6.25	6.20
Apr.	4.59	4.60	4.55
May.	5.11	5.13	5.07
Jun.	3.98	3.99	3.94
Jul.	3.67	3.68	3.63
Aug.	3.09	3.10	3.05
Sep.	4.10	4.12	4.07
Oct.	5.61	5.62	5.57
Nov.	5.56	5.57	5.53
Dec.	5.40	5.41	5.36
Ave.	**5.08**	**5.09**	**5.05**

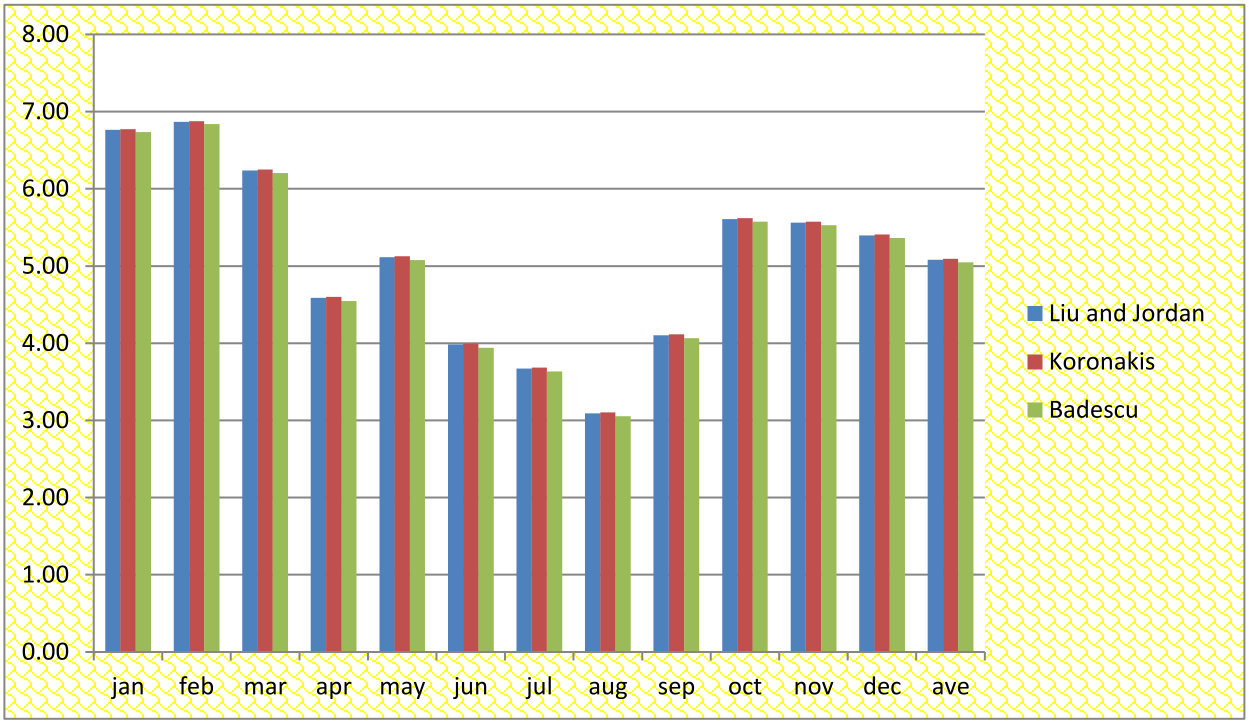


Fig 4.5 average solar radiation on tilted surface using 3 models

Table (4.5) and fig(4.5) shows that major maximum monthly average daily energy available to the load that occurred during the month February (6.87 KWh/m2). The minimum monthly average daily energy available to the load occurred during the month September (3.09 KWh/m2). Using empirical formula I used to calculate the average solar data hourly, daily and monthly data using 3 types of models which is Liu and Jordan model (1963),Koronakis model (1986) and Badescu Model (2002)

4.2 Energy Demand

Table 4.6 Energy demand of the community from collected data

Energy Demand	Appliance	Description	Total number	Total power	Total duration	Total energy	cumulative
High	Lamp (Living room)	11 w bulb	1	11w	4 hour	44 w	672.00
	Lamp 2(Bed room)	11 w bulb	2	22w	4 hour	88 w	
	Radio and tape	12 w radio	1	12 w	5 hour	60 w	
	Tv	60 w TV	1	60 w	3 hour	180 w	
	Refrigerator	60 w	1	60 w	5 hour	300 w	
Medium	Lamp (Living room)	11 w bulb	1	11w	4 hour	44 w	372
	Lamp 2(Bed room)	11 w bulb	2	22w	4 hour	88 w	
	Radio and tape	12 w radio	1	12 w	5 hour	60 w	
	Tv	60 w TV	1	60 w	3 hour	180 w	
Low	Lamp (Living room)	11 w bulb	1	11w	4 hour	44 w	111
	Lamp 2(Bed room)	11 w bulb	2	22w	4 hour	88 w	
	Radio and tape	12 w radio	1	12 w	5 hour	60 w	

Average electricity consumption of the each household shown in the table 4.6

4.2.1 The required material for categorized household

a) Area of the Solar Panel

The PV panel of the solar home system must be sized with the annual minimum of daily available PV electric energy (Eh). In this study, it occurs in the month of Aug. (with a value Discussion of 3.09 KWh/m^2 as determined in table(4.7). Thus, the net energy to the load from the panel per unit area is given by

E_{net}= Eh ηbηc = 309*0.9*0.9 Wh/m 2 day

E_{net}=250

Where:

η_b= efficiency of battery (Assuming to be 90%)

η_c= efficiency of charge controller (Assuming to be 90%)

For Households

The average maximum daily energy consumption of each medium household is 372Wh/day. Hence the required PV panel area will be

$$A_P = \frac{Daily\ energy\ demand}{Enet}$$

$$= \frac{372}{252} = 1.5\ m^2$$

The energy delivered by such amount of solar energy

Ep = Eh * Ap = 309* 1.5 m^2 = 463.5 Wh/day

In order to select PV panel in the market, the panel has to be specified in peak watts, which is the power obtained with irradiation of $1000W/m^2$ at the cell temperature of 25ºC. The monthly global irradiance ranges from 3.09 KWh/day in September to 6.87 KWh/day in February.

