



Roof Top Photovoltaic Energy Potential Mapping.

Case Study of Jemo-1 Condominium Site; Addis Ababa, Ethiopia.

A thesis submitted to Addis Ababa Institute of Technology, Energy Center; in partial fulfillment of the requirement for the degree of Master of Science in Energy Technology.

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ADDIS ABABA INSTITUTE of TECHNOLOGY.

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ABBREVIATIONS

AA: Addis Ababa.
AAWSA: Addis Ababa Water and Sewerage Authority
ALCC: Annualized Life Cycle Cost
A.M.: Air Mass
CRGE: Climate Resilient Green Economy
DC: Direct Current
DS: Data Set.
DOD: Depth of Discharge
ETB: Ethiopian Birr
E_Avail: Available Solar Energy
E_Unused: Unused energy (battery full)
E_Miss: Missing energy
E_User: Energy supplied to the user
E_Load: Energy need of the user (Load)
FF: Fill Factor
RE: Renewable Energy
GHG: Green House Gas
GIS: Geographic Information System.
Glob EffEffective Global, corr. for IAM and shadings
Glob Hor: Global Horizontal irradiation
GTP: Growth and Transformation Plan
IRENA: International Renewable Energy Agency.
kW: Kilo Watt.
LCA: Life Cycle Assessment
LOLP: Loss of Load Probability.
MOWIE: Ministry of Water Irrigation and Electricity.
mm; milli meter.
N/A: No Answer
NASA: National Aeronautics and Space Administration.
NDC: National Determined Contribution

NMA: National Metrology Agency.
NOCT: Normal Operation Cell Temperature
MPPT: Maximum Power Point
RE: Renewable Energy.
RFTPVEPM; Roof Top Photo Voltaic Energy Potential Mapping
SDA: Spatial Data Analysis
SIR: Solar Irradiation.
Sol Frac: Solar fraction
STC: standard Test Condition.
SyTC: System Total Cost
PV: Photovoltaic.
PVSyst: Photovoltaic System
UNFCCC: United Nations Framework Convention on Climate Change
USD: United States Dollar
3D: Three Dimensional

SYMBOLS:

Ahr: Amper hour

$^{\circ}\text{C}$:Degree in centi

CO_2 : Carbon Dioxide

$\dot{\eta}$: Efficiency

I_n : Inflation

I_i : Interest

J1,J2,J3: Jemo 1, Jemo 2, Jemo 3.

kg: killo gram

N,NE,NW,S,SE,SW: North, North east, North West, South, South east, South west

T: Temperature

Jan, feb. ... Dec: January, February.... December.

m/s: Meter per second

,n : Year

S_c : Short Circuit Current

V_{oc} : Open Circout Voltage

V_p Peak Voltage

I_p : Peak Current

P_p :Peak Power

G_{sc} : Solar Constant (Irradiance)

θ_s : Incidence angle

ϕ : Latitude

Y : Solar Azimuth

β :Sope

T_a :Temperature (ambient)

T_c :Temperature (cell)

V : Volt

W/m^2 :Watt per meter square

Whr: Watt hour

$\text{\$}$: US Dollar

ABSTRACT

This study addresses energy potential mapping from photovoltaic panels on rooftops, focusing on geographic, physical, technical, and economic constraints for viable energy prediction. The research was conducted in Jemo condominium housing, representing typical living conditions. Geographic location potential, rooftop orientation for solar insolation, and technical potential aligned with energy demand scenarios were analyzed. Economic potential was also assessed. The adoption of solar PV systems in urban residential houses promises sustainable energy provision. This study evaluates solar energy feasibility through PV applications on rooftops, aiming for self-sufficiency in electrical energy, reduced carbon emissions, and alleviated energy scarcity. Secondary data were used to predict energy potentials via empirical formulations, spreadsheets, graphical analyses, and simulations. Optimal PV system performance was analyzed by incidence angle, azimuth classes, and roof slope. Google Earth was used to quantify physical potential by scanning rooftop orientations and directions. Technical potential was assessed by considering specific modules and their characteristics. Scenarios related to demand, supply, and backup were examined to predict optimums. Economic potential analysis concluded that a building block in Jemo-1 can pay 19,864.00 ETB per month for PV electric service. With a 143 m² rooftop area, 108 solar panels (1.31 m² each) and 7.2 kWhr additional power from storage equipment were determined. The capital investment for this setup is 1,462,406.40 ETB for a demand size of 14.26 kWhr/day or 5,205 kWhr annually. A 15-year life cycle and future worth assessment at local interest conditions suggest a capital investment of 805,649.00 ETB. A GHG effect analysis showed an annual emission of 1,077 kg CO₂ from the conventional grid and 1,540 kg CO₂ from the PV system, a 42% increase for the PV system.

Key Words: Condominium Houses, Potential, PV Systems, Jemo, Potential Mapping, Photovoltaic, Roof-top, Solar Radiation

CHAPTER – ONE

1.0 INTRODUCTION

This chapter explains about background of the subject topic, objective of the research, statement of the problem, scope of the study, material and methodology and so limitations of the research. And after discussing significance of the study; general organization on how the following chapters are laid will be rehearsed.

1.1 Back ground to the Research.

Urban population occupies more than 20% of Ethiopian population and rate of urbanization is near five percent according to the national statistics agency data. As a response to high stock demand, the housing development bureaus of Addis Ababa city had planned and implemented IHDP. A project initiated to reply to the dire housing need of the citizen. Between 2005 and 2010 a total of 80,245 houses with 3, 2, 1 bedrooms and including studio compartment are delivered to registered citizens [1].

Addis Ababa city Condominium housing location concentrates and accommodate as enough dwellers as its size unlike most regional locations who participate in IHDP program but lack the utmost demand and occupation status for similar purpose.

On assessment of perceived needs of condominium residents on functional uses and open spaces, condominium housing is described as a name given to the form of housing tenure where each resident house hold owns their individual unit, but equally shares ownership and responsibility of surroundings [2].

On a similar study for condominium versus environmental sustainability; it is dictated most optimal environment sustainable preposition is to use additional source of renewable energy other than hydroelectric power, like Bio gas, wind or solar PV system and that water and waste should be recycled. Yet long term impact of measure taken to meet immediate need such as parking is not taken for consideration [3].

Environmental sustainability requires that we devise ways of how we can build the needed housing and still conserve nature. This can be done in the way we use energy, the needed water and other resources; by relying more on renewable resources; and by observing limits in the exploitation of non-renewable resources, understanding the threat to nature and the environment.

The use of low carbon energy system to feed urban environments appears as an important way to forward to improve the environmental sustainability of cities while fostering energy security. One such resort is to take natural measures in heating and cooling, ventilation and day lighting strategies and incorporating natural and clean energy options, such as solar energy.

Solar energy for electricity is promising renewable energy resource alongside biomass, hydro and wind power plants in Ethiopia [4].

In line with the foreknown solar power technology exposure expansion from solar powered services such as solar electric generator for small boats on sea, charging station for electric vehicles, space crafts powered from solar insolation, an electric fence, a street and traffic lights, a solar calculator, a pump system assisted by solar, can be raised and argue as; innovative technological identities.

Photovoltaic has become an essential element of an end-use application such as providing “essential electricity” for remote telecommunications, water pumping, home lighting and other off-central grid applications, or providing “clean electricity” for homes, commercial buildings, and other on-grid applications. These shows PV systems have developed from being niche market application in to mature technology used for mainstream electricity generation.

The national energy policy define the energy sector of the country as poverty stricken meaning as insufficient choices in the service, a high dependence and unsustainable use

on bio-mass and petroleum resources, utilization where house hold consumption is 85% of total energy resource available [5].

Decentralized renewable energy systems included in urban context allow security of energy input in general. If energy security is attained urban economic activities would not be completely interrupted in situation in which centralized energy system fail or in case of interruptions on providing essential electricity for sensitive power supply. Interruption can be said as power quality problem and or ineffectiveness in delivering the available power with most perceivable effect on facilities. As compared to other regions both frequency and duration of interruption is very high in Addis Ababa [6].

In todays world (considering the foresighted transition) the electric power industry is a source also for the automotive mobility service by charging electric vehicles. Thus the social cost of unsupplied or unavailable energy and the cost of interruption to electricity consumer is significant or shall be mitigated. These issue showed the significance of more heterogeneous strategy to provide energy and security when centralized system failed or susceptible to a level.

Electrical energy loss of self-sufficiency or scarcity as frequent load shedding, power failure, man-hour loss, closure of facility providers and production decrease is a common phenomenon in our day to day life. The national energy policy; a policy frame work report of the ministry of water irrigation and electricity analyzes generation capacity for the country distribution and transmission taking into account it's ominous in territorial area, total number of sending end and receiving end substation in the national grid counted to 160 with single transformers whereby out of service condition is considerable. Within the report recommendation is given of the need to install additional back up transformers in distribution facilities for improved reliability.

Therefore, renewable energy sources such as solar which are distributed in nature and can be harnessed for mini grid application. Roof top photovoltaic system is thus one approach as a solution for backing up electric energy scarcity ensuring self-sufficiency sustainably

and the research entitled roof top energy potential mapping for selected sites in Ethiopia, under the aim of assessments of PV energy potential is an important theme which is also a research issue of engineering for a number of decades as many literature and studies dictate.

Considering the main and only operator of electric power service for the region has to guarantee sustainable produced power to regionally connected neighboring countries such as Djibouti and Kenya, to the bulk power needed for industries, power utilities for commercial and residential establishments. It is imperative that to shift to or to counter fit to less competitive energy sources which does not have high debt from beginning of construction and are less vulnerable connected issues.

Ethiopia relies heavily on hydroelectric power for its domestic and regional electricity needs. However, this source of energy has some onerous and demanding said if not disadvantageous that could affect its sustainability and feasibility. For instance, hydroelectric power depends on water availability and rainfall patterns, which are subject to climate change and variability. Moreover, hydroelectric power involves large-scale construction projects that require huge capital investment, land acquisition, environmental impact assessment, and regional cooperation. These factors could pose financial, social, political, and ecological challenges for Ethiopia in the long run. Therefore, Ethiopia should consider diversifying its energy mix by adopting solar PV application as an alternative source of energy. Solar PV application has some benefits that could complement hydroelectric power, such as lower operational cost, higher scalability, greater accessibility, and lower greenhouse gas emissions. However, solar PV application also has some limitations that need to be addressed, such as higher upfront cost, lower conversion efficiency, variable output depending on weather and time, and potential land use conflict. Thus, Ethiopia should carefully weigh the pros and cons of both sources of energy and develop a comprehensive and integrated energy policy that ensures optimal utilization of its natural resources.

According to the study on assessments of power Interruptions in Addis Ababa; some examples for poor power quality as arise from; sudden power failure, increment of system loss and load un-balances. And frequent and more duration interruption occur in winter period and that faults and over loaded transformer due increasing demand are some of cases for disordered power supply from electric network that can be from generation facility on transmission to distribution level [6].

1.2 Statement of the Problem

Dependency on fossil fuel for backing up electric power remains the obvious and commonly used choice. Aside from recurring cost of fuel, noise generated when in service from diesel generator is an additional problem to be mitigated. Accordingly, the inability of satisfying loss of electric utility to a sudden and untimed failure of the supply in terms of response shall be supported from electricity source by renewable energy source such as solar power. The sudden unavailability of electric power; an evening without light or our working desktop computer without its power, a refrigerator not keeping its required temperature level until restore of electric power, an operating cloth washing machine or a backing oven stopped while it is on process and many other residential and commercial specific energy demand managements.

Urban housing arrangement like condominium houses, where each families under same roof top can be characterized with different essential electric energy demand. The expense of installation and lack of adequate information to quantify PV technology capacity and thus the return on investments can be taken as barrier to site the technology for utilization. Therefore, identified technical, social and regulatory factors for consumer decision to use PV systems will be useful.

1.3 Research Objectives

1.3.1 General Objective

To evaluate the feasibility and sustainability of rooftop solar PV systems in the case study locations, considering technical, environmental, and economic aspects.

1.3.2 Specific Objectives

- I. To map and determine geographic and physical potential of roof top areas in case study locations.
- II. To evaluate technical potential with optimum PV system deployment.
- III. To estimate GHG reductions to be obtained in kg of CO₂.
- IV. To perform economic analysis using present worth, future worth, capitalized cost, payback period, and life-cycle costing economic theories.

1.4 Significance of the Study.

The research work holds valuable insights for both the general public under regional administration and the scientific community. Specifically, it addresses the advantages of photovoltaic (PV) deployment over diesel generators for electrical energy backup in urban areas. While solar energy applications in urban residential houses through PV systems are not widespread, this study delves into the details of such implementation, particularly in condominium housing locations.

The study emphasizes the importance of resilient energy systems. By integrating PV technology, buildings can ensure a secure and uninterrupted power supply even during disruptions. This continuity of function is especially critical for essential needs, including property guard lighting, refrigeration, water pumps, and reserve power for electric vehicle charging. Additionally, it supports the operation of building elevators, catering to the elderly and those with specific requirements.

1.5 Material Method

Jemo condominium is a communal residential housing location in north west part of Addis Ababa where by reference is made as case study, including the feature of house and the habitat in it as a whole. The rationale for the selection of Jemo condominium housing location as research location is due to the major average and current trend of living condition of our society. The study approach is by classifying into stages of evaluating the geographic, physical, technical and economic potentials in deploying the system. For it secondary data from governmental and international institution was used. Worldwide online tools were used. Basing on literature findings as main procedure for the classified stages to take as procedure is done. Validating findings will be assisted by PVSyst Software as well as scientific model from existing body of knowledge. The assessment of PVSyst V7.3.1 is after it's popularity is common in academic society of AAIT and to mention in various work in validation PV system performance; specially, it's simulation was used to indicate optimal orientation for performance analysis of solar systems installed by MOWIE in various rural parts of Ethiopia as the study paper mentioned in literature review part shows. Thus, the research is qualitative study around certain concepts and also uses facts from past and trends of the future.

1.6 General Organization of the Paper

The paper work is organized in to five chapters. This chapter with earlier proposed title is INTRODUCTION part whereby; background to the study is explained, continuing with describing significance of the research with objectives included. Statement of the problem, scope of the study, limitation where by short fall research study programs are announced and organization of the paper listing next chapters as well.

Chapter two deals on reviews from LITERATURE concepts related with energy potential mapping using photovoltaic application. Chapter three presents METHODOLOGY followed for the research paper output. The fourth chapter thus shows results from the METHODOLOGY discussing with three subtopics. And hence CONCLUDING notes

and RECOMMENDATION feedback are settled in the fifth chapter. To make it whole; appendices containing pictures, data and simulation reports are also found as subsidiary in the last pages.

1.7 Scope and Limitation of the Research

1.7.1 Scope

The main study units are residential houses application and to conduct the study:

- Access the geographic location for PV application and so predict demographic and climatic data inputs.
- Access the physical potential for roof top PV installation availability and suitability.
- Determine the Technical Potential by optimum sizing of PV system; PV type , manufacturers size, roof topology and size to be considered, understanding the solar radiation value to be taken for least power output, PV parameters and local climate and environmental operating factor conditions balancing and taking theoretical, practiced and commercial knowledge's.
- Economic potential analysis for viability prediction.
- Environmental greenhouse gas mitigation consideration result for recommendation.
- Constraint stages mapped energy potential size prediction from the roof top PV application.

1.7.2 Limitation of the Research

Mapping by comparison of users under the roof areas of Jemo societies; like residential roofs from condominium or normal flat story houses or one and two or more level living building houses, or building's roof containing business center, school, and market places is not done. Where, in these mapped circles even if the geographic potential will be one reference as it will be one a two or three kilometers radius location, the physical potential size, availability, technic potential feasibility and economic potential preference would have been paramount interest. That is the size of rooftop available and applicable

contained in the optimal demand varieties associated with characteristics of society under each roof together with its longstanding use.

Physical, technical, economical sizes including result of Kilo gram reduction of green house gas obtained as a result are from hypothetical, qualitative data input.

Physical surface efficiency correction factor for the set slope of roof was not given while used slope degree in the analysis to generate numerical and graphical result is 45 degree which is not same.

The researcher has not used GIS software modeling approach and prediction of the limitation to the solar energy potential by digital elevation model for preview of sky obstruction together with the spatial and temporal variation in SIR.

CHAPTER - TWO

2.0 LITERATURE REVIEW

In this chapter scientific method and applications to photovoltaic system are presented. And especially overview of previously published works on a topic with parallel approach for assessment on roof top photo voltaic energy potential mapping are reviewed and presented. Thus stages from theoretical, geographic, physical, technical and economic potentials are pointed.

2.1 Photo-Voltaic in relation with Energy Potential Mapping.

With Photovoltaic Energy Potential Mapping: photovoltaic; combination of photo (a light or illumination from a source) and voltaic; (a term from the electric phenomenon or potential gained) and therefore; a formed potential from light. And energy which is literally the available quantity of ability for certain sustained task and electrically or scientifically it is power derived from a resource providing a function or work for a determined duration. Potential is capacity or ability in a certain matter.

Mapping is again literally; a diagrammatic representation of physical feature or more specifically a collection of data showing distribution of subject of interest over an area. It can be implemented from cadastral source, from remote sensing image, from aerial photography, by geographic information system application. In this issue it gives solar radiation potential depiction, it can give sky view obstruction details, it can be made to show scaled information and comparison along the map. Mapping can subjectively mean; showing sized areas of roof top in direction and orientation. It can show the classification by type and point in identifier the availability of resource, providers for delivery, financing, installation, maintenance and support system case on regions.

So potential mapping is showing distribution of capacity area. Thus in whole it is showing or locating distribution area of a power with certain ability derived from potential as a result of illumination. This illumination or light is sun light or it's ray so

called as solar power when associated with its heating essence or as a voltage source when the ray forms photoelectric phenomenon from materials made from semiconductor or crystals like solid state diode. The assembly of such diodes called as cells make a solar panel.

A solar cell is simply a semiconductor diode that has been carefully designed and constructed to efficiently absorb and convert light energy from the sun into electrical energy [8].

A Diode is as the name indicates a two terminal device that has the special use to conduct in a certain range of voltage and is either open or short circuit otherwise. Formed from two types of semiconductors with different carrier concentration and upon application of a driving force in this sense absorbed light, generates current and conduct it in specific direction. A diode can be defined as a near-unidirectional conductor whose state of conductivity is determined by the polarity of its terminal voltage.

Crystals are composed of three-dimensional patterns; the patterns consist of atoms in ordered or symmetrical arrangements which are repeated at regular intervals keeping the same orientation to one another. The simplest repeating unit in a crystal is called a unit cell [9].

Combination of cells form a solar panel of rated electrical wattage peak with quantified meter squared size and these panels ordered for desired fit capacity are called arrays.

Conceptually, in its simplest form a photovoltaic device is a solar powered battery whose only consumable is the light that fuels it [10].

2.2 Implementation of PV System

PV system is a solar electric system which produces direct electric current after being illuminated by sunlight. The variable nature of the output in terms of level of output and

it's intermittency according to illumination availability needs to be conditioned and controlled by power conditioning system and these may include necessity of associating energy storages.