Hence, the effective hours with peak radiation (1000W/m^2) for the minimum case is 4.1 hours. As the temperature of the PV panel is not constant, a given correction factor (ft) is taken as 0.89 (Duffie and Beckmann, 1991). From this, the peak power for a given PV panel from the daily available electrical energy of the panel can be obtained as follows:

$$p_p = \frac{E_P}{EH * f_t} = \frac{463.5WH/d}{3.09 * 0.89} = 168.54\text{Wp}$$

Solar Photovoltaic Selection

Based on our review, we have identified the most efficient PV system applicable for higher energy output in given unit of area is that of Mono-crystalline PV modules. In selecting the modules we considered the efficiency, Price, Power output (rated power), Product warranty and other parameters.

Taking this in to consideration we surveyed different modules produced by different PV producers and we have selected Allesun SPM 300W due to its efficiency, power output, and Warranty and price detail description of solar photo voltaic selection see appendix (table 1).

b) Battery

For Households

The minimum energy that can be stored by the battery for the households is given by:

$E_b = \frac{E_u}{\eta_b}$ = 413 Wh/day 0.413 KWh/day

Where:E_u = Energy demand of the household (372 Wh//day)

E_b = Energy that can be stored by the battery

η_b = efficiency of battery (Assuming to be 90%)

Assuming that the working voltage for direct current is 12V, then, the net capacity that the battery can store in Ah/day will be

$$C_{bn} = \frac{E_b}{v_{cc}} = \frac{413}{12} = 34.42 \text{ Ah/day}$$

The net capacity of the battery depends on the depth of the discharge of the battery (DDP), and the depth of discharge determines the life cycle of the battery. Deep cycle lead acid battery can store 30% to 80% depth taking an assumption of DDP = 30% then the total commercial capacity of the of the battery is calculated as

$$C_b = \frac{C_{bn}}{DDP} = 114.7 \text{ Ah/day}$$

This value is correct, if only if there aren't cloudy days. Considering cloudy days, let us assume the battery have energy demand of two or three days.

Therefore

C_b = 114.7 Ah*2 .

C_b = 229.5 Ah

To be safer, the best battery size will be 140 Ah deep cycle. The unit price of one Battery (140 Ah) deep cycle is Birr 2097.01. Since two batteries was needed for each household then the cost of the battery for one household is Birr 2097.01

The summarized result will show the table 4.7 below

Battery selection

The battery selection criteria considered the efficiency, Price, Power output (rated power), Product warranty and other parameters see appendix table(2).

C) Estimating the Inverter capacity

Once the PV module rated capacity have been estimated, the next step is to determine the size of the inverter and the arrangement (layout) of the selected modules.

1. For installations with tilt angle less than 15^{o} RS 1.25 is recommended
2. Since this project installs PV models at an angle 15^{0} ,the RS of inverter is determined to be 1.25

Therefore

Inverter capacity=1.25*PV rated power

Inverter Size (W) = (111 W* 0.25) + 111 W

= 27.75W + 111 W

= 138.75 W

Inverter selection

Inverter select 150 to 200 watt for low, 300 to 450watt medium and 700 to 900 watt for high

Table 4.7To summarize the cost of the material to the 3 household categories

		Low	Medium	High
PV	Peak power	29.74 Wp	168.Wp	337.08 Wp
	Selected PV type	30Wp	30Wp	30Wp
	Required PV size	1 module	1.5 or 2	2.66 or 3
	Price per watt	0.4 Euro/Wp	0.4 Euro/Wp	0.4 Euro/Wp
	Total cost	83.2 Euro	83.2+(83.2*0.5)	6120
	Total cost Birrr	2496 birr	3746	7488
Battery	Capital of the battery	68.52 Ah	229.5 Ah	286 Ah
	Selected battery type	120 Ah deep cycle	250 Ah deep cycle	150AH
	Required size	1 batteries	1 batteries	2 batteres
	Cost for one with	2097.01	3640	6291
	Total cost	2097.01	3640	6291
Inverter	Inverter wattage	150 to 200	400 to 500	700 to 800
	Price	$35 or 1050 birr	$60 or 1800 birr	$70 or 1960

Others	Charge controller	1	1	1
	Cables	Meter	Meter	Meter
	Operation cost	200	300	400
	Over all total	5743	9486	16139

The above table 4.7 source from different importers in the country and international markets which is alibaba.com, allesun and www.northerntool.com and other online sources.

According to the above result in the low household we can use both solar kit and solar home system to electrify the household but the disadvantage of solar kit we can't up grade when the energy demand increase and the life span also short when compared with solar home system.