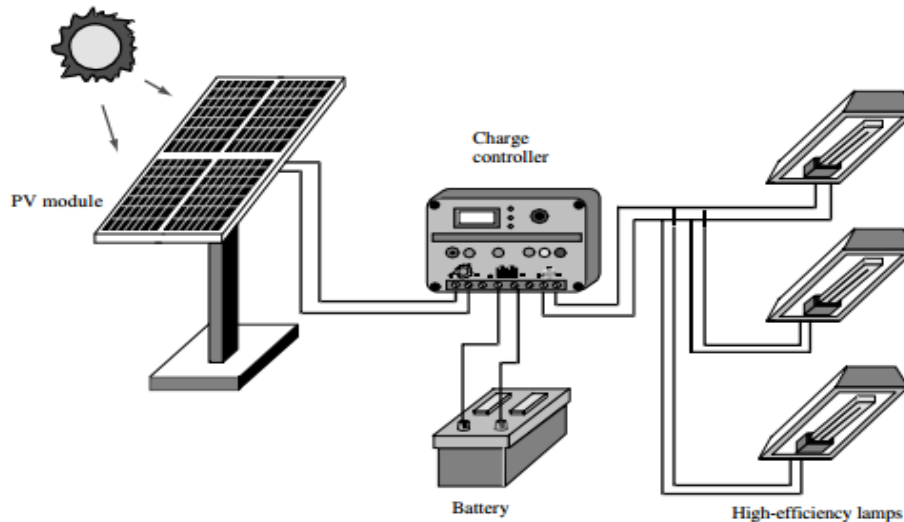


Fig 2.1: Typical PV System Schematic Arrangement [8].

The pictorial illustration shows encapsulated PV panels or a module which used to convert solar radiation in to electricity, a storage device for storing electricity produced and an electronic devise that help control flow of electricity within the setup.

Typical PV systems are stand-alone where there is a direct feed to load supported by batteries as necessary and grid connected where there is an interconnection to more centralized utility system of a region or city. Common application of photo voltaic solar power is in roof top and façade of buildings as in solar home system, others hanging on support for street lights and traffic signs are quite good example.

2. 3 Roof Top PV System

Roof top PV application implies system implementation mainly solar radiation collecting panel on top surface of buildings, cover of homes or car parks as such. The rehearse topic of the subject is how much solar panel could be installed in a certain roof top. And also what is the potential for solar power of this certainly referenced roof top. Thus, answer to potential roof top capacity will be obtained.

When population density is high and land is valuable it is obvious other system apparatus than roof mounted and building integrated cannot be advantageous. Rooftop space is provided by its built up area, it makes able to use generated energy at consumption point near equipment.

Roof added PV module means that PV panels are installed on the rooftop of existing buildings. According to installation, it mainly can be divided into three forms: flat overhead, tilted overhead and close roof mount [11].

Roof top PV application by revalorization of underutilized roof top areas for low carbon electricity production case study analysis discusses ability to accomplish substantial climate mitigation and demonstrate attainability of self sufficiency in electricity production (through such application). The method for implementation of photovoltaic panels in rooftop cities as to the study on South American Cities has pointed out that a GIS model elaboration as a useful tool in managing of quantification mapped area. Correction factors to be applied to exclude areas where objects such as security walls, machines rooms, ventilation engines and other intrusive objects appeared, then a second correction factor consisted in excluding rooftop area in North-South orientation. A final correction had to be taken based on uneven distribution of building heights in the city's skyline that creates shading, that in total bring a determined sized area. Then electric generation computation considering tilt, orientation and general cleanness of the region being referenced taken considered and appropriate efficiency (factor is given) is estimated. Final self sufficiency by the amount electricity produced from PV and saved

GHG emission result evaluated. Thus as a result solar energy potential of the location based on climatic and layout characteristics that would allow them to install photovoltaic panels in percentage range of the rooftop areas was able to be predicted [12].

A similar article for specifying potential area at building top surface in the study paper by topic; optimum selection of photovoltaic panels at urban area in north Africa, a design consideration attributably required in three steps for any PV system in residential and/or commercial buildings, are first, designer should define the total PV installation requirements and power capacity needs by relying on the information of the load consumption inside the studied building, Secondly, the possible amount of sustainable energy which can be extracted from the adopted PV modules under question are determined by designer. This energy is mainly dependent on the efficiency of conversion which determined by the material type and PV technology used. Thirdly, considering that power generation of PV cells is enhanced via more radiation, whilst its efficiency is remarkably degraded in the presence of higher temperature levels, clouds, and partial shading; that is PV power generation is also dominated by variable operating climatic conditions which are commonly defined through spatial data analysis [13].

Research paper of scalable methodology for the photovoltaic solar energy potential assessment based on available roof surface area: approach by defining technical, physical and geographic potentials. The assessment of the photovoltaic solar energy potential requires the evaluation of the physical potential (useful solar radiation), geographical potential (roof surface available) and technical potential (PV system efficiency) set method of global solar radiation evaluation as a first step then useful roof surface area and performance identification. Then population demography data analyses as by categories of number of population per roof area or roof area per capita for assessment of PV potential, this whole defined as theoretical potential. In brief hierarchical procedure proposed accomplished through the evaluation of the useful global solar radiation, the roof surface available for roof-top integrated PV systems and their relative performances [14].

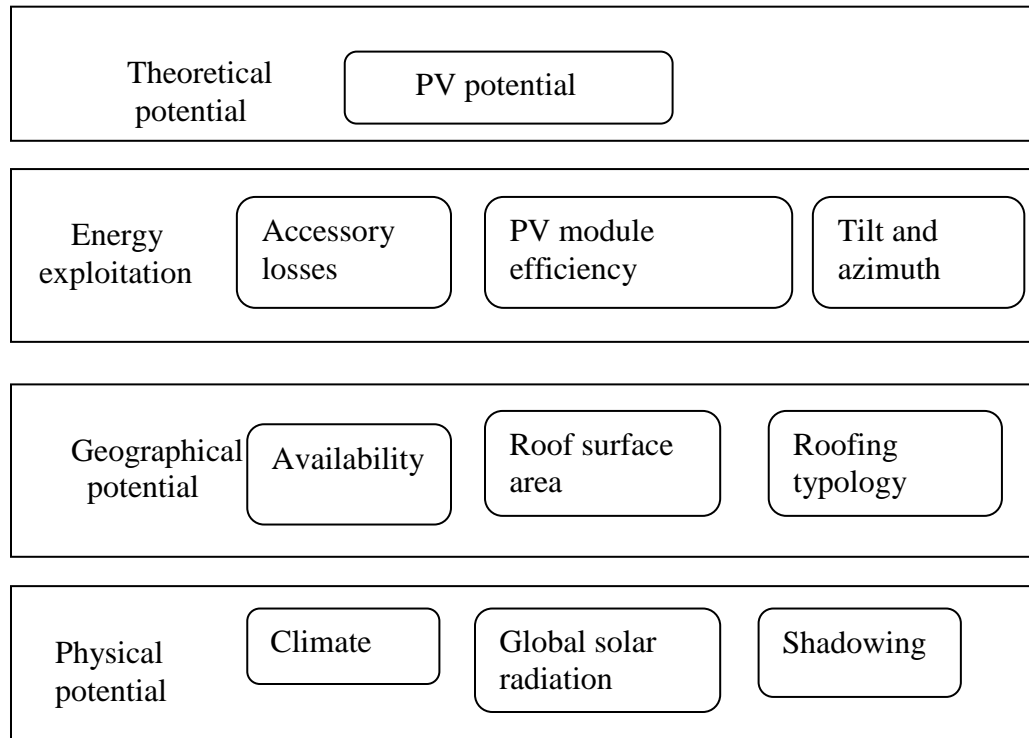


Fig.2.2: Pictorial block diagram for assessment stages of the photovoltaic solar energy potential [14].

The report of NREL on roof top solar Photo voltaic potential assessment for cities in North America shows potential of solar generator by technical as to mean the amount of geographic or resource potential considering theoretical and physical cases that can be converted into electricity under energy content of the resource (given available solar technologies). And economical potential as that account for amount of technical potential that could be realized in practice at a correction for system and topography constraints, market potential of which is predicted by the economy potential under regional competition, policy implementation and regulatory limits [15].

Oxford dictionary defines: - Geographic as “related to geography”. **Theoretical** (also **theoretic**) as “concerned with or involving theory rather than its practical application based on or calculated through theory. **Technical as:**” relating to a particular subject, art,

or craft, or its techniques, involving, or concerned with applied and industrial sciences”.
Physical as:” relating to things perceived through the senses as opposed to the mind, tangible or concrete, relating to physics or the operation of natural forces generally.”
Economic as: “related to economy, careful management of available resources, offering good value for money, a financial saving. **Market:** as “the demand for particular commodity or service”.

Thus understanding for these terms is taken as; Potential of solar generator by technical as to mean the amount of geographic potential that can be converted into electricity given available solar technologies with advantages found from configured physical potential. And economical potential as that account for amount of technical potential that could be realized in practice at a cost compatible with available electric resources or technology or standard. Finally it can be inferred what it would take for a service to be accepted and adapted as market potential.

On the part for motivation for PV application and development in comparison to several other renewable energy sources; theoretical potential does not take into account land use restrictions, conversion efficiencies, storage requirements and so on. The technical potential on the other hand must not be confused with short-term economic potentials, since price situations and capital requirements for activating these energy sources on a large scale are not considered [8].

Therefore, dealing with RTPVEPM going through these potential verifications for the roof top PV case study application is mandatory to come to a methodology for answering the topic subject question. Not limited to these it is also needed to determine weather it is the technical and economic optimal solution or also a feasible approach for the electrification application in the areas under discussion.

2.4 Potentials in PV solar power application (Theoretical and Technical Consideration to Solar Power Application.)

Geographic Potential; Solar radiation interaction with the land scape it surfaces can be described globally, regionally and locally. In relation to location of our living earth around solar system, energy potential from sun in form of light and associated atmospheric and climatic effects condition vary at various locations around the globe. And for one same referenced location there are monthly seasonal variation of solar radiation and the associated atmospheric and climatic effects through-out the year. This fact can also be deduced from day and night condition of solar radiation.

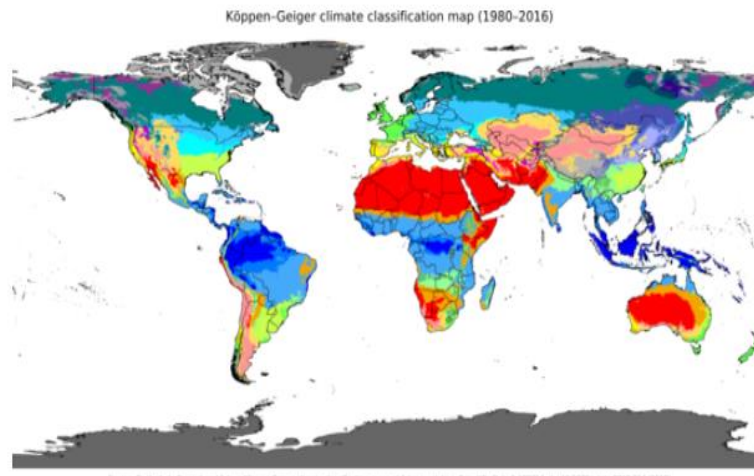


Fig 2.3: Köppen–Geiger Climate Classification Map [16].

Picture showing global climate classification by group of tropical, dry, temperate, continental and polar. Then these intern include seasonal precipitation classes; tropical rainforest, desert etc. Temperature wise; latitude climate, highland climate, summer, winter etc..

The position of the Sun in the sky is a function of both the time and the geographic location of observation on Earth's surface. Most practical application of photovoltaic requires position of the sun relative to an inclined plane to be determined. The parameters

are important factors describing position of sun in the sky and the collecting surface and the obstruction and reflection involved. These are “Latitude”, “Declination”, “Slope”, “Surface azimuth angle”, “Hour angle”, “Angle of incidence”, “Zenith Angle”, “Solar altitude angle”, “Solar Azimuth”.

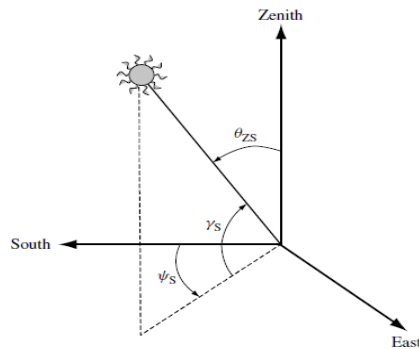


Fig 2.4: Picture Illustrates Position of Sun Relative to a Fixed Point on the Earth [17].

In the typical picture for illustrating position of sun, the angles shown are solar zenith angle “ θ_{zs} ”, Solar Azimuth” ψ_s ”, and Solar Altitude” γ_s ”.

Location of point of interest on earth defined by latitude which increases from zero at equator increasing positively to north pole and the opposite to south pole. Definition of time of the year by declination angle δ , an angle between earths equatorial plane and earth sun line, which will be taken as to north positive and as to south negative, as earth is tilted by 23.45° and the declination angle varies plus or minus this amount. Time of the day is similarly expressed by hour angle, angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis. Zero at local solar noon increase by 15 degree for each hour before solar noon and decreasing at same rate after solar noon by same amount or morning negative, afternoon positive.

Together with this; relations involving length of day and night and declination angle, sun set and sun rise direction displacement annually and the respective due dates and the sun

relative height in the sky during these seasons have also basic foundation in the sub topic geographic potential illustration.

The theoretical basis for earth movement around the sun model considerations are solar constant G_{sc} ; a solar radiation outside the atmosphere in W/m^2 . In addition to the total energy in the solar spectrum (i.e., the solar constant), it is useful to know the spectral distribution of the extraterrestrial radiation, that is, the radiation that would be received in the absence of the atmosphere.

Thus, solar radiation data are either instantaneous measurements (irradiance, a power density) or values integrated over some period of time (irradiation, an energy density) usually hour or day; or measurements are of beam, diffuse, or total radiation; or on receiving surface orientation (usually horizontal, sometimes inclined at a fixed slope, or normal to the beam radiation); and, if averaged, the period over which they are averaged (monthly averages of daily radiation).

As a second step let's come to the physical Potential: Physical potential is availability of roof top area and its typology suitability and where the operation of solar radiation phenomenon takes place.

Position of the sun in the sky, the direction in which beam radiation is incident on surfaces of various orientations, and shading is important in understanding and using solar radiation. By orientation systems can provide continuous or nearly continuous adjustments, with movement of the collector to compensate for the changing position of the sun [18].

Orientations mean finding the direction of the building in such a way that it derives maximum benefit from sun, air and nature [18].

Journal paper application perspective on Indian cities by estimation of rooftop solar photovoltaic potential using geo-spatial techniques stresses that building orientation is of

the utmost importance and must also be accounted for reduction to obtain actual available rooftop area for PV installations [19].

It is a general practice that energy collecting PV module on flat surface, to be orientated from east to west, and tilt angles from horizontal to vertical. The case of stand-alone systems designed to feed equipment having a constant consumption throughout the year is an especially interesting one, and deserves particular mention. The design criterion here is to maximize the energy captured during the period of least radiation, rather than throughout the year. As might be expected such receivers are positioned perpendicular to the winter sunlight, which leads to recommend a tilt angle equal to the location latitude degree greater by 10 degrees [18].

Orientations between east and south east and between south west and west, are fairly reasonable with system angles between 10° and 30° from horizontal. The irradiance will be reduced by around 15% of the maximum. Flat-roof systems with very low angles (between 5° and 10°) can be a good solution for difficult orientations. The loss of irradiance will be between 5% (south) and 20% (north) [8].

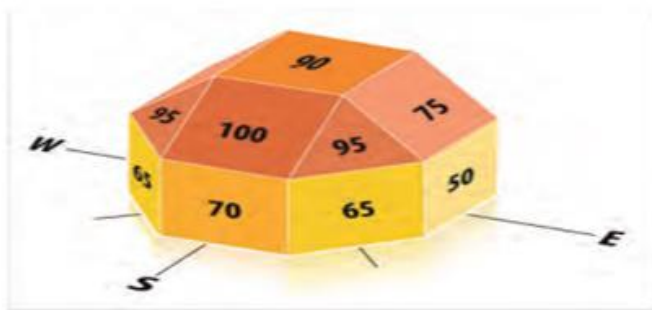


Fig 2.5: Illustration Using a Model for Showing Optimal Energy Production that can be expected from a PV Array at Different Orientation and Tilt Angle [20].

Thus Limitation characteristic for the physical potential are; roof slope (angle), its orientation and surface minimum yearly solar radiation that can either be in relation to solar radiation on the roof surface or non-obstruction by shade. Finding the final result of usable area shall be made considering adding correction factors. Correction factor for most employed roof topology are that will consider for; steepness of the pitch, chimney or other structures on roof location and their associated shades, spaces to be left for solar thermal equipment's, space allocated for satellite television broadcast receivers and or panels self-reciprocal shadowing. As a result available roof top area and typology suitability will be known [12].

An article on Estimation of rooftop solar photovoltaic potential for region in India using geo-spatial techniques: proposes six step procedures. The analysis of available rooftop PV potential assessment as to the paper is verified physical measurement of sample rooftops and a rigorous field survey of region of interest.

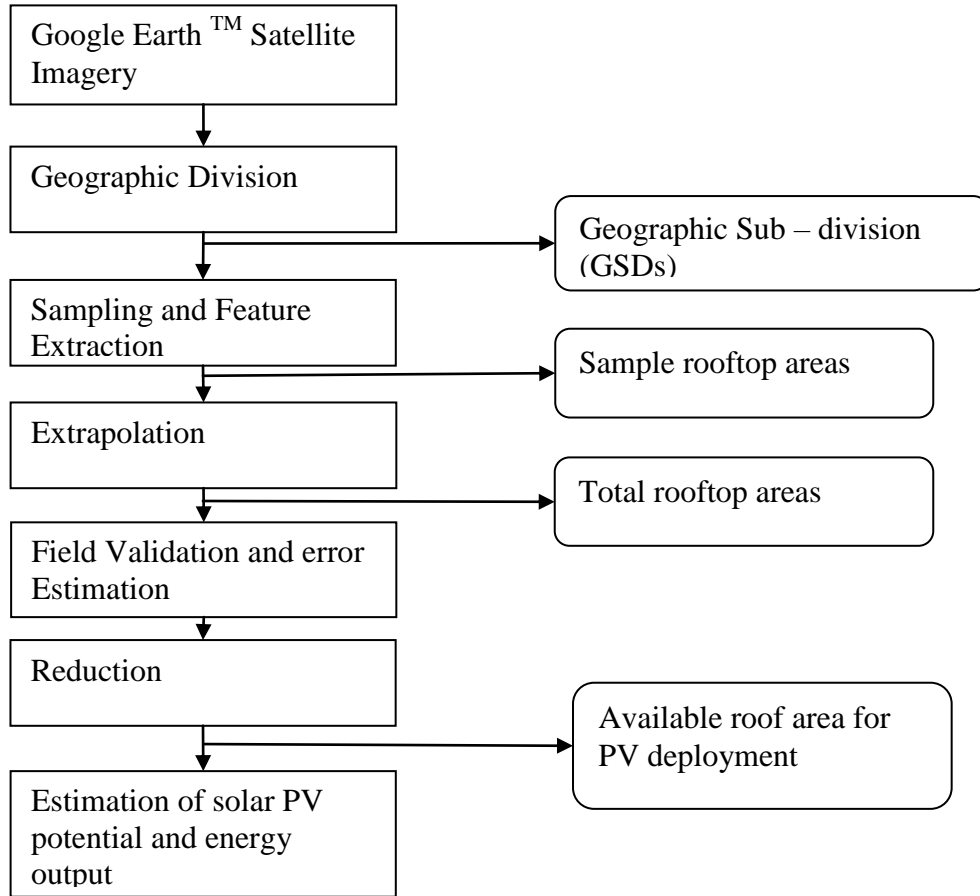


Fig 2.6 Block diagram described procedure for arriving at available area for PV application [19].