4.3 Comparison between kerosene and solar home system

Each rural household spent 4 hours using kerosene for gives the house a light. each household used daily as half a liter these converted to week, month and year they spend allot of money for lighting which means that 3.5 liter per week,15 litter per month and 180 litters of kerosene per year . Each litters of kerosene value 18 birr total costs 3240 birr per year and for tap radio and torch on average spend 20 birr per week 80 birr month and 960 per year. Therefor the pay back of the solar home system as shown table below

The table show that the annual payment for lighting the house using torch and kerosene 4200 birr therefore the house hold spend 11.50 birr per day (4200 birr/365 day) the pay back calculate as follows

4.4 The annual payment

To evaluate the system, an assumption of 10% interest rate and 25 years life span are taken into consideration. The initial capital cost (C) of the PV system for a single household is Birr (Table 4.7). Then, the annual payment become

$$C_A = \frac{\frac{C_I}{(1+i)^n - 1} y}{(1+i)^n} + C_m$$

Where: CA = Annual payment, CI = Capital cost, C_m = maintenance cost, n = life span (assuming 25 years) for solar panel, 10 years for battery & i = interest rate (Assuming 10%)

Low

$C_A = \frac{\frac{5473}{(1+0.1)^{25} - 1}}{(1+0.1)^{25}} + 200 = \frac{554.6}{10.83} + 200 = +51.385 + 200 = 251.384$

The totalprice= 234.434+5473=5724

Total battery cost for a single household $= \frac{total\ battery\ cost\ for\ single\ household}{life\ spane}$

Total battery cost for a single household $= \frac{2097}{10}$ =209.7 per year

Annual price to pay$= \frac{5724}{12}$ =477 birr per month

Per day $= \frac{5724}{360}$ =15.9 birr

Price per watt $= \frac{5724\ birr}{365 * 111 wh/d}$ = 0.1432birr/Wh or 143.243birr/KWh

Medium

$C_A=\frac{\frac{9486}{(1+0.1)^{25}-1}}{(1+0.1)^{25}}$ + 250= $\frac{964.5}{10.83}$+250 =330.7 birr

Total price= 330.7+9486 =9816.7

Total battery cost for a single household $\frac{3640}{10}$=364 per year

Price per watt =$\frac{9486\ birr}{365*372wh/d}$= 0.06992birr/Wh or 69.86 birr/KWh

High

$C_A=\frac{\frac{16139}{(1+0.1)^{25}-1}}{(1+0.1)^{25}}$ + 250= $\frac{964.5}{10.83}$+300=437.4birr

Total price= 437.4+16139 =16576.4

Total battery cost for a single household =$\frac{6291}{10}$=629.1 per year

Price per watt =$\frac{16139\ birr}{365*672wh/d}$= 0.0657 birr/Wh or 65.86 birr/KWh

Table 4.8Summery of pay back

Item	Daily	Monthly	Annual	Annual price	Pay back
Estimated energy demand					
Low	111Wh	3330 Wh	40515Wh	143.24 birr/Kwh	1.2 year
Medium	372Wh	11160 Wh	135780Wh		2 year
High	672Wh	20160 Wh	245280Wh		3.5 year
Traditional energy consumption					
Kerosene pries per litter	0.5 L	15 L	180 L	3240 birr	
Batter for torch radio and other		16 ray cell	192 dray cell	960 birr	
Average total spend per year				4200 birr per year	

4.5 Comparison between community based and solar home system

The community based off-grid solar electricity production and Compare that of each house holds generates. Every solar home system highly productive and Convenient in many ways for example in our office Addis Ababa EPA 5000 watt could be installed before 5 years for back up purpose during electricity interruption. it works properly until now without any maintenance and replacement of appliance. When compared to 3 categorized rural households with this price we can generate 173 low, 100 for medium and 67 for high energy demand households.

If we look at in the case of production of energy 5000 watt serve only 45 low, 13 medium and 7 high energy demand households this indicated that individual energy generation was very profitable and appropriate for different aspects

4.6 Emission redaction

The proposed PV system in this study can generate up to40515Wh, 135780Wh and 245280Whelectricity annually that can be generated . The GHG emission factor of the baseline electricity mix (fuel type) in Ethiopia is 0.135 tCO_2/MWh and $1tCO_2$costs $12 (Mghouchi et al or IPCC. 2014). The net annual GHG emission reduction and CO^2 per ton of the proposed system would be shown in the table below

Table 4.9 redaction and CO_2 cost per tone

	Low	Medium	High
Estimated energy	40515 Wh or 0.0405 MWh	135780 watt or 0.13578MWh	245280Wh or 0.25 MWh
Emission reduction	0.2852 tCO_2	1 tCO_2	1.762 tCO_2
CO2 Price per Ton	$3.4224	$ 12	$ 21.144

The a bove table 4.9 show that each household can reduce such amount of CO2 per year cumulative result of society very high

4.7Discussion

To make Ethiopian rural people energy independent solar energy is the best solution. Solar panel can be used as source of everyenergy for any activity. Ethiopia is steel energy deficit country in the world to fill this gap rural people needs alternative energy the local and national government need to plan growing this technology. Both political as well as social point of view consider this technology as only source for solving electrical access and provide opportunity to investors bringing the technology because the technology needs only initial investment. Ones the rural community invest the most interesting thing in the solar technology is it is free. The most interesting thing to use the solar technology is (SHS) including solar kit was

- No need to pay to use it
- No need to supply chain
- We can use it everywhere
- In large scale solar project supply the project and power the city

- We can use it small and individual scale to power the village and household
- No need to distribute network to use it
- No need to infrastructure like road at all

This is the best sector of technology to bring energy to the rural community in the far away part of Ethiopia. The country thinking about coal power plant, oil power plant, nuclear, hydropower and others technologies but we have here technology it is undisturbed which is solar home system.

Inspiration to use the technology it could work any were it needs to plan the technology as an important source or number one source of electrical energy in the local community because it is no need any grid, any sophisticated technology, no need of any additional cost ones you invest they can get power any were from every were.

The solar cost chipper every year this makes preferable for future alternative energy solar energy transform light of the poorest people in Ethiopia. it cost today the revolution of eco cell phone in Africa as well as in our country it is wireless that revolution is as about wireless and that revolution is solar and it is distributed solar. As the cell phone distributed through ought the country they fall on every roof top to generate their own enough energy to be sufficient for every household needs that is incredible thing.

There is also problem with it up until now the technology hasn't be there to be make it happen and the mindset has been that we have to have the grid provide. In our country energy use more than big nuclear reactor up there in the sky and Africa specially Ethiopia more endued with that solar energy which means solar power come from the sky.

The three thing we need to consider in this study is

1. The cost of solar productivity come down

So putting solar panel in to roof top of the rural people is not more than smart phone or buying small cow

2. The appliance of that we have gotten used to We all want, we all see as a part of our everyday life that give as health and security .if we talk LED light the amount of light gives 10 times and they last 30 times as long
3. Cell phone revolution we can make decentralized customer money for small payment

   Where they are now affordable We can paid for them a daily or a weekly schedule

This all thing make incredible change in the economy that is start to happening now Most of rural part they spend the amount of money for batteries and kerosene to light their home. If they are replace this small solar system it is a kit rather than a planetary thing so, small solar system allow to lighting four or five LED bulbs at night, radios and tape, TV , charging mobile and other purposes it is fantastic.

In the result show that the average solar energy tilted 15% north can produce 5.09KWh/m^2 this indicate All parts of the area It is asserting that in the solar energy is viable to generate electricity.

Chapter Five

Conclusion and Recommendation

3.1 Conclusion

In both cases to say that, if we use, energy production estimation tool and empirical formula the potential of electrifying community more than enough the potential that utilizable at the site 5.09 kWh/m^2. This means that we can electrify using small scale SHS all over the specific area as well as the country. Community based and grid connected solar energy electricity generation solar home system or solar kit it's best for various reasons the potential of to generate electricity through the year without any interruption affordability, efficiency , appropriateness and etc.

This is the only sector technology in Ethiopian rural community to bring light in future and economically feasible to install SHS

5.2 Recommendation

Like that of education and health the energy sector also need an attention for all stakeholders from government, society and other. Solving this problem have lots of benefits social environmental and economic. It recommended that further investigation about relating with solving the energy problem asolution to health, education, women's and children's, social, Environmentaland etc problem solving.

All stakeholders of

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Appendix

Table 1Declination angle

Month	n for I th day of the month	For the average day of the month		
		Date	N	$\boldsymbol{\delta}$
January	I	17		−20.9
February	31 + i	16		−13.0
March	59 + i	16		−2.4
April	90+i	15		9.4
May	120+i	15		18.8
June	151+i	11		23.1
July	181+i	17		21.2
August	212+i	16		13.5
September	243+i	15		2.2
October	273+i	15		−9.6
November	304 + i	14		−18.9
December	334 + i	10		−23.0

Table 2 Battery selection

Model	RECOM RCM 280-6MB BB	SunLink SL220-20M285	Allesun SPM 300W
Specification			
power			
price $		0.393 Euro/Wp	0.339 Euro/Wp
Warranty	10	10	5
Product Warranty (min)	10 year 90%, 25 Year 80%	12 year 90%, 25 Year 80%	10 year 90%, 25 Year 80%
Electrical Data at STC			
Maximum Power (Pmax)	285 W	285 W	300 W
Voltage at Maximum Power (Vmmpp)	32.5 V	31.9 V	32.15
Current at Maximum Power (Impp)	8.67 A	8.94 A	9.35 A
open circuit Voltage (Voc)	39.2 V	38.5 V	39.45 V
Short Circuit Voltage (Isc)	8.99 A	9.94 A	9.9 A
Pannel Efficiency	17.30%	17.50%	18.50%
Power Tolerance (positive)	3%	3%	3%
Power Tolerance (Negative)	-3%		-3%
Electrical Data at NOCT			
Maximum Power (Pmax)		208 Wp	
Voltage at Maximum Power (Vmmpp)		30.2 V	
Current at Maximum Power (Impp)		6.89 A	
open circuit Voltage (Voc)		35.1	
Short Circuit Currunt (Isc)		7.55A	
Temprature	45+/-2 c	45+/-2 c	45+/-2 c
operating Temperature Range	(-40 - 85)	(-40 - 85)	(-40 - 90)
Temp Coeffi of Pmax	-0.39%	-0.45%	-0.45%
Temp Coeffi of Voc	-0.32%	-0.35%	-0.34%
Temp Coeffi of Ics	-0.05%	-0.06%	-0.05%
Maximum Ratings			
Maximum system Voltage	1000 V	1000 V	1000 V
Material Data			
Dimensions (H/W/D)	1640x992x35 mm	1640x992x35 mm	1640x992x35 mm
Weight	19 Kg	18 Kg	19 Kg
Cell Type	Monocrystalline	Monocrystalline	Monocrystalline
Cell Number	60	60	60
Glass Type	Tempered, Anti-reflecting Coating Low Iron	Tempered	Tempered, High Transmittance
Glass Thickness	3.2 mm	3.2 mm	3.2 mm
Frame Type	Anodized Aluminium Alloy	Anodized Aluminium Alloy	Anodized Aluminium Alloy
Junction Box Diodes	3	3	
Junction Box Protection	IP67	IP67	
connector Type	MC4	MC4	
Cable Crosssection	4 mm2		
cable lengthe	1000 mm	900 mm	900 mm

Table 3inverter selection

1. Functional Parameter		5. Environment Temperature	
Nominal Voltage	12V	Discharge Temperature	-20~60°C
Nominal Capacity (10 hour rate)	200Ah	Charge Temperature	0~50°C
Number of Cells	6cells	Storage Temperature	-20~60°C
2. Rated Capacity at 25°C (77° F)		6. Inner Resistance & Max . Discharge Current	
10 hour rate (0.1C, 10.8V)	200Ah	Fully Charged battery at 25°C (77° F)	3.5mΩ
3 hour rate (0.25C, 10.8V)	144.7Ah	Max. Discharge Current	3000A (5s)
1 hour rate (0.55C, 10.5V)	110.1Ah	Short Circuit Current	10000A
3. Capacity affected by Temperature (10 hour rate)		7. Self-discharge at 25°C (77° F)	
40°C (104° F)	103%	Capacity after 3 month storage	91%
25°C (77° F)	100%	Capacity after 6 month storage	82%
0°C (32° F)	85%	Capacity after 9 month storage	73%
-15°C (5° F)	65%	Capacity after 12 month storage	64%
4. Dimension and Weight		8. Constant voltage charging at 25°C (77° F)	
Length	522mm	Cyclic use	14.4~14.9V
Width	240mm	Maximum charging current	50A
Height	219mm	Temperature compensation	-30mV/°C
Total Height	223mm	Float use	13.6~13.8V
Reference Weight	60kg	Temperature compensation	-20mV/°C

Source alibaba.com world’s largest supplier base.