The article main methodology procedure as seen in flow chart picture follows six steps for arriving available roof area for PV deployment); First, Google Earth™ satellite imagery of location under study has been segmented into small geographic units so that land area and population density information can be easily extracted for smaller units. The extracted information has been used for sampling processes in which rooftop areas of have been obtained through automated feature extraction technique. In third step, sample information of roof areas has been extrapolated to entire area. In the fourth step, a rigorous field validation process has been performed. Next, total rooftop area has been reduced to analyze available roof area for PV deployment through the physical measurement of sample rooftops and field survey.

It also shows other similar methods for roof top physical potential assessment methods; Combination of land-use data and GIS based image analysis of sample satellite images; Use of Quick bird imagery to compute bright rooftop area and analysis by software, Use of high resolution grid map of solar radiation, meteorological data and aerial maps to analyze the potential of roof mounted PV system.



Fig 2.7 Typical roof top solar panel laid in two orientations from total four sides of the building [21].

Technical Potential: Factors affecting the distribution needs to be considered at all levels in way to achieve maximum result, technical capability of the solar PV needs to be optimized through appropriate installation with a recommended tilt and azimuth angle. Poor technical performance is often a result of selecting inappropriate accessories of PV systems and lack of proper maintenance [22].

Establishing a PV module rating condition, at which power performance and other characteristics are specified and defining a method for calculating performance at the prevailing environmental conditions such as solar irradiance, ambient temperature, wind

speed and so on are basis for predicting the generator energy delivery that is the technical potential. As an electrical component, the electric generating device shall exhibit voltage and current relationships. Thus basic solar cell figure of merits are Open Circuit Voltage V_{oc} , Short Circuit Current I_{sc} , Maximum Power Point M_{PP} . Maximum power point with V_{mp} and I_{mp} is particular interest point on I-V curve or characteristic of a typical solar cell, at this point power produced is maximum. On the characteristic curve the area defined by I_{sc} , V_{oc} and the corresponding V_{mp} and I_{mp} forms a rectangle whose area has value of maximum power. This figure of merit named as fill factor measures the squares of the rectangle, it is the maximum power result of V_{mp} and I_{mp} factor to the operating point power of V_{oc} and I_{sc} . Thus efficiency that is conversion efficiency defines the ratio of maximum power to the input power from solar insolation.

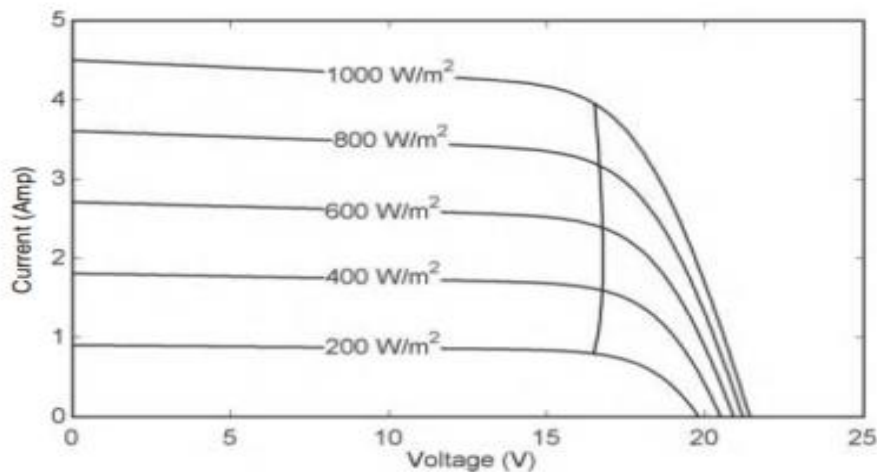


Fig 2.8 Typical I-V curves for a PV generator at several radiation levels [13].

Another decisive factor on performance of solar cell is temperature. The NOCT of a module is a fixed temperature that the module would operate at if it is exposed to the nominal thermal environment ($20^{\circ}C$ air temperature, $800 Wm^{-2}$ total irradiance, and a wind speed of $1 ms^{-1}$). Accordingly, NOCT normal operating cell temperature found from module manufacturer at the stated STC and with A.M. equals to 1.5 is from formulation of $T_C = T_{amb} + (T_0 - 20^{\circ}C) Et / Go Wm^{-2}$, the formulation is indeed a

standard. Where T_c is module temperature, t_{amb} is air temperature and T_o equates NOCT. E_t is total incident radiation and G_o equals 800 W/m^2 [17].

A general theoretical approach to determine potential electricity generation from installed PV is using the collector area of photo voltaic electric generator and its manufactured efficiency. With yearly Potential of electricity generation in kilo watt hour equals the collector area multiplied average efficiency of the array together with power transferring and conditioning equipment's and again multiplied by annual total global irradiation in watt hour per meter squared.

In addition to the quality of the system components and the construction of the system, the sizing of the solar generator and the storage battery plays an important role in the operating reliability of a photovoltaic power supply. The dimensions of the solar generator and the storage battery determine what proportion of the consumer's energy demand can be met by the photovoltaic ally generated electricity.

Power transferring and conditioning parts make what is called balance of system. It combines energy storing batteries, control unit charge controller, inverter from direct to alternating quantity, receptacles, and outlets, electric cabling, protection fuses, and grounding rod and disconnect switches. Luminaries, wiring, conduit, metal structure for mounting the modules also are part of the system.

Importance of this power conditioning parts can be seen considering the rapid change in solar power that have impact on utility within durations sub divided to hourly values and so reserve requirement, regulation requirement for the net load variability and operation of other generator as back up accordingly.

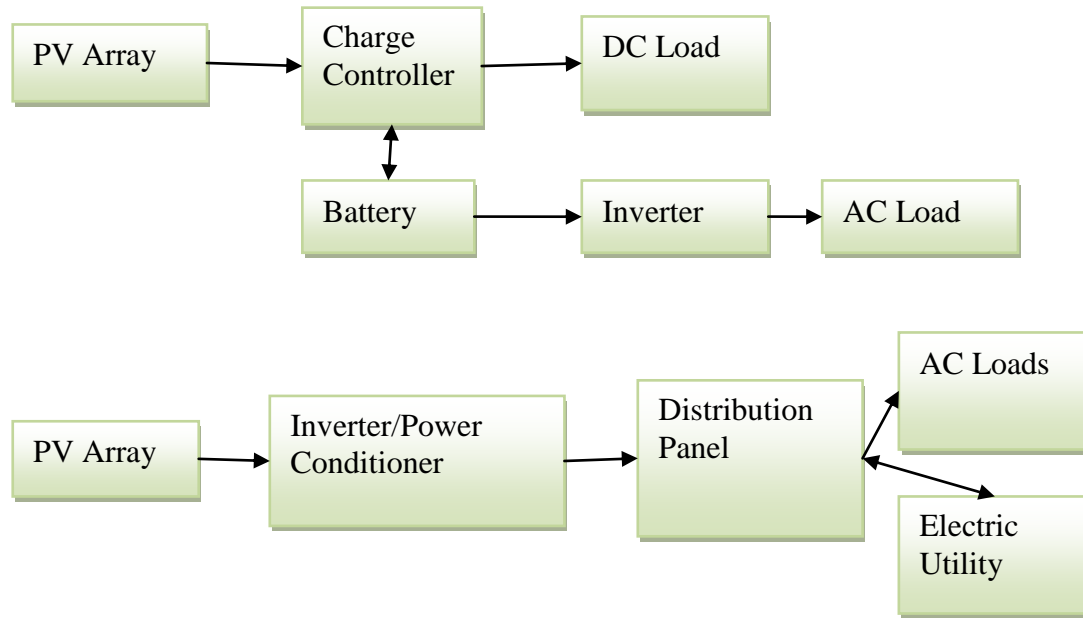


Fig 2.9: Diagram of System Configuration; Left part in Stand-Alone PV System and Grid Connected to the Right [23].

Another main performance set for result is efficiency. Energy efficiency is by itself a role in that even environmental friendly renewable energy projects shall have their own provision of efficiency by saving, by conservation and by output. Produced energy conversion efficiency, efficient in using physical space can be mentioned.

A study paper on assessing geographic and technical potential of solar energy study paper also confirms that efficiency of PV modules reduce in practice compared to STC, due increase in temperature, dust and humidity, and decreasing SR. Therefore evaluating technical potential for PV generation is by taking into account for performance ratio of PV system which equal difference between nominal efficiency and efficiency achievable in practice.

Appropriate material cost for the desired application needs identification from types of product modules. Silicon has characteristics of being transparent at wavelength longer than 1.1 micro where 23 percent of sunlight passes right through with no effect which is theoretical efficiency for silicon solar cell. Selection of photovoltaic generator comparison by application, availability and cost shall be made. Single crystalline type of solar modules is good for commercial application. Accordingly, qualitative subjective comparison and objective quantitative comparison can be made from crystalline to non-crystal types (multi crystal, poly crystal and ribbon silicon [8]).

Silicon crystalline is applicable and found for commercial application, from single crystalline to non-crystalline, amorphous silicon. It has forms of multi, polycrystalline and ribbon silicon. PV cell module comparison can be made on efficiency, weight, resistance to damage from cosmic radiation, weather condition, external physical effects, by top surface feature (absorption, reflection, transmission, texturing).

The actual output of a PV module or system in the field is a function of orientation, total irradiance, spectral irradiance, wind speed, air temperature, soiling, and various system-related losses.

Economic Potential: The success of PV system will be measured by availability of the power source to the load during its expected life time [23].

Earlier definition to economic is set us careful management of available resources, offering good value for money and a financial saving. In this concept availability of power during system life time and the expected life time itself are two indicators as said for the success of a PV system. A decision to utilize PV system calls for address of issue of weather the system is good choice for customer, investor or institutions.

Electricity supply from PV encompasses competition of financial, reliability, environmental performance consideration from other sources of energy and these are defined by which energy supply technology best meets well defined economic criteria's.

An economic assessment compares cost and benefits of a system. Decision making on holding RE investment from point of estimating initial cost and operational or lifecycle cost is done by Life Cycle Cost analysis or by determining energy pay back time [8].

The life cycle cost of a PV system; as the term life cycle purely dictates from birth onto death more subjectively start of assembly to end of giving service and dismantling. These includes the sum of all the present worth (PW's) of the costs of the PV modules, storage batteries, battery charger, and inverter, the cost of the installation, and the maintenance, operation cost to so called salvage value.

Life Cycle energy analysis accordingly on the conference paper in title *cost and energy analysis of PV battery grid back up System for a residential load*; define it as the ratio of output energy to indirect energy input. Indirect energy inputs are energy expenses from raw material to transportation and implementation so direct is the direct natural energy input. By this concept a ratio of lifecycle energy which is greater than zero is expected for viability [24].

Like wise, a pay back period depiction on cash flow diagram where first investment cost for material is considered at current time as negative and replacement costs in future operation period as negative also wherever they appear and the advantage in terms of saved bill for the customized demand assumed from each end year up to life time end as positive gains. Future costs and gains are evaluated for possible zero coming of these positive and negative cost amounts so determine the point in time of the year in counted generally from one to the pay back year.

Thus in the study of RTPVEPM; evaluating or accessing potential is made by classifying to Geographical, Physical, Technical and Economic Potentials.

CHAPTER - THREE

3. METHODOLOGY

In this chapter sequential procedures used as a methodology will be seen. It outlines in sequence of potential finding procedure from geographic up to economic steps or workflow that are involved in the analysis. Procedure for data analysis and result getting methods or formulations starting from description of research location and going through potential identification methodologies are made. It also shows general simulation running method of PVSyst modeling software application.

3.1 Location of the Study Area

Roof top application is compulsory in that it directly involves in the energy usage demand of the building and it reduces the carbon foot print of the building. It increases the property value of the building and may also be have an attractive view. On roof application widens the opportunity for protection and security to the panel though not the easiness for installation, maintenance accessibility.

Among roof tops solar panel application on urban areas revalorization to reduce the environmental impact system waste and to improve replacement economy for the solar industry would be an advantage [12].

In this context, condominium housing location selected, first as generic case study, second because it is trend of living and is major future plan of the city.

Hence, Jemo located at Nefas-Silk Lafto sub city south west periphery of Addis Ababa is a permanent residential space. Its population is thriving and growing thanks to being residential, commercial place and near to outskirts of the city and also has continuing contact to center of city.

The socio economic characteristics of the Addis Ababa expressed in per capita income is \$1600, and it's economy dominated by the service sector, population is on average 5165 per square killo meter and growth rate is 2.1 % [1].

The Jemo condominium complex consists of over 10,000 apartments and is home to some 50,000 people, the beneficiaries are low and middle-income people of the city. The Jemo condominium site faces some challenges in accessing adequate and reliable water supply [25].

For this, a first step conducted was to characterize the selected location from social, environment and economic perspectives. On the one hand, data related to potential of renewable energy was analyzed. In connection, economic and social aspect which are closely linked to energy consumption, together with population density and growth were considered.

Jemo among Furi, Wechecha, Yerer and Entoto mountain plateaus contain the urban land mass of Addis Ababa. Thus until recently that is before three and four decades; Jemo surrounding was used for industrial or commercial purposes. However, the urbanization process of condominium housing construction made the residents who moved to Jemo from slum areas in the city center to faced challenges such as lack of income, social isolation, and poor transportation. The urbanization process also increased the demand for water, electricity, and waste management in Jemo, which could have negative effects on the natural resources and ecosystems [25].

Launched by the year 2010 in two phases for each five year by duration; the growth and transformation plan in its concept as a leading proposal not only for urban areas but for rural areas as well envisioned a middle income economy by 2025 with a per capita income of at least \$1,045. One of its targets was to develop 15 hectares of urban land for housing and business purposes for operators who were organized in micro and small enterprises. Even if on actual realizable plan the so called GTP is outdated, the Climate Resilient Green Economy (CRGE) initiative was another strategy that Ethiopia launched

in 2011 to support and complement the GTP. It had four pillars or goals: expanding electric generation from renewable energy sources; reducing emissions from deforestation and forest degradation; improving crop and livestock production systems; and coping with climate change impacts.

In the energy sector, one of the initiatives is to increase the share of renewable energy sources such as hydro, wind, geothermal, and solar. In the transport sector, one of the initiatives is to shift from road to rail transport and to improve fuel efficiency and vehicle standards [26].

3.2 Data Accusations

Data required to map potential energy so the self-sufficiency in the location include, range of climatic indicator demographic data, topographical features. Including day lighting, renewable energy systems and climate data availability, best practice guidelines, observational data, past and future data, spatial data set to describe location or shape of roof with coordinate and area. Attribute data of energy conversion system components. Secondary sources of data, pertinent documents, load demand time series data.

3.2.1 Geographic Potential

Describe study area (Region of Interest):

- Find regional or local description:
- Measure the location on the surface of Earth (or locate the position) as coordinates by Latitude and Longitude degrees, using global or regional map or online tools (Google Maps).
- Find Data Information: That are instrumental for the required result, intended search on recent sources from research outputs and from government or institution report outputs or their websites.

Data Collection:

- The geographic and climatic based data's required are mainly: annual, monthly, daily and hourly incident solar radiation especially to location of interest. These also include climate data of each month of the year with mean monthly sunshine hours, approximate length of day of each season of the year and altitude, sun path and shade length associated with each hour of the day, daily maximum- minimum temperature ranges, general seasonal variation for the region of interest.
- Selected outputs from these searches are to be compared with best practices and by theoretical and simulation analysis wherever appropriate and possible for physical, technical and economic criteria's fit.

3.2.2 Physical Data Analysis

Google Earth™ imagery good resolution picture. Accordingly, manual selecting using Google Earth Imagery, from whole Jemo 1,2 and 3 communal buildings, sampling and extrapolation to entire houses of selected region ; Count the number of building blocks of subject area and identify rooftop direction orientation.

- Specific prediction on the map using tools: Using its distance and area measurement tools sample area sizes are measured in m².

- Find good Orientation (guide lines) Rule of Thumb

For “PV module orientations (Roof orientation for flat PV module) with east to west, and tilt angles from horizontal to vertical”

- Theoretical design for case; “maximize the energy captured during the period of least radiation, rather than throughout the year”.

>> Receivers positioned perpendicular to the winter sunlight, which is a tilt angle (β) approximates latitude degree ($\varphi + 10^\circ$). Orientations between east and southeast, and

between southwest and west, are fairly reasonable with system angles between 10° and 30° from horizontal.”

>> In terms of solar panel orientation (azimuth), studies conclusion that south facing orientation as by far the most optimal position to will be used.

- Identify shade appearance on selected part of roof area and determine shade characteristics (length, duration appearance).
- Optimal tilt angle roof top & (panel angle per year to account for changes in the sun’s position)
- Optimum tilt angle overall for urban area should be at a slightly flatter angle to accommodate for surrounding obstacles such as buildings.
- Determine Correction factor for roof area for possible spaces to be left.

3.2.3 Technical Potential

- Predicting the generator energy delivery that is the technical potential;
 - Energy generating body that is the solar panel size and system balance components type, operating characteristics and efficiency are data information to be collected as a whole.

First, climatic data solar radiation and temperature data are identified. Second size of available area assessed. Physically: available area, uncertain area, optimal area of roof surfaces. Third, electric consumption on daily basis of a building, a case of customized electric consumption and a research demand quantified. And technically: building load consumption, predetermined demand, energy usage trend, electric energy consumption per capita, all demand, portable demand, seasonal demand, demand required to cover extra fossil fuel demand, demand per person or family for customized and or research demand setting.

The standard of living of any given country can be directly related to per capita energy consumption, which is measure of per capita income. Roof top per capita decreases with

increasing population density, (the per capita electric consumption per annum in the country is 100 kWhr [5].

To compare the trend of electric consumption on daily basis of a building with the average annual per capita consumption of electricity in Ethiopia, daily electric consumption of the building in kWhr for each day of the year an average value can be taken. This data can be obtained from the electricity meter or bill of the building and average annual per capita consumption of electricity in Ethiopia in kWhr is 69.20 kWhr in 2014, 79 (kWhr) per year in 2019. This is significantly lower than the global average of 3,041 kWhr per year. Though the values for the subsequent years can be found from growth rate based on historical data an average amount can be taken also [27].