Table 4metrological data

ቁጥር DPDT/4718/2010

ቀን 21/07/2010

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ጠያቂው፡- Yohannes Tsegay

ቀን 23/3/2018 የሚቲዎሮሎጂ መረጃ ለክፍሉ የሚገባቸውን ክፍያ 102.85 /አንድ መቶ ሁለት ብ
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No	Elements	No. of Stations	Year	Total requested Months *(0.08)	Cost/year	Total C… in Bir…
1	Global Solar Radiation	1	5	-	4.57	22…
					Service Charge	80.
						102.

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Table 5Table of analysis

										Liyu and jorda	koronakes mod	Badescu model
Month		wh/m-2	extra t.rad	Hd/h	Hd	HB	θ	θ_z	R_b	HT	HT	HT
january	492.6442	5911.73	8611	0.258996	127.5928	365.0514	0.973171	0.814033	1.195493	563.5151846	564.2382102	561.378006
february	531.3243	6375.892	9492.75	0.272329	144.6949	386.6294	1.004913	0.907177	1.107736	572.3250088	573.1449468	569.9013687
march	513.1856	6158.228	10500	0.347639	178.4035	334.7821	0.999957	0.976723	1.023788	519.8615054	520.8724586	516.8732466
april	395.1001	4741.201	11159	0.504733	199.42	195.6801	0.952928	1.009071	0.944362	382.1660376	383.2960842	378.8257528
may	462.9469	5555.363	10964	0.42093	194.8683	268.0786	0.872542	1.003693	0.869332	426.1787531	427.2830066	422.9147096
june	360.6599	4327.919	10873	0.535131	193.0003	167.6596	0.846218	1.007842	0.839634	331.7181707	332.8118391	328.4854157
july	329.0915	3949.098	10429	0.558186	183.6943	145.3972	0.863649	1.011195	0.854088	305.8724369	306.9133712	302.7955577
august	267.1255	3205.506	10873	0.670663	179.1512	87.97435	0.926971	1.012188	0.915809	257.5815437	258.5967335	254.5807619
septembe	345.3932	4144.718	10645.8	0.545378	188.3699	157.0233	0.960318	0.96882	0.991224	341.9871799	343.0546091	338.8319847
october	447.2261	5366.714	10075	0.396424	177.2913	269.9348	1.00712	0.932521	1.079998	467.3269468	468.3315977	464.3573169
novembe	424.6674	5096.008	9244.8	0.379359	161.1015	263.5659	0.983738	0.853797	1.152192	463.4851602	464.3980688	460.7867095
december	407.5435	4890.522	9792	0.427916	174.3945	233.149	0.96803	0.814906	1.187903	449.7739233	450.7621585	446.852816
Ave	414.7423											

Table 6 Hourly solar average global solar radiation available to the load

Average global solar radiation 7 AM to 6 PM **Year 2013**

Jan-13	
7 AM	53.67903
8 AM	210.0871
9 AM	402.9315
10 AM	567.5645
11 AM	681.8379
12 PM	699.8427
1 PM	696.0218
2 PM	621.829
3 PM	482.271
4 PM	322.2145
5 PM	123.3266
6 PM	12.18387
Average	406.1491

Feb-13	
7:00 AM	70.89808
8:00 AM	243.7126
9:00 AM	602.5
10:00 AM	614.0152
11:00 AM	762.3126
12:00 PM	804.9073
1:00 PM	811.6171
2:00 PM	719.3343
3:00 PM	570.0464
4:00 PM	395.6389
5:00 PM	185.0306
6:00 PM	30.63333
ave	484.2205

Mar-13	
7:00 AM	94.31933
8:00 AM	286.0561
9:00 AM	504.5182
10:00 AM	626.2813
11:00 AM	719.484
12:00 PM	734.0205
1:00 PM	638.2843
2:00 PM	556.3541
3:00 PM	399.0598
4:00 PM	291.4645
5:00 PM	121.0117
6:00 PM	21.58144
	416.0363

Apr-13	
7:00 AM	119.3992
8:00 AM	306.337
9:00 AM	493.8339
10:00 AM	635.8669
11:00 AM	660.0126
12:00 PM	666.1142
1:00 PM	597.9893
2:00 PM	505.1839
3:00 PM	271.1958
4:00 PM	217.4387
5:00 PM	108.9244
6:00 PM	29.31429
AVE	384.3008

May-13	
7 AM	115.6629
8 AM	286.1129
9 AM	445.5161
10 AM	563.4605
11 AM	640.0718
12 PM	607.2653
1 PM	582.3992
2 PM	421.6476
3 PM	231.6298
4 PM	191.9694
5 PM	89.37984
6 PM	17.87016
AVE	349.4155

Jun-13	
7 AM	105.4367
8 AM	256.78
9 AM	422.8617
10 AM	557.0367
11 AM	567.8233
12 PM	568.71
1 PM	462.98
2 PM	337.1883
3 PM	197.6292
4 PM	138.5983
5 PM	75.2775
6 PM	19.18583
AVE	309.1256