Not only trend of electric consumption shall be investigated but also other socio economic demands. Thus apart from transform data to average annual per capita consumption, per capital electric consumption in kWhr and its percentage which is from hydroelectric source, total average domestic water requirement per person of Addis Ababa target average per capital water on consumption is 110 liter or cubic meter per day. For average five house family it is 550 cubic or liter per day. And AAWSA average daily per capita water demand for wash room is 18 % of 701 liter or meter cubic per day [28].

3.2.4 Environmental Assessments.

For assessment on GHG emission generated in life cycle of implantation the PV solar system as assessment is by following; UNFCCC methodology, frame work target set such as CGRE 2011 which is ratified to achieve sustainable development by keeping green house gas emission constant. Other is taking and consideration of Addis Ababa concept for cleaner, environmental capital city and generally considering the general attitude for use of solar panel technology [29].

Moreover, a comparative analysis with current centralized electric mix that nourishes the building under assessment was provided. In the context of function that provide a certain amount of electric energy for the self sufficiency and economic scenarios. An initial reference unit to which environment values were referred to research demand of electricity produced and available for consumption.

Thereafter, the selected reference for the current and projected scenarios were homogenized to kWhr/m², in which unit area correspond to the total built area, functional unit is found in meter square area of roof top. Variation in GHG emission between electricity produced by PV system and the conventional grid system was seen. System boundary for back up electric system unavailability index of the grid central power and the cost of unavailable service and also affects from fissile fuel input and service output assessed.

3.2.5. Economic Analysis

First determine Demand Potential:

- Calculate the monthly energy demand in kilowatt-hours (kWhr).
- Convert this demand into monetary terms (USD) based on the local electricity rate.

Second estimate System Capital Cost:

- Identify the total capital cost of the photovoltaic (PV) system, including installation, equipment, and any additional components (e.g., storage systems).
- Average cost of solar panel = {Cost of solar panel per watt peak * Watt age peak of solar panel* # of module }
- Cost of storage system = {System voltage of selected battery * it's rated amper hour; compared with research demand of needed storage size}.

Third calculate Monthly Savings:

- Estimate the monthly savings by comparing the cost of electricity generated by the PV system to the cost of purchasing the same amount of electricity from the grid; and by Characterize economic potential;

-No of people in house hold and in a block.

- List research demands and economic cost of giving service

- Item in a refrigerator cost and the conventional electric power unavailability index.

- Cost of service per item. = Item cost * Conventional Electric Power Unavailability index

- Cost of sanitary service.

Estimated cost of quality service involving toilet at a meal house.

Cost of sanitary service = {Estimated cost * # of people in a house hold * # house hold per block. * local sanitary service water unavailability index}.

- Cost of lighting as back up = {Selling Price of electricity of conventional electric source* wattage* # of working hours per day * conventional electric power unavailability index}

Fourth; Find Payback Period:

{Payback Period} = {System Capital Cost (USD) / {Monthly Savings (USD)}

This will give the number of months required to recover the initial investment.

- Initial Capital Outlay Cost equates System Cost

- Estimate Additional costs (Maintenances, Guarding, Cleaning...)

- Calculate Replacement Cost (battery replacement on number of operational year cycles)

- Service Gains equates to Saved Cost from bill of conventional electric power source.

- Payback year equals change from negation to positive in (sum of Negative Additional Costs, Replacement Costs, negative Initial Cost, and positive Service Gains) annually.

- Compare Initial Capital Outlay Cost, Profit gained from saved Capital Cost with roof top solar panel investment profit, at Payback year.

- Re check initial Capital Outlay Cost profit gained from Saved Capital Cost with roof top solar panel investment profit, at the number of estimated life cycle years of the plant.
- At end of life cycle year, solar PV Capital Investment Profit minus Profit from interest for saved Investment Cost equates Economic Cost of system at the lifecycle year.
- Take Present Value of the Economic Cost of the system.

3.3 Sensitivity Analysis.

Certain variable that were assumed in the study are highly variable with subsequent influence on final result. It is noted that residential density or demand, efficiency of module or per capital consumption required increment may have impact on result. Thus, it was necessary to analyze how the variation of these values determines the self-sufficiency of the building by proposing alternative scenario in sensitivity analysis.

3.3.1 Estimation of maximum value of residential population density allowed in order maintaining a monthly energy self-sufficient factor not less than one.

3.3.2 Based on technology advancement there will be module with increased efficiency. Thus assumed 25 percent efficiency value of solar module.

3.3.3 One and two step in addition monitor maximum value of one, in order to maintain a monthly energy self-sufficient factor not less than one, if the efficiency of solar module equals 25%.

3.3.4 Predict self-sufficiency ratio that will be attained on year 2035 for this increased in electric demand per capital and population density were observed on annual basis.

3.3.5. Demo project from PVSyst shall be tested with RTPVEPM approach for validity check. Approach Methodology as to Simulating Software

Noted steps are to be followed from the simulating software features: the demonstration for a standalone system starts by setting of the project then variant consideration of orientation using plane tilt and azimuth optimization for predicting respective global radiation values on the collector plane and also associated losses with respect to what is called optimum. This global radiation value comparison will be done for seasons of the year; winter, summer and annually. Horizon views, entry of user needs, analysis on near shading and system type identification the predicting the losses associated are also procedures. As a result energy balance and all losses along system will be predicted on arrow loss diagram similar to Sankey diagram from Global Incident to each stage of losses with different magnitude to energy delivered at end. Running simulation for graphical and numerical report shows the result. And finally a result of produced energy in mega watt hour specific production or potential of system which is power out put per power nominal of array in killo watt hour per killo watt peak per year, Percentage performance ratio as a quantifier for quality of system will be presented.

CHAPTER FOUR

4. RESULT AND DISCUSSION

The quest of finding result, quantifying a hypothesis and interpreting the result by discussion to the subject topic objective or verifying it will be seen in this finalizing part of the thesis.

4.1 Results

4.1.1 Geographic Potential

Describe study area (Region of Interest):

- The study area is located in East Africa, specifically in Addis Ababa, Ethiopia, east of the prime meridian and north of the equator. The precise coordinates, determined using Google Earth Maps, are $8^{\circ}57'19''$ N and $38^{\circ}41'49''$ E, accurate to within hundreds of meters.



Fig 4.1: Regional Global Map Description of Study Area [30].

- Jemo Condominium Housing is situated in Nefas Silk Sub City of Addis Ababa: Near “Jemo Yasin” roundabout and “Lebawi Academy” (Jemo 2), Near “Prime Bridge Academy” (Jemo 1), Around “Mark International Academy” and above “Lebu-Medhanealem Church” (Jemo 3).



Fig 4.2: A Figure Pointing the Sub-City Inside Addis Ababa where the Subject Area of Interest Communal Houses Found [31].

The coordinates (8°57'19" N; 38°41'49" E) represent degrees, minutes, and seconds. The latitude is in the north, and the longitude is in the east. Therefore, 8 degrees is the desired result for latitude.



Fig 4.3: Google Earth Screen Photo of Jemo1,2 and 3 Condominiums Sites of Nifas-Silk Sub-City [30].

Meteorological Data Collection:

To gain a general perspective on geographic and climatic data:

- Solar Radiation Data: Global horizontal solar radiation potential is measured in kWhr/m² (kilowatt-hour per square meter). For example, North Africa and parts of Southern Africa, known for their desert conditions, have long-term average annual solar radiation ranging from 2100 to 2500 kWhr/m². Other parts of Africa range from 1800 to 2000 kWhr/m². This general global annual prediction does not show resolution to national regional variations but motivates the exploration of solar radiation potential availability [32].
- Global Horizontal Irradiation: At the country level, yearly and daily totals show that parts of Northern and Eastern Ethiopia, including the Rift Valley, receive around 2337 kWhr/m² of horizontal irradiation. Other areas, including Addis Ababa, receive around 2000 kWhr/m². Daily totals in these zones are approximately 6.4 and 5.8 kWhr/m², respectively [32].

- Monthly and Daily Solar Radiation: Expressed in kWhr/m²/day, the data shows a yearly range with a maximum of 6.38 kWhr/m² in February and a minimum of 4.75 kWhr/m² in July, averaging 5.81 kWhr/m², aligning with global predictions [Annex 1.0].
- Temperature Trends: Monthly maximum and minimum temperatures show an increase to 21°C in April and a decrease to 16°C in August. Seasonal variations in Ethiopia are described as “Belg” (spring, February to May), “Kiremt” (winter, June to September), and “Bega” (summer, October to February) [Annex 1.0].
- Climate Classification: Addis Ababa, Ethiopia, falls under the dry winter, rainy summer subtropical highland climate [33].

4.1.2 Physical Potential of the Region.

To determine the physical potential of rooftop areas:

- Orientation: Locate orientations between east and southeast, and between southwest and west (azimuth, south-facing orientation).
- Selection: Using Google Earth Imagery, manually select regions from Jemo 1, 2, and 3 communal buildings. Classify these as J₁, J₂, and J₃ (right and left) for meaningful visual representation. J₁ is selected for analysis.
- Rooftop Area: The initial rooftop area computed using Google Earth Imagery for Jemo condominium housing is an average of 286 m² for residential and 216 m² for communal buildings [34].
- Rooftop Topologies: In Jemo-1, rooftop topologies include A2 type 4, type 9 B, type 10 C, type 11 D, and E. These topologies face four directions, including northeast, northwest, southeast, and southwest. A similar but higher-story school building is equivalent to the residential building with 286 m² (BU₁). Additionally, a garment warehouse of 500m² (BU₂) is included.

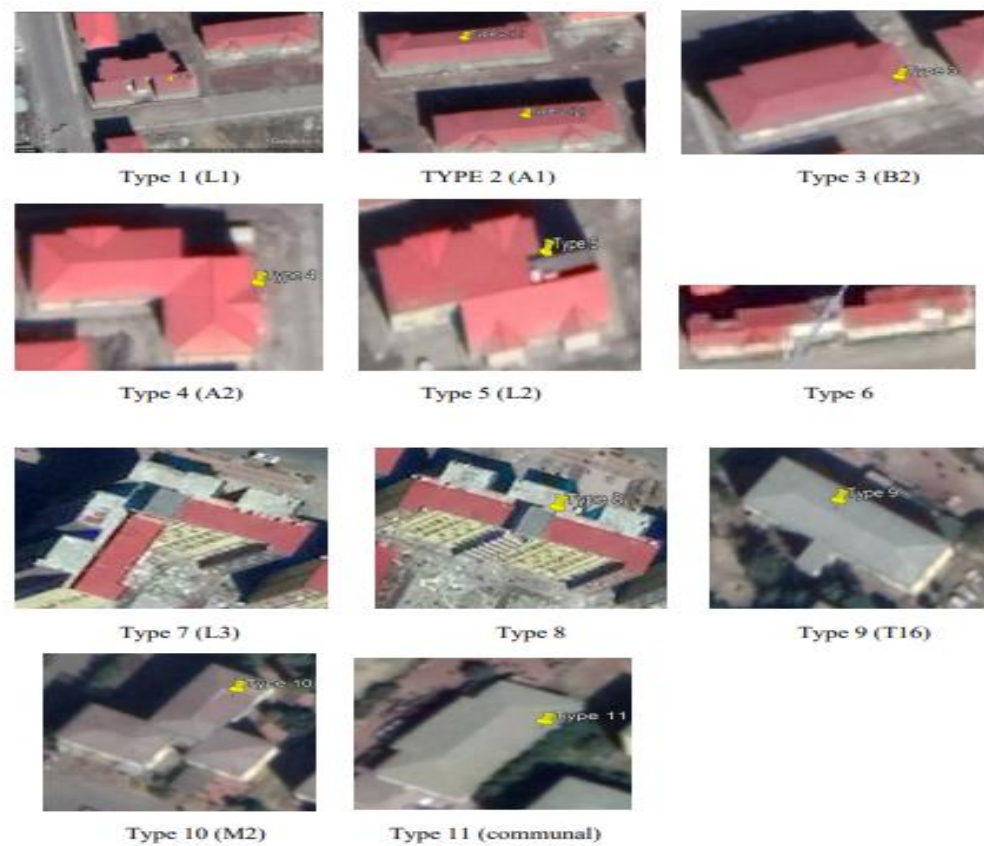


Fig 4.4: Roof Top Typology Types Schematics Adopted for Area Sizing [35]

- After applying the first correction factor to exclude areas with objects like ventilation engines, ducts, and satellite dish receivers, the available rooftop area remained the original size for CR and CC but was reduced to 257 m² for BU₁ and 400 m² for BU₂.
- The second correction factor excluded rooftop areas from east to west in an anti-clockwise direction. Using Google Earth imagery, blocks were manually selected, and roofs were classified by orientation and azimuth. Only rooftops oriented south and east-west were considered, resulting in 143 m² for CR, 108 m² for CC, 129 m² for BU₁, and 200 m² for BU₂.

- A final correction accounted for interference and uneven distribution height in the city skyline, which causes permanent shading. This adjustment resulted in final available rooftop areas of 143 m² for CR, 97.2 m² for CC, 129 m² for BU₁, and 180 m² for BU₂.

Table 4.1 Potential Physical Surface Area Sizing after Efficiency Correction Factors

| Description | Building and Physical Surface Efficiency Correction factors | | | | Building | | | |
|--------------------------------------|---|------|-----------------|-----------------|----------|-----|-----------------|-----------------|
| | CR | CC | BU ₁ | BU ₂ | CR | CC | BU ₁ | BU ₂ |
| Roof top area | | | | | 286 | 216 | 286 | 500 |
| Population density | | | | | 120 | 720 | 2500 | 50 |
| Interferences | Null | Null | 0.9 | 0.8 | 286 | 216 | 257 | 400 |
| Orientation | 0.5 | 0.5 | 0.5 | 0.5 | 143 | 108 | 129 | 200 |
| Shading | Null | 0.9 | Null | 0.9 | | | | |
| Integrated area correction factor. | 0.5 | 0.45 | 0.45 | 0.36 | | | | |
| Final Potential area, m ² | | | | | 143 | 97 | 129 | 180 |

- The table above shows the factors used to calculate the total effective area for installing PV modules. The aggregate correction factors are 0.5 for CR buildings, 0.6 for CC buildings, 0.6 for BU₁, and 0.8 for BU₂.
- Applying these factors, Jemo 1, with 337 CR buildings, has a total available rooftop area of 48,191 m², equating to 1.2 m² per person for a population of 40,400. The 50 CC buildings at Jemo 1 provide 4,860 m² of available area. BU₁ offers 129 m², and BU₂ offers 180 m².

- For BU₁, with a lower population density of 0.05 m² per person, the total associated use is 2,500 people. BU₂, with the highest population density of 3.6 m² per person, serves 50 people. The communal CC buildings, with a medium aggregate correction factor, provide 0.05 m² per person for the same population of 40,400 at the Jemo 1 site.



Fig 4.5: Selected Suitable Roof-Top Orientation Colored Classified as West, South-West, South, South and East

The color coding is used for identifying and counting roof orientations: red for west, amber for southwest, orange for south, green for southeast, and blue for east.

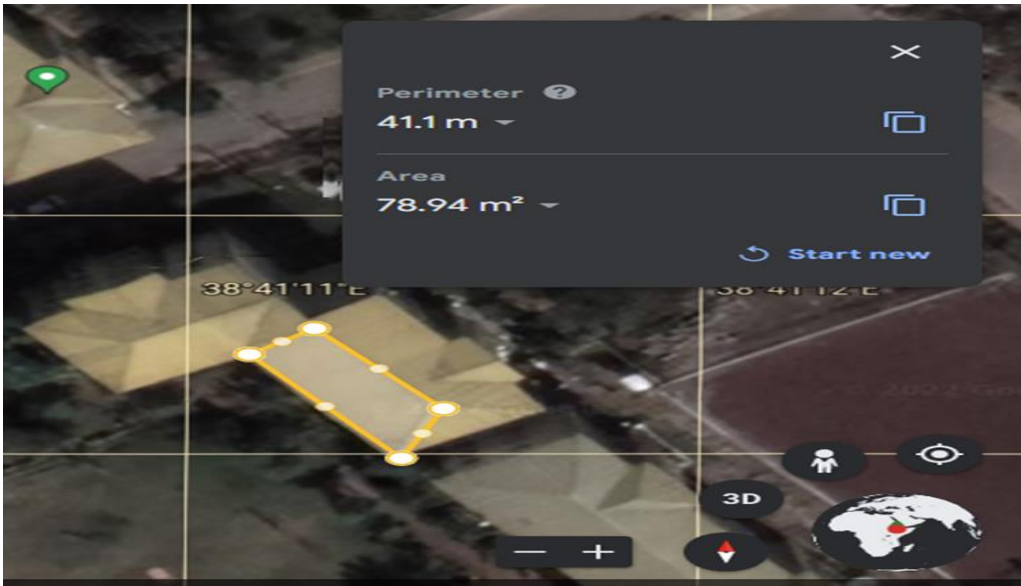


Fig 4.6: Sample Roof Top Typology Type'4' Schematics Adopted for Area Sizing

- For Jemo 1 area with 356 blocks: 59 blocks oriented East-West, 125 blocks oriented South-East, 119 blocks oriented South-West, 53 blocks oriented North-South.

4.1.2.1 Calculation of Efficiency Correction Factor

Efficiency correction factors for tilt and cleaning were considered for the buildings. For CR and CC, the integrated correction factors were 0.95 and 0.97, respectively, given that most rooftops in the city are inclined around 15 degrees. For BU₁, with roofs sloped at 20 degrees, the correction factor was 0.95. Similarly, for flatter warehouse roofs at 10 degrees, the correction factor was 0.98. Thus, solar modules can be installed with optimal tilts based on the geographic latitude.

Table 4.2 Physical Surface Efficiency Correction factors for Integrated Correction on Orientation.

| Description | Building and Physical Surface Efficiency Correction factors | | | |
|--|---|------|-----------------|-----------------|
| | CR | CC | BU ₁ | BU ₂ |
| Slope of roof | 1 | 1 | 1 | 1 |
| Cleaning | 0.95 | 0.97 | 0.95 | 0.98 |
| Tilt | 1 | 1 | 1 | 1 |
| Integrated efficiency correction factor. | 0.95 | 0.97 | 0.95 | 0.98 |

4.1.2.2 Prediction of Usable Slopes and Azimuth for the Roof Top Area as Physical Potential.

Comparison with Theoretical and Graphical Analysis: the angle of incidence throughout the day for each month of the year is analyzed. The theoretical incidence angle for representative days of the 12 months, for a surface at zero azimuth and slope, shows smaller angles as low as 20° near zero hour angle in June and around 65° in December.

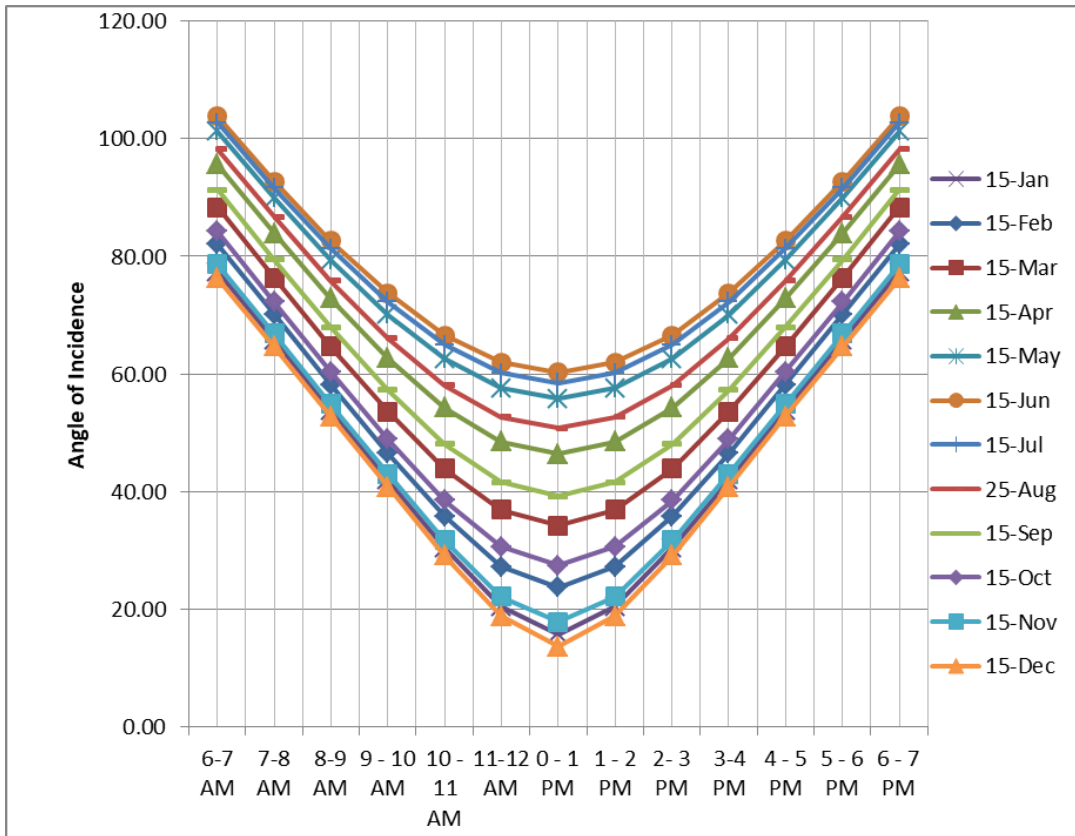


Fig 4.7: Angle of Incidences versus Hours of a Day for an Average Day of Each Month.

- The angle of incidence for the average day of each month is analyzed for azimuth classes ($0 \pm 45^\circ$, $\pm 90^\circ$) and slopes varying from 0° to 95° at various hour angles throughout the day.

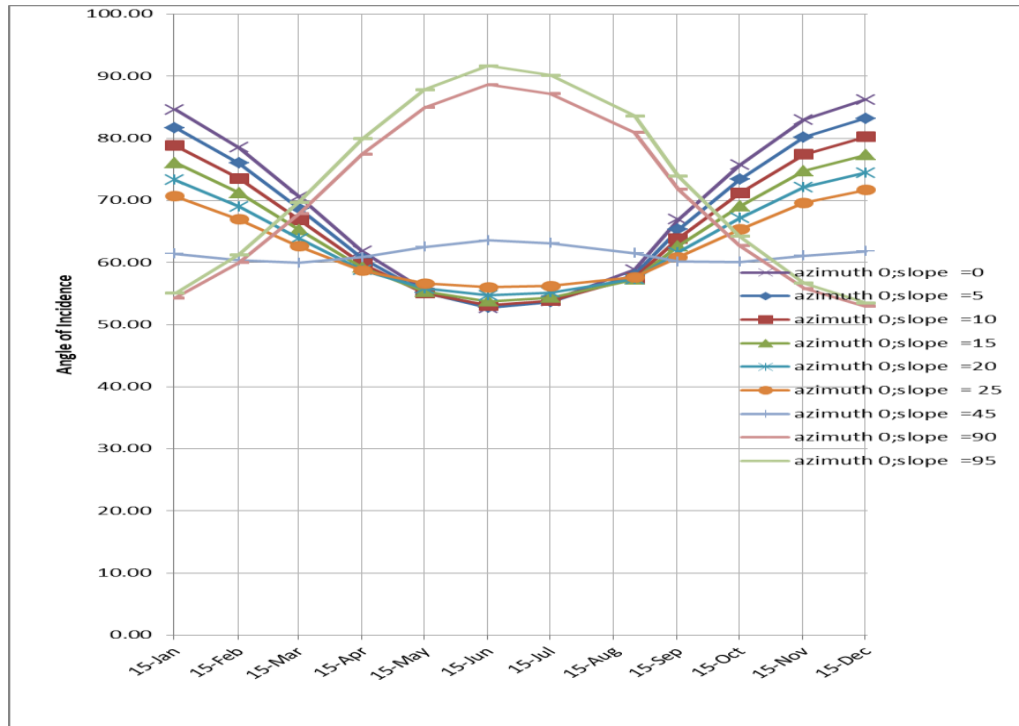


Fig 4.8: Angle of Incidence versus average day of each month of a year for Azimuth 0 degree and Slope varying from 0 to 95 degree @ hour -60 degree

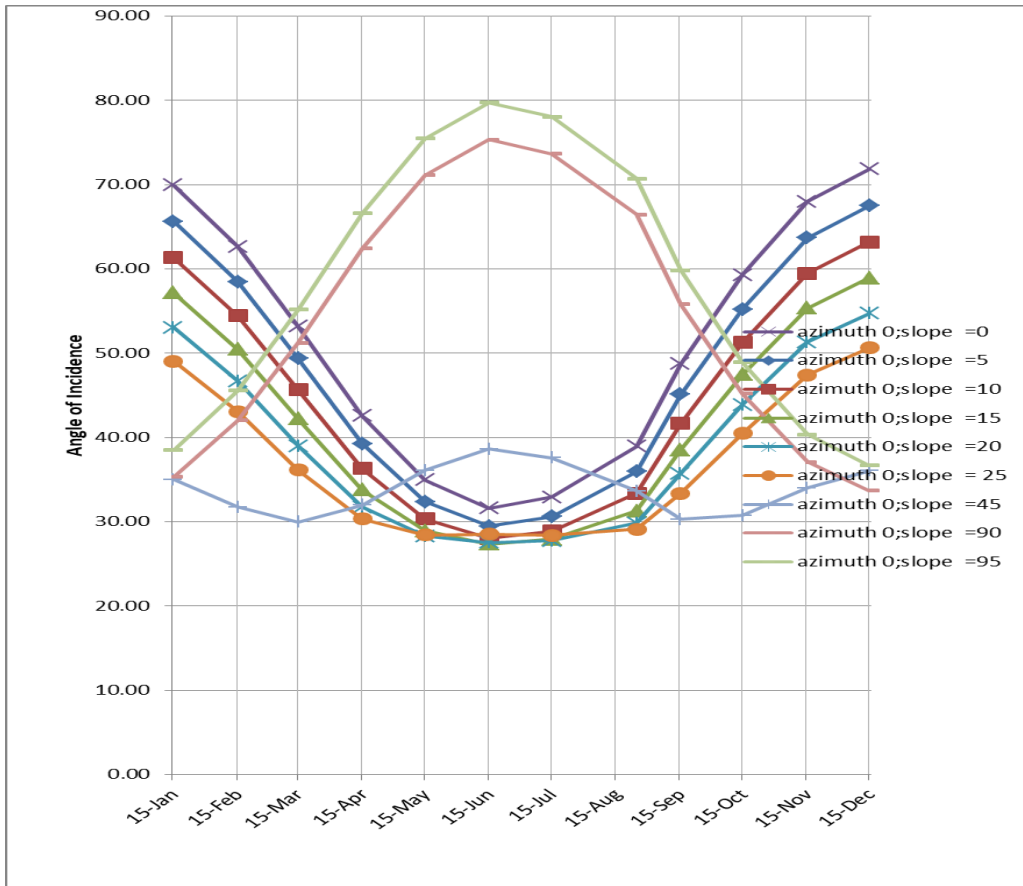


Fig 4.9: Angle of Incidence versus average day of each month of a year for Azimuth 0 degree and Slope varying from 0 to 95 degree @ hour -30 degree.

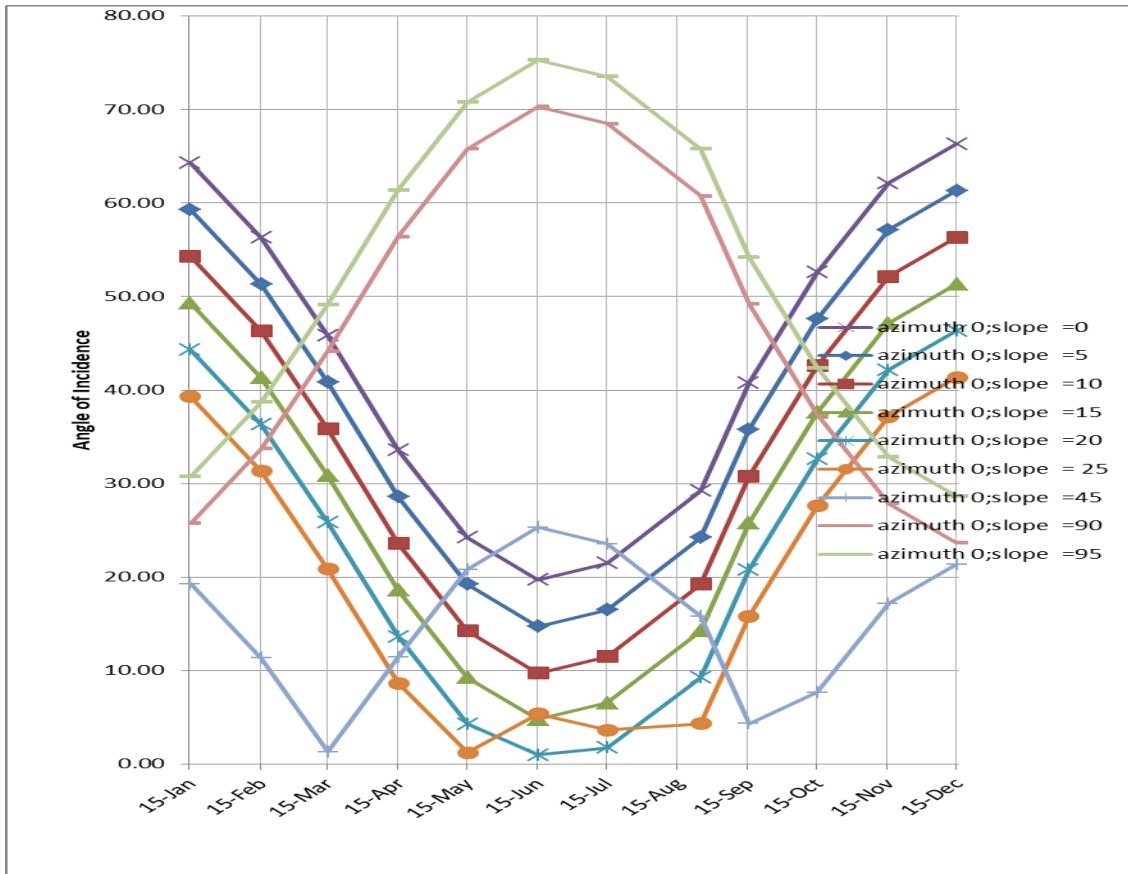


Fig 4.10: Angle of Incidence versus average day of each month of a year for Azimuth 0 degree and Slope varying from 0 to 95 degree @ hour 0 degree.

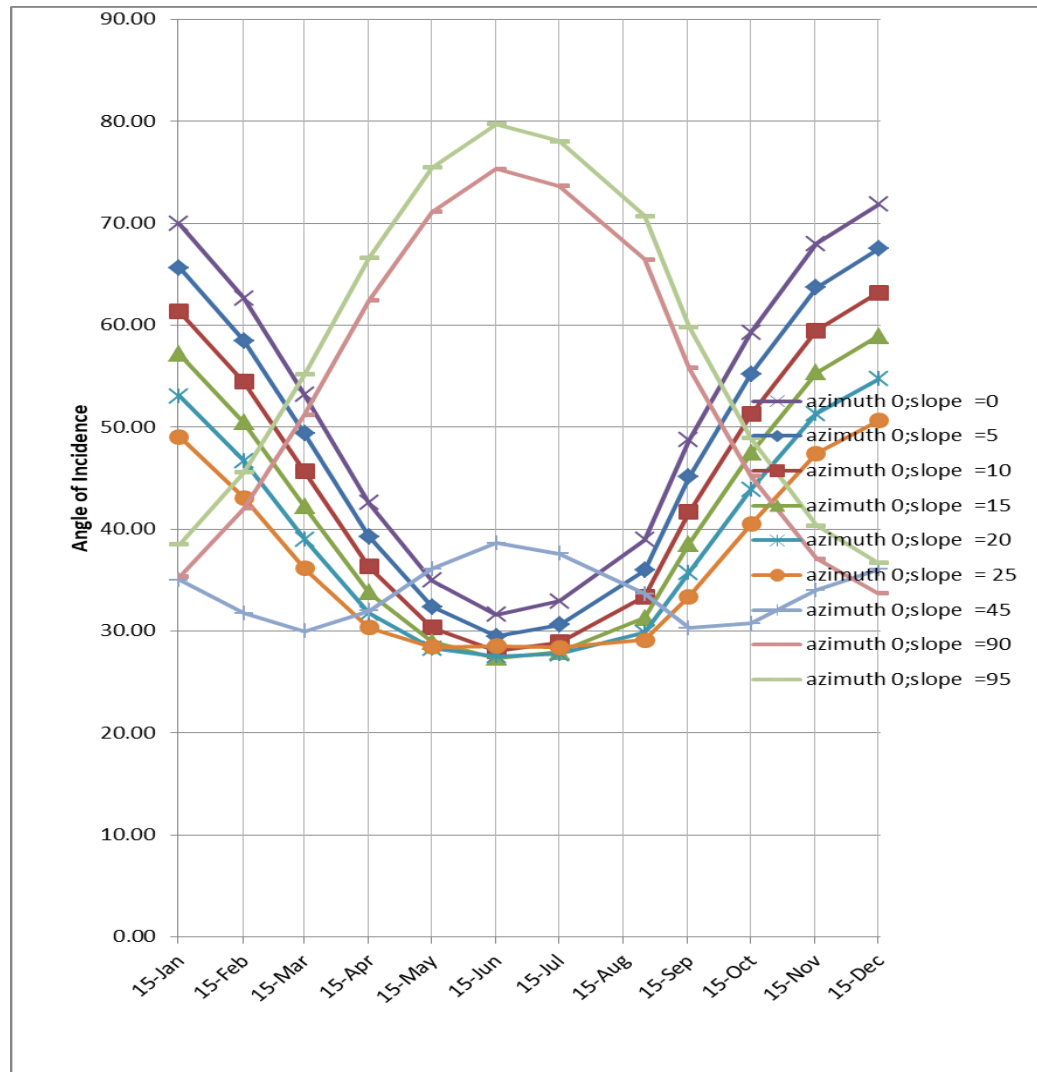


Fig 4.11: Angle of Incidence versus average day of each month of a year for Azimuth 0 degree and Slope varying from 0 to 95 degree @ hour 30 degree.

Taking the 45 degree best slope characteristic with average lower incidence angle, showing azimuth direction with lower incidence is the next step.

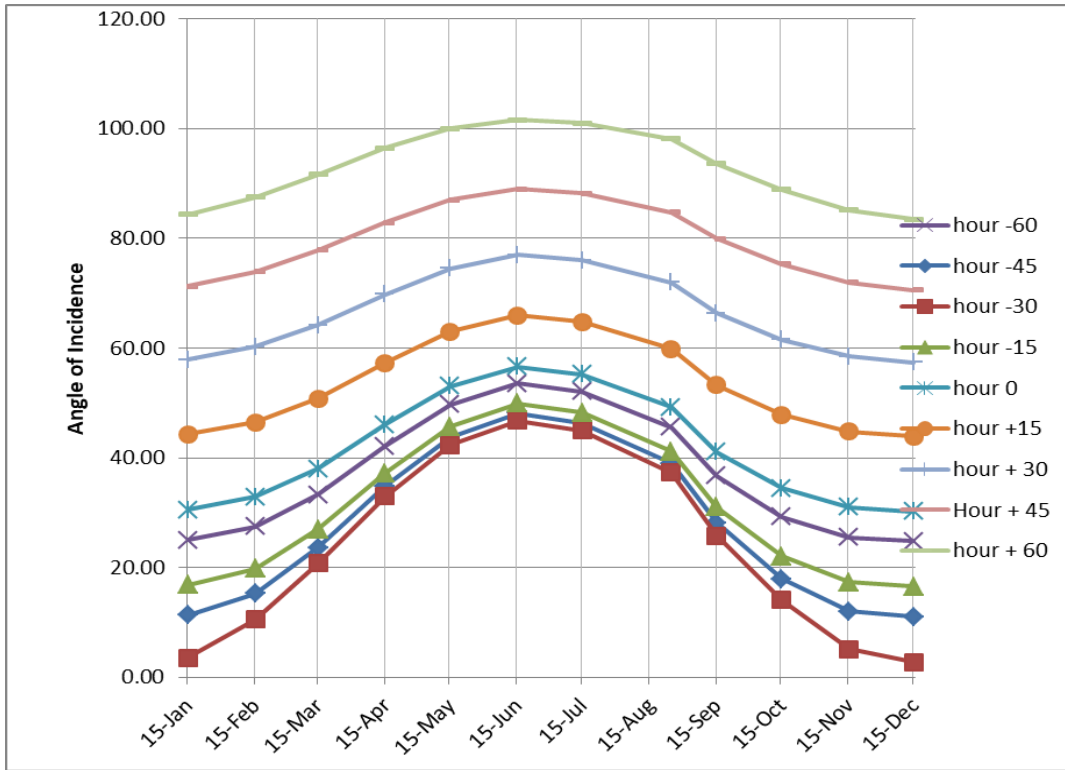


Fig 4.12: Angle of Incidence versus average day of each month of a year for Azimuth -45 degree and Slope 45 degree, hour of the day varying from -60 to +60 degree .