Jul-13	
7 AM	54.74274
8 AM	142.7492
9 AM	283.0419
10 AM	416.3427
11 AM	485.3476
12 PM	510.0024
1 PM	463.2903
2 PM	365.0565
3 PM	191.5315
4 PM	115.4492
5 PM	59.03548
6 PM	19.93306
ave	258.8769

Aug-13	
7 AM	59.10161
8 AM	168.4952
9 AM	294.8702
10 AM	412.8306
11 AM	439.1726
12 PM	528.8492
1 PM	444.1645
2 PM	282.229
3 PM	171.725
4 PM	143.1065
5 PM	73.425
6 PM	16.37984
Ave	252.8624

Sep-13	
7 AM	104.9625
8 AM	271.8358
9 AM	468.1167
10 AM	597.51
11 AM	671.5983
12 PM	615.8233
1 PM	505.4833
2 PM	331.5108
3 PM	222.0567
4 PM	177.9592
5 PM	77.04167
6 PM	10.575
AVE	337.8728

Oct-13	
7 AM	127.7323
8 AM	316.0379
9 AM	488.6081
10 AM	604.5258
11 AM	648.1105
12 PM	648.6411
1 PM	578.1169
2 PM	484.5081
3 PM	395.7371
4 PM	238.7847
5 PM	88.1879
6 PM	4.170968
Ave	385.2634

Nov-13	
7 AM	122.8775
8 AM	288.005
9 AM	478.685
10 AM	599.5558
11 AM	663.9758
12 PM	721.7208
1 PM	683.1625
2 PM	579.8858
3 PM	452.4908
4 PM	259.0942
5 PM	58.5825
6 PM	2.545
ave	409.2151

Dec-13	
7 AM	71.31613
8 AM	264.7315
9 AM	453.1774
10 AM	606.4774
11 AM	700.4452
12 PM	727.3073
1 PM	701.6742
2 PM	601.8032
3 PM	453.9169
4 PM	287.304
5 PM	59.97339
6 PM	5.250806
ave	411.1148

2014

Jan-14	
7 AM	46.8911
8 AM	182.636
9 AM	372.377
10 AM	515.754
11 AM	652.759
12 PM	702.976
1 PM	684.849
2 PM	565.682
3 PM	456.72
4 PM	287.019
5 PM	101.89
6 PM	10.6984
	381.688

Feb-14	
7 AM	44.0973
8 AM	183.948
9 AM	347.962
10 AM	510.741
11 AM	616.997
12 PM	651.399
1 PM	646.588
2 PM	562.516
3 PM	446.62
4 PM	276.137
5 PM	119.554
6 PM	17.8205
Ave	368.698

Mar-14	
7 AM	74.0718
8 AM	258.026
9 AM	440.784
10 AM	560.581
11 AM	640.052
12 PM	724.844
1 PM	680.169
2 PM	575.493
3 PM	349.255
4 PM	301.323
5 PM	139.24
6 PM	18.6613
Ave	396.875

Apr-14	
7 AM	109.313
8 AM	293.484
9 AM	437.016
10 AM	543.417
11 AM	641.343
12 PM	621.542
1 PM	612.435
2 PM	564.169
3 PM	275.211
4 PM	261.998
5 PM	124.451
6 PM	17.2442
Ave	375.135

14-May	
7:00 AM	122.3279
8:00 AM	293.9175
9:00 AM	482.0529
12:00 AM	521.9235
1:00 AM	565.4107
2:00 PM	598.622
1:00 PM	671.1696
2:00 PM	472.9578
3:00 PM	425.5095
4:00 PM	346.8333
5:00 PM	164.484
6:00 PM	16.94186
AVE	390.1792

Jun-14	
7 AM	116.971
8 AM	276.891
9 AM	445.181
10 AM	561.172
11 AM	591.627
12 PM	564.649
1 PM	527.286
2 PM	388.489
3 PM	221.764
4 PM	172.832
5 PM	98.27
6 PM	20.5733
AVE	332.142

Jul-14	
7 AM	68.3468
8 AM	177.271
9 AM	290.96
10 AM	402.956
11 AM	430.415
12 PM	457.808
1 PM	427.376
2 PM	342.797
3 PM	209.929
4 PM	156.571
5 PM	97.0847
6 PM	23.3056
Ave	257.068

Aug-14	
7 AM	65.1379
8 AM	180.079
9 AM	294.94
10 AM	423.677
11 AM	506.667
12 PM	538.965
1 PM	475.12
2 PM	385.615
3 PM	211.726
4 PM	186.524
5 PM	103.598
6 PM	17.9145
ave	282.497

Sep-14	
7 AM	86.2667
8 AM	245.503
9 AM	398.073
10 AM	538.032
11 AM	560.373
12 PM	533.928
1 PM	473.361
2 PM	373.303
3 PM	238.744
4 PM	170.648
5 PM	83.7533
6 PM	9.85
AVE	309.32

Oct-14	
7 AM	119.624
8 AM	301.918
9 AM	443.172
10 AM	584.726
11 AM	721.181
12 PM	697.637
1 PM	656.135
2 PM	546.441
3 PM	441.094
4 PM	249.081
5 PM	89.2306
6 PM	4.79194
Ave	404.586

Nov-14	
7 AM	114.548
8 AM	275.112
9 AM	472.878
10 AM	591.281
11 AM	679.215
12 PM	657.024
1 PM	649.763
2 PM	547.734
3 PM	407.983
4 PM	250.658
5 PM	300.9
6 PM	2.61083
Ave	412.476

Dec-14	
7 AM	69.1371
8 AM	239.515
9 AM	429.156
10 AM	583.273
11 AM	670.933
12 PM	701.002
1 PM	671.18
2 PM	593.623
3 PM	445.033
4 PM	269.235
5 PM	178.831
6 PM	50.1153
Ave	408.419

2015

Jan-14	
7 AM	46.89113
8 AM	182.6363
9 AM	372.3774
10 AM	515.754
11 AM	652.7589
12 PM	702.9758
1 PM	684.8492
2 PM	565.6823
3 PM	456.7202
4 PM	287.0185
5 PM	101.8895
6 PM	10.69839
	381.6876

Feb-15	
7 AM	63.49732
8 AM	239.6705
9 AM	424.7821
10 AM	611.1357
11 AM	752.9893
12 PM	778.2866
1 PM	783.9545
2 PM	686.2732
3 PM	564.3304
4 PM	365.9955
5 PM	172.3384
6 PM	23.61339
ave	455.5722

Mar-15	
7 AM	82.13387
8 AM	259.1815
9 AM	452.1363
10 AM	614.7774
11 AM	715.3339
12 PM	722.6363
1 PM	694.1331
2 PM	591.7508
3 PM	348.6137
4 PM	331.3774
5 PM	148.4823
6 PM	20.75161
Ave	415.109

Apr-14	
7 AM	128.7117
8 AM	314.4592
9 AM	501.9117
10 AM	635.0933
11 AM	723.9642
12 PM	713.8325
1 PM	680.3308
2 PM	565.1158
3 PM	299.7867
4 PM	285.1383
5 PM	137.315
6 PM	21.96833
Ave	417.3023

May-15	
7 AM	120.3194
8 AM	272.5073
9 AM	438.2508
10 AM	563.2363
11 AM	581.1161
12 PM	585.0411
1 PM	480.6355
2 PM	286.104
3 PM	310.3476
4 PM	213.0774
5 PM	106.8347
6 PM	17.87339
Ave	331.2786

Jun-15	
7 AM	96.54833
8 AM	238.7283
9 AM	386.5083
10 AM	492.515
11 AM	527.67
12 PM	466.6483
1 PM	422.7133
2 PM	295.72
3 PM	241.9117
4 PM	156.4883
5 PM	82.02417
6 PM	18.075
Ave	285.4626

Jul-15	
7 AM	74.8871
8 AM	217.5677
9 AM	326.7008
10 AM	384.3653
11 AM	590.4306
12 PM	611.3581
1 PM	525.1992
2 PM	389.7065
3 PM	190.8573
4 PM	125.1177
5 PM	72.67339
6 PM	19.9371
Ave	294.0667

Aug-15	
7 AM	55.06371
8 AM	173.6903
9 AM	291.0258
10 AM	353.9976
11 AM	546.1887
12 PM	635.4419
1 PM	558.1863
2 PM	447.996
3 PM	313.0411
4 PM	207.1419
5 PM	101.7266
6 PM	20.32339
Ave	308.6519

Sep-15	
7 AM	106.0658
8 AM	263.4308
9 AM	346.2408
10 AM	450.1483
11 AM	589.2317
12 PM	604.2117
1 PM	603.6533
2 PM	509.5125
3 PM	388.5617
4 PM	234.9242
5 PM	108.8717
6 PM	10.30917
ave	351.2635

Oct-15	
7 AM	119.929
8 AM	309.4161
9 AM	447.2355
10 AM	594.8952
11 AM	730.0492
12 PM	778.5339
1 PM	702.2484
2 PM	603.6169
3 PM	441.8726
4 PM	275.2395
5 PM	95.48226
6 PM	4.687097
Ave	425.2671

Nov-15	
7 AM	10854.9
8 AM	30915
9 AM	50157.2
10 AM	65871.9
11 AM	77961.8
12 PM	77609.2
1 PM	73243.1
2 PM	65173.8
3 PM	52171.8
4 PM	29218.4
5 PM	7035.2
6 PM	323.4
ave	45044.64

Dec-15	
7 AM	64.57742
8 AM	210.7226
9 AM	358.6798
10 AM	461.7911
11 AM	570.7742
12 PM	566.8669
1 PM	593.5863
2 PM	515.0073
3 PM	368.8702
4 PM	245.4097
5 PM	72.99516
6 PM	4.170161
	336.1209

2016

Jan-16	
7 AM	36.25
8 AM	147.896
9 AM	304.342
10 AM	446.065
11 AM	536.969
12 PM	598.933
1 PM	608.975
2 PM	536.235
3 PM	419.798
4 PM	280.848
5 PM	104.674
6 PM	10.0621
	335.921

Feb-16	
7 AM	43.4371
8 AM	181.161
9 AM	343.331
10 AM	516.862
11 AM	635.316
12 PM	731.172
1 PM	728.822
2 PM	655.115
3 PM	531.047
4 PM	355.675
5 PM	161.008
6 PM	22.2517
Ave	408.766

Mar-16	
7 AM	67.1589
8 AM	234.618
9 AM	386.987
10 AM	376.568
11 AM	642.928
12 PM	656.098
1 PM	666.415
2 PM	595.469
3 PM	460.177
4 PM	277.531
5 PM	128.272
6 PM	18.6161
Ave	375.903

Mar-16	
7:00 AM	73.7171
8:00 AM	188.026
9:00 AM	280.926
10:00 AM	338.797
11:00 AM	447.344
12:00 PM	445.799
1:00 PM	500.628
2:00 PM	396.145
3:00 PM	298.536
4:00 PM	189.941
5:00 PM	104.816
6:00 PM	21.099
ave	273.814

May-16	
7 AM	98.1419
8 AM	231.822
9 AM	295.173
10 AM	384.102
11 AM	567.802
12 PM	583.112
1 PM	570.985
2 PM	424.485
3 PM	335.825
4 PM	170.124
5 PM	89.379
6 PM	16.8218
Ave	313.981