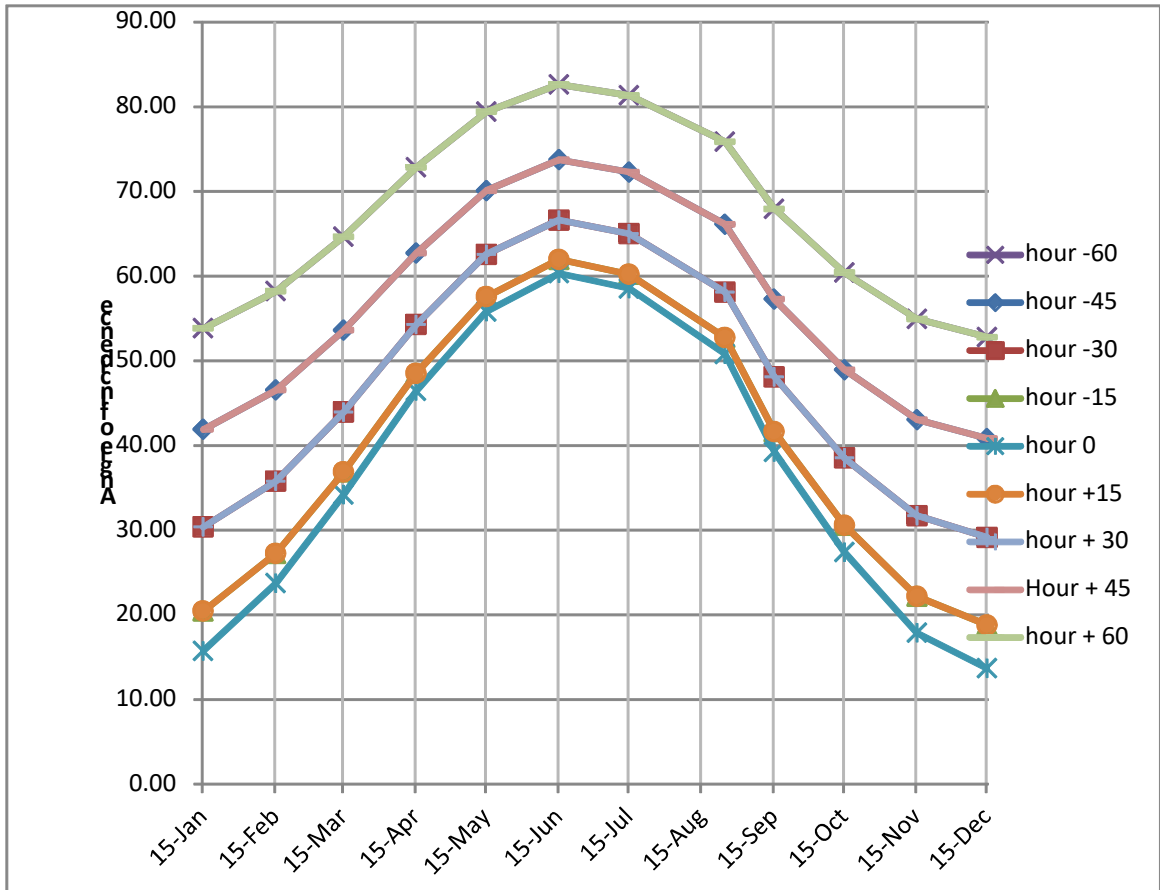


Fig 4.13: Angle of Incidence versus average day of each month of a year for Azimuth 0 degree and Slope 45 degree, hour of the day varying from -60 to +60 degree .

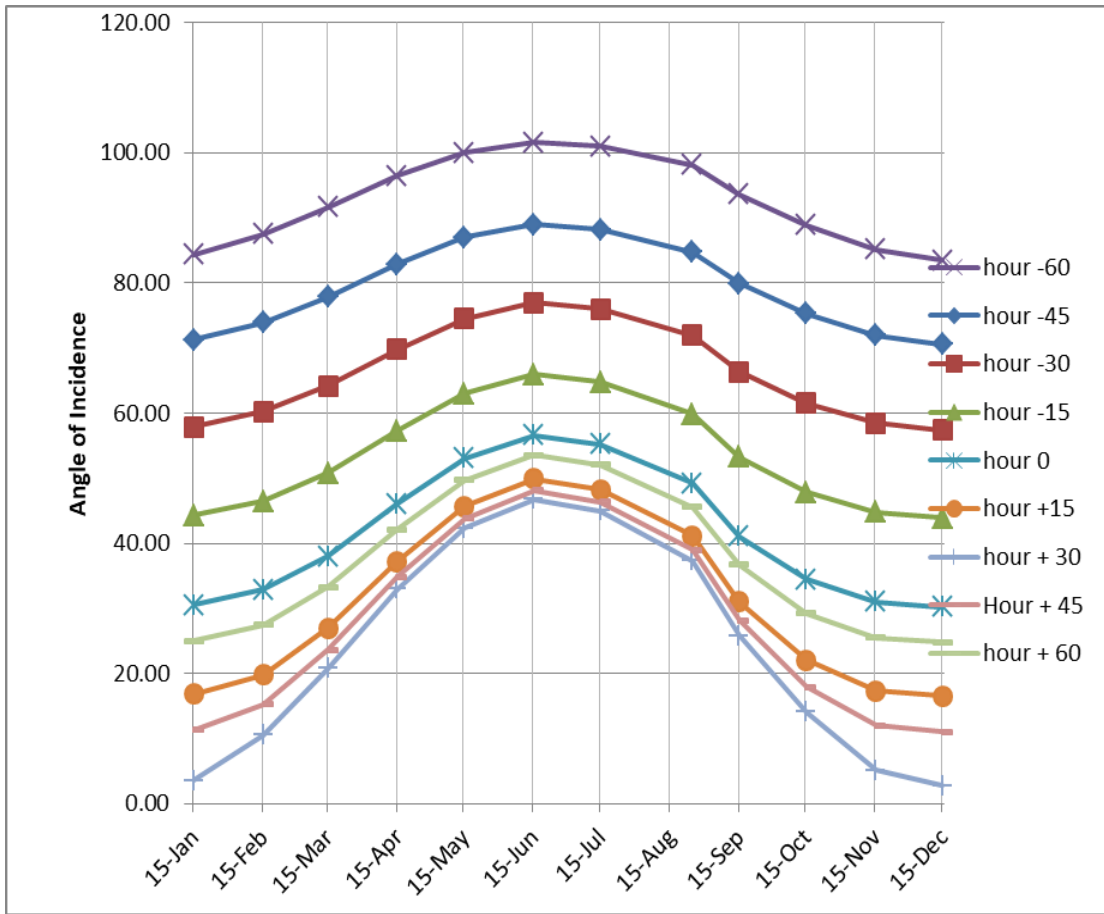


Fig 4.14: Angle of Incidence versus average day of each month of a year for Azimuth 45 degree and Slope 45 degree, hour of the day varying from -60 to +60 degree.

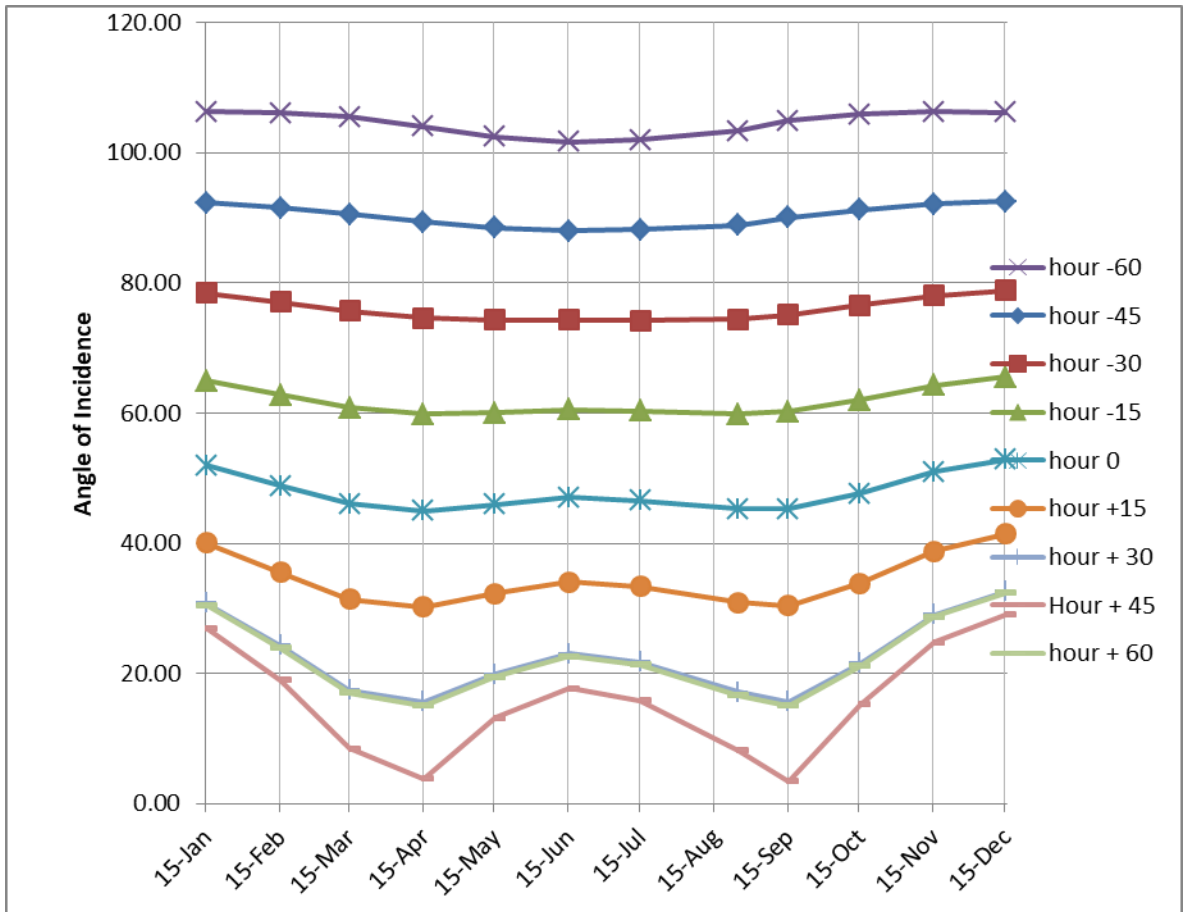


Fig 4.15: Angle of Incidence versus average day of each month of a year for Azimuth 90 degree and Slope 45 degree, hour of the day varying from -60 to +60 degree .

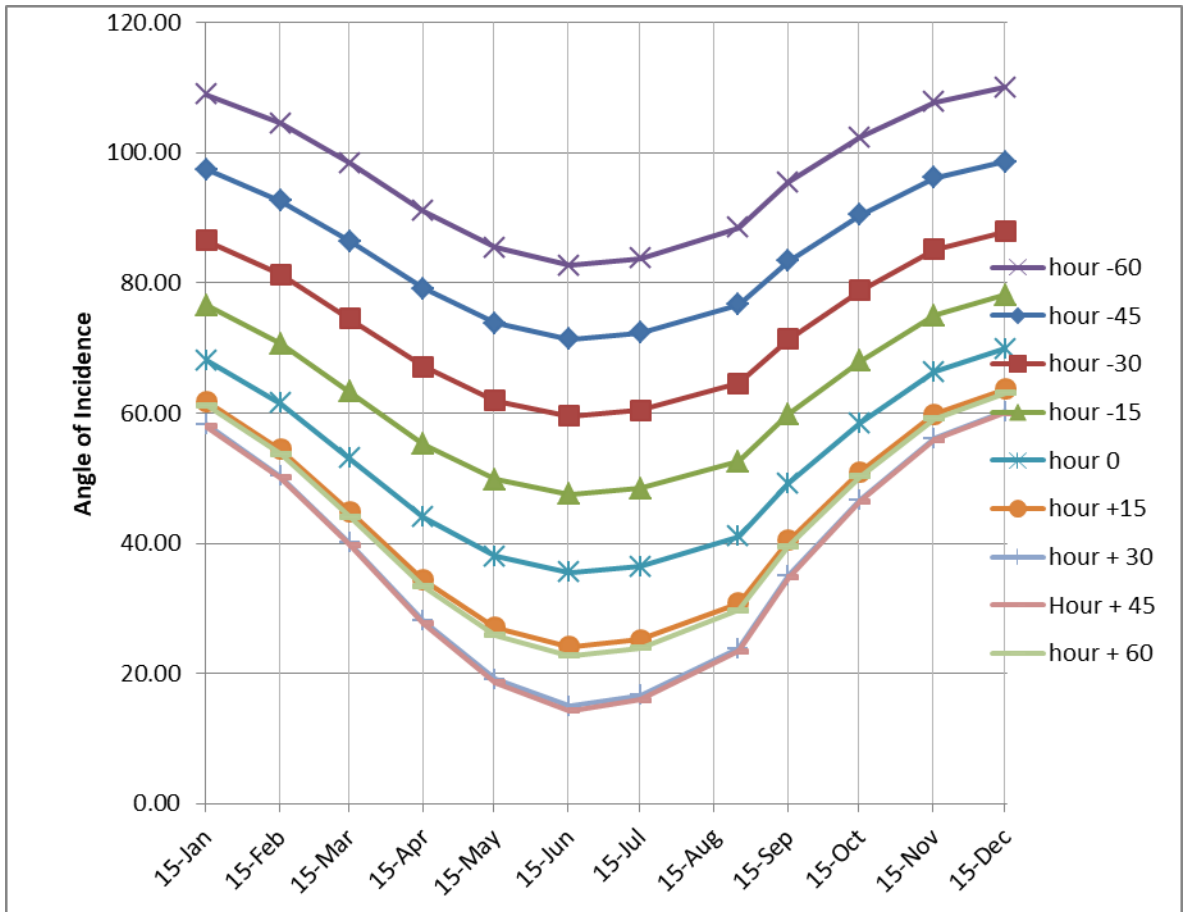


Fig 4.16: Angle of Incidence versus average day of each month of a year for Azimuth 135 degree and Slope 45 degree, hour of the day varying from -60 to + 60 degree.

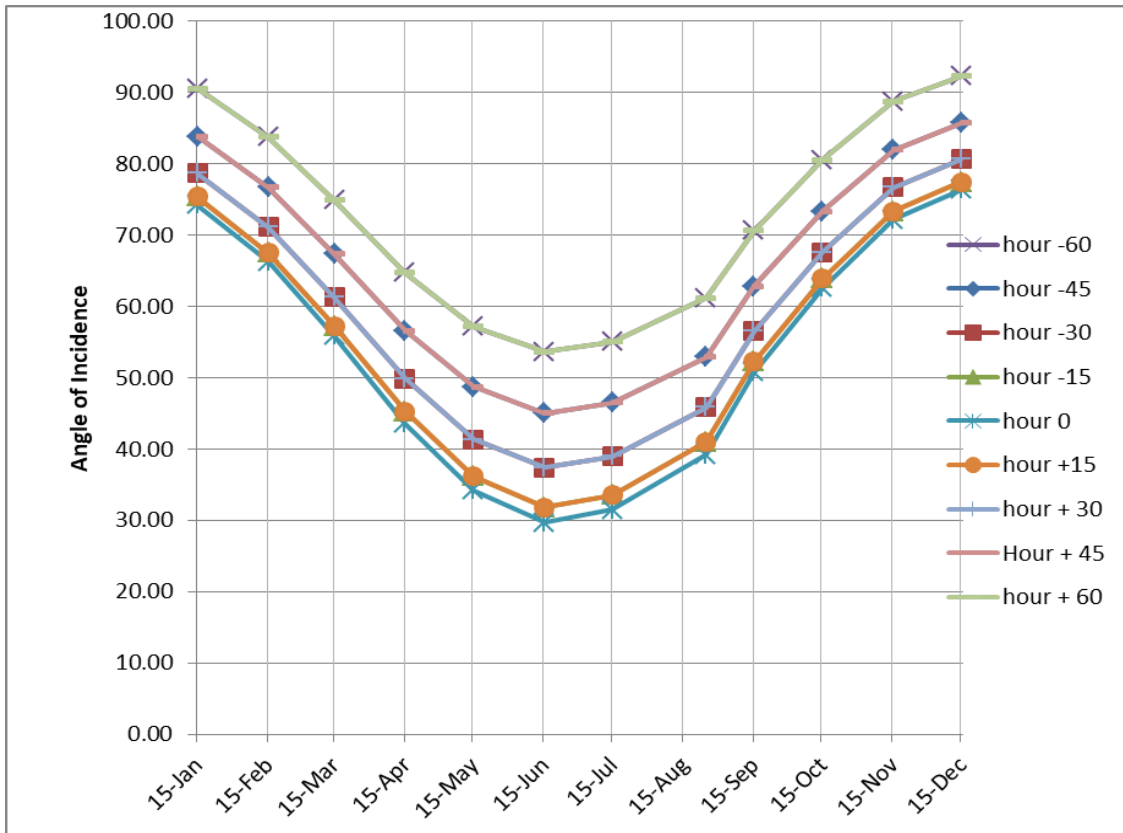


Fig 4.17: Angle of Incidence versus average day of each month of a year for Azimuth 180 degree and Slope 45 degree, hour of the day varying from -60 to +60 degree.

As can be seen all classes of azimuths have more or less similar characteristics with zero azimuth class as better. And months around January and December has lower incidence angle and increases to maximum on June.

For the graphical depiction instance and for further analysis the generated numerical result; when azimuth is at 90 degree, slope at 45 degree and hour angle -60 is shown in the table result. {Latitude in degree set at 8; G_{sc} used 1367, “a” (constant used for H_g) = 0.25; “b” (constant used for H_g) = 0.6; K_T (monthly average clearness index) = 0.4150} [Appendix 1.0].

4.1.3 Technical Potential

A 162 W nominal power (NDQ2E3E/ND162E1) LG Poly crystalline photovoltaic module of 1.31 m² area and with specifications at standard test conditions (i.e., 1000 W/m² and 25°C); Peak Power 162 W_P, Peak-Power Voltage 22.8 V, Peak-Power current 7.11 A, Short-Circuit Current 7.92 A is selected for comparative assessment.

For analysis on technical potential; this common house hold electrical load, common for residential houses are noted. An electrical loading demand assessed for 10 variety houses of the site with an average 17.15 kW per day is set. Scenario1 for this kW is calculated for 30 houses per building with total 321.97 kW/day demand. Two ranges of solar panel efficiencies; 12% and 25 % considered. This daily consumption of 30 households has average value of 40.25 kW per day.

Here under demand of the 30 households in a building from mid night to mid-day; for households of 10 varieties. Where; eight houses are variety of families, one is a studio used for small business as hair salon and the other is a meal house or a restaurant [Appendix 2.0].

Table 4.3 Common House-holds electrical load demand

| No. | Appliances | Total Power (kW) per 10 House hold varieties | Total kWhr/Day per block, 30 houses |
|-----|--|--|-------------------------------------|
| 1 | Lighting (NO. and watts per hour) | 4,419 | 11,213 |
| 2 | Refrigerators (NO. and watts per hour) | 51,576 | 133,080 |
| 3 | Cloth Washing Machine | 4,900 | 15,700 |

| | Appliances | Total Power (KW) | Total KWH/Day |
|---|--|-------------------------|----------------------|
| 4 | Boiler or water heater | 4,050 | 12,150 |
| 5 | Electric Mitad for Enjira backing, (For House No#9 UV sterilizers) | 21,300 | 21,300 |
| 6 | Electric Stove (Cooker and Oven) | 107,750 | 107,750 |
| 7 | Iron for Clothes | 1,800 | 1,800 |
| 8 | Electronic Utilities (LCD Televisions, Mobile Chargers) | 18,980 | 18,980 |
| | TOTAL | 137.23 | 321.97 |

To satisfy the average demand a required solar radiation greater than 2.35 kW/m²/day is required using 12% efficiency level of say the selected module. In a similar trend for efficiency reached 25% to satisfy the average demand a required solar radiation 1.13 kW/m²/day was predicted. Peak power available of the selected panel application at standard solar insolation 1000W/m² and for 143m² area is seen as 17.46 kW/m²/day. Peak power demand per day of the block was 5.51 kWhr at 5.00AM but which falls on not applicable period of the solar radiation.