Jun-16	
7 AM	75.6625
8 AM	179.493
9 AM	274.428
10 AM	359.312
11 AM	488.835
12 PM	509.708
1 PM	487.028
2 PM	368.482
3 PM	270.163
4 PM	152.733
5 PM	84.2892
6 PM	20.735
Ave	272.572

Jul-16	
7 AM	44.9476
8 AM	133.285
9 AM	231.466
10 AM	295.016
11 AM	454.348
12 PM	469.915
1 PM	459.39
2 PM	339.866
3 PM	180
4 PM	149.655
5 PM	83.7935
6 PM	19.9863
Ave	238.472

Aug-16	
7 AM	54.175
8 AM	142.758
9 AM	246.7
10 AM	304.191
11 AM	420.304
12 PM	463.004
1 PM	472.525
2 PM	359.99
3 PM	282.042
4 PM	207.96
5 PM	94.3145
6 PM	18.4073
Ave	255.531

Sep-16	
7 AM	59.3
8 AM	217.675
9 AM	405.775
10 AM	531.975
11 AM	634.075
12 PM	645.3
1 PM	544.175
2 PM	453.075
3 PM	366.2
4 PM	257.525
5 PM	95.65
6 PM	4.275
Ave	351.25

Oct-16	
7 AM	79.3
8 AM	227.675
9 AM	415.775
10 AM	571.975
11 AM	634.075
12 PM	645.3
1 PM	544.175
2 PM	453.075
3 PM	366.2
4 PM	257.525
5 PM	95.65
6 PM	3.275
Ave	357.833

Nov-16	
7 AM	55.9893
8 AM	209.076
9 AM	386.217
10 AM	534.729
11 AM	636.425
12 PM	677.155
1 PM	661.074
2 PM	586.111
3 PM	453.338
4 PM	285.829
5 PM	107.925
6 PM	5.3131
Ave	383.265

Dec-16	
7 AM	68.2952
8 AM	233.823
9 AM	417.121
10 AM	579.392
11 AM	672.768
12 PM	712.924
1 PM	695.105
2 PM	613.978
3 PM	484.745
4 PM	309.608
5 PM	94.4296
6 PM	5.23426
Ave	407.285

2017

Jan-17	
7 AM	45.0024
8 AM	198.756
9 AM	396.558
10 AM	566.186
11 AM	684.184
12 PM	744.131
1 PM	727.756
2 PM	653.252
3 PM	527.924
4 PM	355.836
5 PM	140.672
6 PM	10.396
Ave	420.888

Feb-17	
7 AM	37.5116
8 AM	165.528
9 AM	304.454
10 AM	457.422
11 AM	561.875
12 PM	644.571
1 PM	653.685
2 PM	593.49
3 PM	485.846
4 PM	333.188
5 PM	155.812
6 PM	24.0795
Ave	368.122

Mar-17	
7 AM	61.8581
8 AM	231.815
9 AM	380.112
10 AM	394.636
11 AM	628.084
12 PM	710.286
1 PM	751.27
2 PM	650.19
3 PM	512.53
4 PM	338.19
5 PM	169.53
6 PM	19.0298
Ave	403.961

Apr-17	
7 AM	99.595
8 AM	266.875
9 AM	354.123
10 AM	438.825
11 AM	662.749
12 PM	702.693
1 PM	711.993
2 PM	642.013
3 PM	470.43
4 PM	279.653
5 PM	125.916
6 PM	17.6
Ave	397.705

Oct-17	
7 AM	89.3
8 AM	237.1
9 AM	294.7
10 AM	424
11 AM	536.7
12 PM	552.39
1 PM	484.33
2 PM	459.2
3 PM	326.3
4 PM	215.5
5 PM	109.5
6 PM	20.16
Ave	312.432

Jun-17	
7 AM	94.9633
8 AM	231.962
9 AM	318.06
10 AM	386.822
11 AM	590.052
12 PM	601.999
1 PM	511.768
2 PM	338.367
3 PM	232.009
4 PM	167.053
5 PM	98.105
6 PM	25.2733
Ave	299.703

Jul-17	
7 AM	53.8847
8 AM	131.755
9 AM	214.359
10 AM	282.159
11 AM	436.031
12 PM	426.769
1 PM	436.35
2 PM	338.01
3 PM	201.267
4 PM	141.885
5 PM	68.0524
6 PM	16.2355
Ave	228.896

Aug-17	
7 AM	52.679
8 AM	158.934
9 AM	230.956
10 AM	294.007
11 AM	432.489
12 PM	455.295
1 PM	450.181
2 PM	390.515
3 PM	246.669
4 PM	167.112
5 PM	84.7702
6 PM	17.271
Ave	248.407

Sep-17	
7 AM	89.3633
8 AM	223.813
9 AM	296.44
10 AM	434.867
11 AM	540.604
12 PM	529.085
1 PM	401.236
2 PM	317.222
3 PM	271.914
4 PM	179.089
5 PM	82.8658
6 PM	10.3317
Ave	281.403

Oct-17	
7 AM	101.888
8 AM	265.175
9 AM	422.616
10 AM	556.301
11 AM	623.669
12 PM	626.535
1 PM	588.566
2 PM	476.644
3 PM	374.308
4 PM	229.542
5 PM	81.4202
6 PM	4.02661
Ave	362.558

Nov-17	
7 AM	89.245
8 AM	256.505
9 AM	444.901
10 AM	542.319
11 AM	648.283
12 PM	686.424
1 PM	641.29
2 PM	544.909
3 PM	406.992
4 PM	246.132
5 PM	71.2583
6 PM	2.5175
Ave	381.731

Dec-17	
7 AM	61.7935
8 AM	218.855
9 AM	391.799
10 AM	544.484
11 AM	644.102
12 PM	681.215
1 PM	657.326
2 PM	577.946
3 PM	443.452
4 PM	276.308
5 PM	100.012
6 PM	4.67984
ave	383.498

2018