In consideration of this size comparative Jemo environment accommodations of the communal building, a near by secondary school and a warehouse areas other than the CR was 97; 129; 180 m². At the baseline efficiency and to satisfy their average daily consumption which was 30, 41.67, 20.75 kWhr per day respectively a required solar radiation 2.58, 2.69, 0.96 kWhr/m²/day is required using 12 % efficiency. The greater efficiency 25% shows give a required solar radiation 1.24, 1.29, 0.46 kWhr/m²/day.

Peak power available at standard solar insolation 1000 W/m^2 and for 97m^2 area is seen as $11.64 \text{ kW/m}^2/\text{day}$. Which is lesser of the peak power demand per day of the house that was 30.00 kWhr . Similarly, peak power available for 129m^2 and 180 m^2 areas was 15.48 and $21.6 \text{ kW/m}^2/\text{day}$ respectively. Which is lesser of the peak power demand per day 127.00 and 24.75 kWhr .

Table 4.4 Annual photovoltaic electricity production comparison to total required energy annually.

| No. | Description | Efficiency Range | CR | CC | BU ₁ | BU ₂ |
|-----|--|------------------|------------|------------|-----------------|-----------------|
| | Annual photovoltaic electricity production (with corrections) kWhr | 12% | 34,320.00 | 23,328.00 | 30,888.00 | 43,200.00 |
| | | 25% | 71,500.00 | 48,600.00 | 64,350.00 | 90,000.00 |
| | Total required energy, annual; kWhr | | 115,909.20 | 262,800.00 | 220,000.00 | 181,770.00 |
| | Percentage of PV generation to Required Energy | 12% | 29.61% | 8.87% | 14.04% | 23.76% |
| | | 25% | 61.69% | 18.49% | 29.25% | 49.51% |

Table shows computation of electricity obtained from PV sources quantified square meter. These after total electric generation potential with these modules is presented for buildings and compared to total required energy.

Result show for all building the amount of produced electricity at standard condition would be lesser than the required electricity demand based on the demand assumed in the case study. For instance, CR a total of 34,320.00 to 71,500.00 kWhr per year could be produced if all usable area for solar module in roof top were operational for efficiency range from 12 % to 25% and 2000 kWhr/m square solar radiation annually; this value represents 30% to 62% of energy usage in the building. For case of CC a total of 23,280.00 to 48,500.00 kWhr per year could be produced if all usable area for solar module in roof top were operational for efficiency range from 12 % to 25%; this value represents 8.86% to 18.46% of energy usage in the building CC. CC building, potential production is substantially lower due to less available area for solar modules and less energy potential per unit area and also to the high special demand of electric vehicle. Even so, in a similar way BU₁ building a total of 30,960.00 to 64,500.00 kWhr per year could be produced if all usable area for solar module in roof top were operational for the efficiency range taken; this value represents 14.07% to 29.32% of energy usage in the building. In such away BU₂ building a total of 43,200.00 to 90,000.00 kWhr per year could be produced if all usable area for solar module in roof top were operational for the efficiency range taken; this value represents 23.77% to 49.51% of energy usage in the building.

Thus going further, another scenario called as “research demand” was set with 14.23 kWhr per day demand which is calculated for customized demand of lamp usage for limited hour of the day, refrigerators use and for a pump load which pumps up contained water so as to feed non potable demand especially reserved for sanitation uses of building. Similar instead of 3 vehicle electric charging for 24 hours, one vehicle at 10 kW for 2 hour of the day is taken for the communal building. Likewise an optimized use of fixed no of projector, printer computer and pump are taken for the school. The ware house has also limited its lighting for night time a lesser no of ventilators.

Table 4.5. Customized daily electric demand set for CR type of building.

| Appliances | Qty. | Usage Power (kw) | Total Power (kw) | Working Hour/Day | Total kwh/Day |
|-------------------|-------------|--------------------------|-------------------------|-------------------------|----------------------|
| Refrigerator | 2 | 0.5 | 1 | 12 | 12 |
| Water pump | 1 | 0.817 | 0.817 | 1 | 0.817 |
| Electric lighting | 6 | 0.04 | 0.24 | 6 | 1.44 |
| Sum | | | 2.06 | | 14.26 |

Table 4.6. Customized daily electric demand set for CC type of building.

| No. | Appliances | Qty. | Usage Power (kW) | Total Power (KW) | Working Hour/Day | Total kWh/Day |
|------------|---------------------------|-------------|--------------------------|-------------------------|-------------------------|----------------------|
| | Electric Vehicle Charging | 1 | 10 | 10 | 2 | 20 |
| | Sum | | | 10 | | 20 |

Table 4.7. Customized daily electric demand set for BU₁ type of building.

| No. | Appliances | Qty. | Usage Power (kW) | Total Power (KW) | Working Hour/Day | Total KWh/Day |
|-----|--------------------|------|-------------------|------------------|------------------|---------------|
| | Fluorescent lights | 10 | 0.04 | 0.40 | 8 | 3.2 |
| | Ceiling fans | 0 | 0.75 | 0.00 | 8 | 0 |
| | Computers | 5 | 0.15 | 0.75 | 6 | 4.5 |
| | Printers | 1 | 0.3 | 0.30 | 2 | 0.6 |
| | Projectors | 5 | 0.4 | 2.00 | 2 | 4 |
| | Refrigerators | 2 | 0.5 | 1.00 | 12 | 12 |
| | Water pump, | 1 | 1 | 1.00 | 1 | 1 |
| | Sum | | | 5.45 | | 25.30 |

Table 4.8. Customized daily electric demand set for BU₂ type of building.

| No. | Appliances | Qty. | Usage Power (kW) | Total Power (KW) | Working Hour/Day | Total KWh/Day |
|-----|--------------------|------|-------------------|------------------|------------------|---------------|
| | Fluorescent lights | 10 | 0.04 | 0.40 | 8 | 3.2 |
| | Ceiling fans | 5 | 0.75 | 3.75 | 24 | 90 |
| | Sum | | | 5.45 | | 25.30 |

Table 4.9. Annual photovoltaic electricity production comparison to customized daily electric demand for the building types.

| | Description | Efficiency Range | CR | CC | BU₁ | BU₂ |
|--|--|-------------------------|-----------|-----------|-----------------------|-----------------------|
| | Annual photovoltaic electricity production (with corrections) kWhr | 12% | 34,320.00 | 23,328.00 | 30,888.00 | 43,200.00 |
| | | 25% | 71,500.00 | 48,600.00 | 64,350.00 | 90,000.00 |
| | Total required energy, annual; kWhr | | 5,132.52 | 7,200.00 | 5,566.00 | 33,552.00 |
| | Percentage of PV generation to Required Energy | 12% | 668.68% | 324.00% | 554.94% | 128.76% |
| | | 25% | 1393.08% | 675.00% | 1156.13% | 268.24% |

As Table 4.9 shows at this scenario for all building the amount of produced electricity annually has satisfied the required self-sufficiency amount to required customized electricity demand based on the demand assumed in the case study. For instance, CR a total of 34,320.00 to 71,500.00 kWhr per year could be produced if all usable area for solar module in roof top were operational for efficiency range from 12 % to 25% and 2000 kWhr /m² solar radiation annually; this value represents 7 times or 6684.68% to 14 times or 1393.01% of energy usage in the building, which is sufficient.

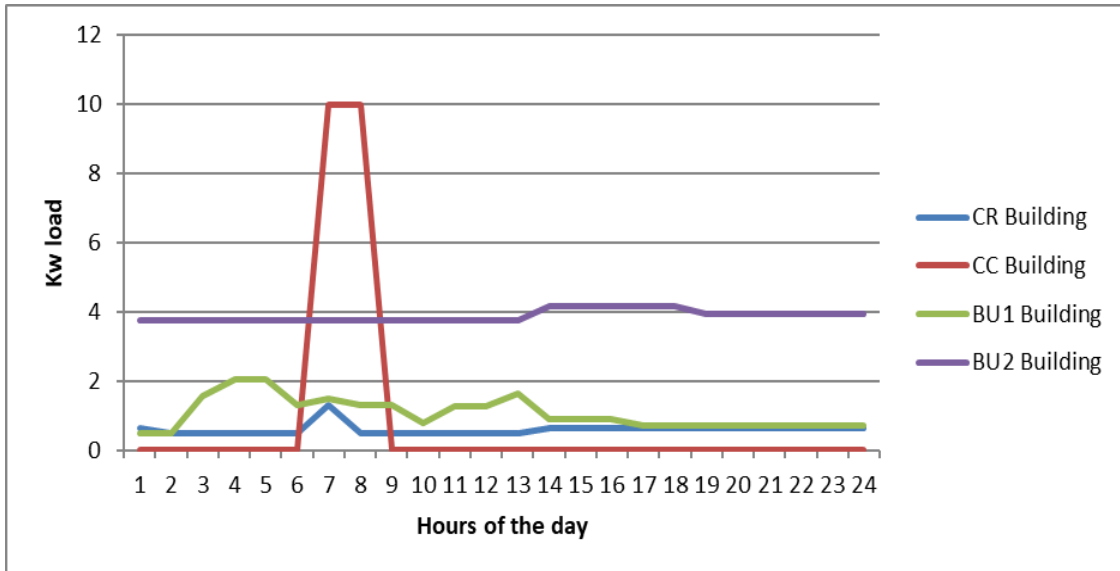


Fig 4.18: Customized electric demands in kW for hour of the day in the 4 buildings types as used in the study

The figure compares the customized demand for four types of buildings, each with a research-specific electric load.

4.1.3.1 Energy Balance

To have a reflection on energy used and unused ratio typical assessments similar to loss diagram was needed. Thus, for all building type considered the amount of produced electricity for hours of specific day of the months from the year was studied. As an obvious founding the hours of the night can not have available output power and the daily demand sufficiency is not going with the demand constant. Thus how much associated back up power by storage needed prediction is also studied.

Considering intermittency and balance of system, backup power by storage needed was also included in the study was assumed to carry average hourly night time load close to

600W for 12hrs become 7,200.00Whr for CR customized. A similar look on loading of hours of the day made to set a preliminary 200, 4,800 and 63,910 Whr storage size need for CC, BU₁ and BU₂ buildings respectively.

Here under is the data set generated for the month February selected as has higher solar radiation, here it is seen in part for one representative day of month February from hour gaps of the 24 hours of day; the rest of the months are also found [Appendix 3.0].

Table 4.10. Data set generated to observe solar fraction of PV system under research demand case for month February.

| Hou r (Gap) | T _a , ^o C | IT(GJ) | Z _i | η | E _i (kw h) | L _i (Wh) | X _{c,i} | φ | E _{ex,I} (kW h) | E _{li} (kW h) |
|-----------------------|------------------------------------|--------------|----------------|------------|-----------------------------|-------------------------|------------------|------|--------------------------------|---------------------------|
| 12-- 1 | 13.00 | (435.2 7) | 34.1 1 | (0.52) | 8.90 | 620.00 | 0.07 | 0.00 | 0.04 | 8.86 |
| 1--2 | 12.00 | (460.2 8) | 26.4 6 | (0.42) | 7.60 | 620.00 | 0.08 | 0.00 | 0.03 | 7.57 |
| 2--3 | 12.00 | (485.7 5) | 17.4 7 | (0.28) | 5.25 | 620.00 | 0.12 | 0.00 | 0.01 | 5.24 |
| 3--4 | 11.00 | (470.3 6) | 10.9 0 | (0.15) | 2.73 | 620.00 | 0.23 | 0.00 | 0.00 | 2.73 |
| 4--5 | 10.00 | (369.4 5) | 6.86 | (0.05) | 0.74 | 620.00 | 0.84 | 0.00 | 0.00 | 0.74 |

| | Ta, o C | IT(GJ) | Zi | $\dot{\eta}$ | Ei (kw h) | Li(wh) | Xc,i | ϕ | Eex,I (kwh) | Eli,(kwh) |
|----------------|------------|--------------|------|--------------|-----------------|--------------|------------|------------|--------------------|---------------|
| 5--6 | 11.00 | (150.3 3) | 4.34 | 0.03 | (0.16) | 620.00 | (3.79) | (0.01) | 0.00 | (0.16) |
| 6--7 | 12.00 | 194.94 | 3.28 | 0.08 | 0.64 | 620.00 | 0.98 | 0.03 | 0.02 | 0.62 |
| H 7- -8 | 13.00 | 642.82 | 2.46 | 0.12 | 3.14 | 500.00 | 0.16 | 0.18 | 0.58 | 2.56 |
| 8--9 | 15.00 | 1,139.9 3 | 1.95 | 0.16 | 7.12 | 500.00 | 0.07 | 0.42 | 2.98 | 4.14 |
| 9-- 10 | 16.00 | 1,612.8 2 | 1.65 | 0.18 | 11.4 4 | 500.00 | 0.04 | 0.67 | 7.70 | 3.74 |
| H 10- 11 | 17.00 | 1,983.5 5 | 1.47 | 0.20 | 15.2 4 | 500.00 | 0.03 | 0.90 | 13.67 | 1.58 |
| H 11- 12 | 18.00 | 2,187.2 9 | 1.39 | 0.21 | 17.6 3 | 500.00 | 0.03 | 1.04 | 18.29 | (0.65) |
| H 12-1 | 20.00 | 2,187.2 9 | 1.39 | 0.21 | 18.4 2 | 1,317.0 0 | 0.07 | 0.41 | 7.58 | 10.84 |
| H 1- 2 | 22.00 | 1,983.5 5 | 1.47 | 0.22 | 17.0 4 | 500.00 | 0.03 | 1.00 | 17.08 | (0.04) |
| H 2- 3 | 23.00 | 1,612.8 2 | 1.65 | 0.21 | 13.4 9 | 500.00 | 0.04 | 0.79 | 10.70 | 2.79 |

| | Ta, o C | IT(GJ) | Zi | $\dot{\eta}$ | Ei (kwh) | Li(wh) | Xc,i | ϕ | Eex,I (kwh) | Eli,(kwh) |
|----------------|------------|--------------|-----------|--------------|-------------|--------|------------|------------|----------------|-----------|
| H 3- 4 | 22.00 | 1,139.9 3 | 1.95 | 0.19 | 8.57 | 500.00 | 0.06 | 0.50 | 4.32 | 4.25 |
| H 4- 5 | 21.00 | 642.82 | 2.46 | 0.16 | 4.07 | 500.00 | 0.12 | 0.24 | 0.98 | 3.10 |
| H 5- 6 | 20.00 | 194.94 | 3.28 | 0.12 | 0.92 | 500.00 | 0.54 | 0.05 | 0.05 | 0.87 |
| H 6- 7 | 18.00 | (150.3 3) | 4.34 | 0.06 | (0.35) | 500.00 | (1.41) | (0.02) | 0.01 | (0.36) |
| H 7- 8 | 17.00 | (369.4 5) | 6.86 | (0.02) | 0.27 | 620.00 | 2.30 | 0.01 | 0.00 | 0.27 |
| H 8- 9 | 16.00 | (470.3 6) | 10.9 0 | (0.12) | 2.31 | 620.00 | 0.27 | 0.00 | 0.00 | 2.31 |
| H 9- 10 | 15.00 | (485.7 5) | 17.4 7 | (0.26) | 4.99 | 620.00 | 0.12 | 0.00 | 0.01 | 4.97 |
| H 10- 11 | 14.00 | (460.2 8) | 26.4 6 | (0.41) | 7.43 | 620.00 | 0.08 | 0.00 | 0.03 | 7.40 |
| H 11- 12 | 13.00 | (435.2 7) | 34.1 1 | (0.52) | 8.90 | 620.00 | 0.07 | 0.00 | 0.04 | 8.86 |

Coming to need of the energy balance:

- the monthly fraction of the load carried by system is sum of contribution by battery system (Δf_s , a function of; dumped energy with out storage, upper-limit on fraction of load met by solar, monthly average total load, battery total capacity and clearness index) and without battery system (Δf_o , which is ratio of total monthly average daily energy to load to total monthly average daily demands or load).
- Thus monthly average daily electric output in Whr. is the fraction of load carried by PV system multiplied to monthly average daily total demand or load.

Therefore the month's result of PV system load carrying status is:

Table 4.11. Solar fraction of the PV system under research demand case for the twelve months CR customized case with 14,257 Whr daily demand.

| Month | (Fraction of load by PV with out battery) Δf_o | load carried by PV without battery; Whr | (Fraction of load carried by battery storage, Δf_s | load carried by PV without battery, Whr | fraction by PV; f_s | Load carried by PV system, Whr |
|-------|---|--|---|--|--------------------------|-----------------------------------|
| Jan | 2.4924 | 35,533.87 | (1.82) | 25,912.09 | 4.31 | 61,445.96 |
| Feb | 2.33 | 33,259.78 | (1.55) | 22,115.44 | 3.88 | 55,375.21 |
| March | 2.27 | 32,434.23 | (1.46) | 20,863.01 | 3.74 | 53,297.24 |
| April | 2.45 | 34,945.60 | (1.75) | 24,971.62 | 4.20 | 59,917.23 |

| Month | (Fraction of load by PV with out battery) Δf_o | load carried by PV without battery; Whr | (Fraction of load carried by battery storage, Δf_s | load carried by PV without battery, Whr | fraction by PV; f_s | load carried by PV system, Whr |
|--------------|--|--|--|--|---|---|
| May | 2.70 | 38,438.32 | (2.28) | 32,516.56 | 4.98 | 70,954.87 |
| June | 2.81 | 40,058.86 | (2.70) | 38,536.19 | 5.51 | 78,595.06 |
| July | 2.84 | 40,437.98 | (2.79) | 39,800.53 | 5.63 | 80,238.51 |
| Aug | 2.73 | 38,877.45 | (2.40) | 34,230.19 | 5.13 | 73,107.64 |
| Sept | 2.58 | 36,787.51 | (1.99) | 28,411.28 | 4.57 | 65,198.79 |
| Oct | 2.38 | 33,891.60 | (1.63) | 23,230.65 | 4.01 | 57,122.25 |
| Nov | 2.56 | 36,482.82 | (1.95) | 27,777.43 | 4.51 | 64,260.25 |
| Dec | 2.60 | 37,014.96 | (2.03) | 28,900.18 | 4.62 | 65,915.14 |
| Sum | | 438,162.98 | | 347,265.18 | | 785,428.16 |

Table. 4.12 Monthly average daily PV system under research demand case for the twelve months for CC customized case with 20,000 Whr daily demand.

| Month | (Fraction of load by PV with out battery) Δf_0 | load carried by PV without battery; Whr | (Fraction of load carried by battery storage, Δf_s | load carried by PV without battery, Whr | fraction by PV; f_s | load carried by PV system, Whr |
|--------------|--|--|--|--|---|---------------------------------------|
| Jan | 0.0983 | 1,966.25 | 0.69 | 13,847.89 | 0.79 | 15,814.14 |
| Feb | 0.11 | 2,106.56 | 0.69 | 13,750.76 | 0.79 | 15,857.33 |
| March | 0.11 | 2,131.85 | 0.69 | 13,761.93 | 0.79 | 15,893.78 |
| April | 0.10 | 2,021.33 | 0.69 | 13,755.95 | 0.79 | 15,777.29 |
| May | 0.09 | 1,860.00 | 0.69 | 13,702.24 | 0.78 | 15,562.24 |
| June | 0.09 | 1,727.49 | 0.68 | 13,600.32 | 0.77 | 15,327.80 |
| July | 0.09 | 1,753.83 | 0.68 | 13,520.72 | 0.76 | 15,274.55 |
| Aug | 0.08 | 1,585.32 | 0.70 | 14,071.72 | 0.78 | 15,657.04 |
| Sept | 0.10 | 2,023.33 | 0.68 | 13,636.03 | 0.78 | 15,659.35 |
| | | | | | | |

| Month | (Fraction of load by PV with out battery) Δf_o | load carried by PV without battery; Whr | (Fraction of load carried by battery storage, Δf_s | load carried by PV without battery, Whr | fraction by PV; f_s | load carried by PV system, Whr |
|--------------|--|--|--|--|---|---|
| Oct | 0.10 | 2,017.41 | 0.69 | 13,794.61 | 0.79 | 15,812.01 |
| Nov | 0.10 | 1,974.30 | 0.69 | 13,739.20 | 0.79 | 15,713.50 |
| Dec | 0.10 | 1,918.69 | 0.69 | 13,783.36 | 0.79 | 15,702.05 |
| Sum | | 23,086.36 | | 164,964.71 | | 188,051.07 |

Table. 4.13 Monthly average daily PV system under research demand case for the twelve months for BU₁ customized case with 25,300.00 Whr daily demands.

| | (Fraction of load by PV with out battery) Δf_o | load carried by PV without battery; Whr | (Fraction of load carried by battery storage, Δf_s | load carried by PV without battery, Whr | fraction by PV; f_s | load carried by PV system, Whr |
|-----|--|--|--|--|---|---|
| Jan | 2.0819 | 52,671.53 | N/A | N/A | N/A | N/A |
| Feb | 2.02 | 51,212.25 | (1.92) | 48,557.86 | 3.94 | 99,770.11 |

| Month | (Fraction of load by PV with out battery) Δf_o | load carried by PV without battery; Whr | (Fraction of load carried by battery storage, Δf_s | load carried by PV without battery, Whr | fraction by PV; fs | load carried by PV system, Whr |
|--------------|--|--|--|--|-------------------------------|---|
| March | 2.03 | 51,277.03 | (1.93) | 48,942.44 | 3.96 | 100,219.47 |
| April | 2.11 | 53,455.55 | N/A | N/A | N/A | N/A |
| May | 2.19 | 55,403.44 | N/A | N/A | N/A | N/A |
| June | 2.23 | 56,335.83 | N/A | N/A | N/A | N/A |
| July | 2.19 | 55,344.06 | N/A | N/A | N/A | N/A |
| Aug | 2.20 | 55,594.85 | N/A | N/A | N/A | N/A |
| Sept | 2.13 | 53,883.95 | N/A | N/A | N/A | N/A |
| Oct | 2.09 | 52,892.91 | N/A | N/A | N/A | N/A |
| Nov | 2.12 | 53,645.78 | N/A | N/A | N/A | N/A |
| Dec | 2.12 | 53,758.04 | N/A | N/A | N/A | N/A |
| Sum | | 645,475.22 | | N/A | | N/A |

Table. 4.14 Monthly average daily PV system under research demand case for the twelve months for BU₂ customized case with 93,200Whr daily demand.

| Month | (Fraction of load by PV with out battery) Δf_o | load carried by PV without battery; Whr | (Fraction of load carried by battery storage, Δf_s | load carried by PV without battery, Whr | fraction by PV; f_s | load carried by PV system, Whr |
|-------|---|--|---|--|--------------------------|-----------------------------------|
| Jan | 1.7090 | 159,280.92 | (1.05) | 98,024.69 | 2.76 | 257,305.61 |
| Feb | 1.84 | 171,142.90 | (1.29) | 120,122.88 | 3.13 | 291,265.78 |
| March | 1.92 | 178,692.68 | (1.45) | 135,197.13 | 3.37 | 313,889.81 |
| April | 1.81 | 168,893.16 | (1.25) | 116,570.87 | 3.06 | 285,464.03 |
| May | 1.68 | 156,590.08 | (1.01) | 94,270.26 | 2.69 | 250,860.34 |
| June | 1.59 | 147,874.68 | (0.85) | 79,222.17 | 2.44 | 227,096.85 |
| July | 1.52 | 142,065.54 | (0.74) | 69,412.17 | 2.27 | 211,477.71 |
| Aug | 1.59 | 148,311.02 | (0.86) | 79,784.29 | 2.45 | 228,095.31 |
| Sept | 1.74 | 161,847.37 | (1.11) | 103,268.53 | 2.84 | 265,115.90 |

| Month | (Fraction of load by PV with out battery) Δf_o | load carried by PV without battery; Whr | (Fraction of load carried by battery storage, Δf_s | load carried by PV without battery, Whr | fraction by PV; f_s | load carried by PV system, Whr |
|-------|---|--|---|--|--------------------------|-----------------------------------|
| Oct | 1.78 | 166,115.20 | (1.19) | 110,823.73 | 2.97 | 276,938.94 |
| Nov | 1.68 | 156,439.82 | (1.00) | 93,070.26 | 2.68 | 249,510.08 |
| Dec | 1.63 | 151,825.36 | (0.91) | 84,956.70 | 2.54 | 236,782.06 |
| Sum | | 1,909,078.73 | | 1,184,723.69 | | 3,093,802.42 |
| | | | | | | |

4.1.4 Economic Potential

7,200.00 size of storage battery capability required with efficiency 0.9 together with 0.95 subordinate conversion efficiencies was taken these in association with inverter, converter and as such. A 150 Ahr, 30V battery with efficiency 0.9 assures by greater than the required storage requirement. Thus to get the required capability 7,200.00 Whr a quantity multiplier 2 was needed. Accordingly, with 162 Wp, 22.8 peak voltage and 7.11A peak current rated panel shall be configured to the produce the desired input to the inverter and or to have capability to charge the storage battery otherwise.

Given we have the charger converter control devise at hand, for our consideration of demand at standard condition for common house hold near 220V, and up to 8A in alternating current capacity at out of the converter. For near 220 volt we need 10 number

22.8 V peak panel that guarantee as a practical 220 v and also 7.11 multiplied by 10 numbers in series configuration a direct current output for input near 8A. However, as this assumption at standard condition of panel rating, our previous need where all our calculation based was of 143 m² that requires a quantity requirement of 108 panels for 1.31 squared meter sized unit module.

Similar assessments for CC building type requires 74 panels, BU₁ building type 98 Panel and BU₂ building type 137 number of panel.

4.2 DISCUSSION

Optimum incidence angle per hours of the day for each month in specific class of azimuth class was determined by appropriate formulation interpretation on graphical analysis for best fits, then again taking average day of each month of a year for azimuth classes of (0, to +_45, to +_90) and also for slope varying from 0 to 90 degree at various hour angle of the day (hour angle) for each month of the year was seen predicting best and recommendable physical potential in terms of slope.

Using theoretical formulation; average sunshine length is 12 hour with minimum in December and maximum in June. Then setting at one azimuth angle and at certain hour angle from sunrise to sunset a slope or tilt angle variation is made observation on incidence angle variation is made by changing slope from 0 degree to 90 degree that is for each representative days of each month of the year. So 45 degree gives degree best slope characteristic with average lower incidence angle. Then taking this tilt angle of the collector Incidence angles values observation is made for different azimuths. And azimuth classes that are equivalent to South, South-West and West are selected.

To this end, considering higher incidence angle month June is the worst month; however, months around December show lower global radiation and this making it worst month in it's own case. Therefore, determining one needs another more influential factor. And

azimuth classes' equivalent to South, south east, South-West and West have showed average total decreasing incidence angle thorough out the day of representative day. This has also proved the fact that increase of azimuth angle from due south, the annual collectible radiation decreases.

To find the annual form monthly sum electrical output and solar fractions of the system the following analysis is done. This is intern is found from monthly average daily electrical output of hours of the day:

>>First representative day of each month around 15th of each selected, hour of the day classified in succession, the monthly representative extraterrestrial radiation for the hour, \underline{I}_o , which is function of G_{sc} , n , declination angle, latitude and hour angle, incident on the array for the hour calculated in joule.

>> \underline{K}_T is also set by factoring “mean monthly average, daily global irradiation” by “ H_o ”, (month average) the day's solar radiation on a horizontal surface in the absence of the atmosphere”. Parameter ratios; r_t “total radiation in an hour to total in a day; r_d “ratio of diffuse radiation in an hour to total in a day” which are functions of hour angle and sun set hour angle also determined. Ratio of beam radiation on tilt to that on a horizontal surface, plane of measurement “ R_b ” function of azimuth and zenti determined.

>>Then a general assumption to approximate ratio of “ diffuse monthly average daily irradiation to total irradiation” a value taken for each month Jan (0.25), Feb (0.2424), Mar (0.2429), Apr (0.3538), May (0.3333), June (0.2353), July (0.3485), Aug. (0.3281), Sept.(0.3582), Oct (0.2424), Nov (0.2381), Dec (0.2381), where it is obvious that in rainy and cloudy months are more diffuse and sunny months are less diffuse, where as to study, the region of interest; diffuse radiation lies around 0.3 [Annex2.0].

>> With these values inserted to formulation for getting “ \underline{I}_T ” (monthly average hourly incident radiation on the collector or energy generating surface).

Table. 4.15 Typical result for high and low solar radiation month from energy balance analysis.

| Ho ur of the day | FEB | | | Energy available to Demand | July | | Energy available to Demand |
|------------------------------|--------|------------------|----------------|-------------------------------------|------------------|------------|----------------------------------|
| | Li(wh) | IT(MJ) | Ei(wh) | | IT(MJ) | Ei(wh) | |
| 12-- -1 | 620.00 | (549,932 .56) | (1,454.78) | (2.35) | (672,898. 76) | (1,183.48) | (1.91) |
| 1-- 2 | 620.00 | (549,932 .56) | (1,242.47) | (2.00) | (589,321. 28) | (1,035.10) | (1.67) |
| 2-- 3 | 620.00 | (461,490 .72) | (886.95) | (1.43) | (427,704. 74) | (725.77) | (1.17) |
| 3-- 4 | 620.00 | (290,441 .61) | (380.36) | (0.61) | (198,790. 64) | (330.62) | (0.53) |
| 4-- 5 | 620.00 | (48,108. 38) | 210.72 | 0.34 | 82,135.4 0 | 150.58 | 0.24 |
| 5-- 6 | 620.00 | 249,379. 51 | 900.48 | 1.45 | 396,201. 14 | 696.85 | 1.12 |

| | Li(wh) | IT(MJ) | Ei(wh) | Energy available to Demand | IT(MJ) | Ei(wh) | Energy available to Demand |
|----------------------|--------------|------------------|----------|----------------------------|------------------|----------|----------------------------|
| 6-- 7 | 620.00 | 582,082. 33 | 1,648.97 | 2.66 | 722,160. 76 | 1,303.14 | 2.10 |
| H 7-- 8 | 500.00 | 927,519. 52 | 2,415.00 | 4.83 | 1,037,80 0.67 | 1,921.35 | 3.84 |
| 8-- 9 | 500.00 | 1,262,15 0.09 | 3,222.58 | 6.45 | 1,321,45 3.25 | 2,512.98 | 5.03 |
| 9-- 10 | 500.00 | 1,562,97 6.95 | 3,870.56 | 7.74 | 1,553,51 5.67 | 3,034.22 | 6.07 |
| H 10- -- 11 | 500.00 | 1,809,16 5.67 | 4,375.36 | 8.75 | 1,717,85 8.75 | 3,444.30 | 6.89 |
| H 11- -- 12 | 500.00 | 1,983,55 3.74 | 4,696.10 | 9.39 | 1,803,01 0.39 | 3,699.38 | 7.40 |
| H 12- --1 | 1,317.0 0 | 2,073,92 3.34 | 4,911.68 | 3.73 | 1,803,01 0.39 | 3,802.46 | 2.89 |
| H 1--- 2 | 500.00 | 2,073,92 3.34 | 4,890.83 | 9.78 | 1,717,85 8.75 | 3,712.16 | 7.42 |

| | Li(wh) | IT(MJ) | Ei(wh) | Energy available to Demand | IT(MJ) | Ei(wh) | Energy available to Demand |
|-----------------|--------|------------------|----------|----------------------------|------------------|----------|----------------------------|
| H 2--- 3 | 500.00 | 1,983,55 3.74 | 4,528.78 | 9.06 | 1,553,51 5.67 | 3,437.94 | 6.88 |
| H 3--- 4 | 500.00 | 1,809,16 5.67 | 3,791.23 | 7.58 | 1,321,45 3.25 | 2,993.76 | 5.99 |
| H 4--- 5 | 500.00 | 1,562,97 6.95 | 2,939.80 | 5.88 | 1,037,80 0.67 | 2,244.99 | 4.49 |
| H 5--- 6 | 500.00 | 1,262,15 0.09 | 2,034.64 | 4.07 | 722,160. 76 | 1,528.35 | 3.06 |
| H 6--- 7 | 500.00 | 927,519. 52 | 1,112.26 | 2.22 | 396,201. 14 | 820.41 | 1.64 |
| H 7--- 8 | 620.00 | 582,082. 33 | 301.46 | 0.49 | 82,135.4 0 | 176.19 | 0.28 |
| H 8--- 9 | 620.00 | 249,379. 51 | (392.86) | (0.63) | (198,790. 64) | (371.95) | (0.60) |
| H 9--- 10 | 620.00 | (48,108. 38) | (932.23) | (1.50) | (427,704. 74) | (770.23) | (1.24) |

| | Li(wh) | IT(MJ) | Ei(wh) | Energy available to Demand | IT(MJ) | Ei(wh) | Energy available to Demand |
|----------------------|--------|------------------|----------------|----------------------------|------------------|------------|----------------------------|
| H 10- -- 11 | 620.00 | (290,441 .61) | (1,290.44) | (2.08) | (589,321. 28) | (1,035.10) | (1.67) |
| H 11- -- 12 | 620.00 | (461,490 .72) | (1,454.78) | (2.35) | (672,898. 76) | (1,183.48) | (1.91) |

The daily hours temperatures are as found from meteorology data; the daily hours load are as those in energy balance diagram or the research demand.

The hour monthly average electrical output is the hour efficiency multiplied by module area and I_T . Thus to find efficiency of the hour, the equation which involve incident radiation, transmittance absorbtance efficiencies, NOCT characteristics, a parameter " Z_i ", max power point efficiency of the module and efficiency of other balance of systems or control electronics is used. ' Z_i ' is the long term distribution of hourly radiation as a function of slope of collector, clearness index K_T , I_o , I_T, R_B and reflectance of surrounding which is taken as 0.5 i.e reflectance not as high as snow or not as dull as dark soil.

Thus ones monthly average hourly electrical output is found by minimizing from it what would be an excess energy monthly energy to the load can be found.

The excess energy if available is found from the relation monthly average electrical output and a "*utilizablity coefficient ϕ* ". The coefficient is the measure of the radiation above the critical level, or amount of solar radiation the can be converted to usefulness. It

is a function of geographically declination angle, monthly average hourly clearness index, ratio of monthly average hourly radiation on the tilted surface to that on a horizontal surface and slope from physical character of the collector.

For the coefficient it is deduced that it equates to one whenever there is no demanding source or load, it is smaller when the radiation available is greater in comparison to the demand and vice versa. From annual months, the month with maximum radiation availability from geographic potential is given lowest utilizablity coefficient (February, 0.2) in comparison to the month with minimum solar radiation that is (July a value of 0.5). That is it relates with ratio of critical radiation level (demand of the hour) to monthly average hourly electric output of the system.

In this procedure monthly average total electric generation, monthly average total excess energy and the monthly average total energy to load predicted.

As shown in the preliminary study energy in shortage sum up from, the night time load would be taken as in shortage 100% but taking good radiation month February the hourly month averaged daily demand is in shortage from 34% to in excess 978% during the day time from noon to sunset with close to all the times there was energy demand above 100% of the demand.

Monthly average daily PV system result showing table presents

- Annual research demand needed of size (14.26×365) equals to 5,205 kWhr greater than generated and supported by the PV system which is 1,323 kWhr for CR building.
- Annual research demand needed of size (20.00×365) equals to 7,300 kWhr less than generated and supported by the PV system which is 186.45 kWhr for CC building.
- Annual research demand needed of size (25.30×365) equals to 9,234.5 kWhr unpredictably to the generated and supported by the PV system quantity for BU₁ building.
- Annual research demand needed of size (93.2×365) equals to 34,018.0 kWhr less than generated and supported by the PV system which is 3,093.81kWhr for BU₂ building.

To have a comparative look at the result found; product item relevant output is seen as follows:

Table. 4.16 Output from variety of PV module types in relation to research demand case.

| Panel Type | Efficiency | Power output for block, KW, Annual | Peak Power; KW/hr/day/ annually | Percentage of Peak Power |
|-------------------------------|------------|------------------------------------|---------------------------------|--------------------------|
| Mono-crystalline Si (C-Si) | 22.90% | 65.49 | 480.71 | 13.62% |
| Poly-crystalline Si (P-Si) | 18.50% | 52.91 | | 11.01 |
| Amorphous Si (a-Si) | 12.20% | 34.89 | | 7.26 |
| Cadimium – Telluride (Cd Te) | 17.50% | 50.05 | | 10.41 |

The table shows size of amount variation output that can be expected from different product items, however performance characteristic and also cost related with each variety will be direct vise versa.

Solar polar potential and annual energy outputs for different scenarious of PV technplogy and self sufficiency have been computed. It has been realized that mono-crystal Si based rooftop PV system could provide highest percentage of jemo residential building peak research demand. This is also true for the communal building demand , for building type 1 and 2 power demands.

This much coverage implies promoting motivation for diffusion of PV to cater local electric demand, thereby preventing the production of noise, fuel emission that would otherwise go without it. In this time due to murmuring sound of fuel electric generators in every small business doors, the less noiser environment of the city is deteriorated. Roof top PV system with its environment friendly nature can be an alternatively and sustainable supportive solution to make daily “self sufficient” “supportive” solution to back up energy requirement of Addis Ababa metropolis.

It is pertinent to mention here that the megacity of Addis Ababa with its hundered thousands of condominium house holds in total would show great potential crucial for deployment of roof top PV systems in lot application.

However; lack of market potential, lack of a pilot application, lack of initiation would become a real hinderance in adption of solar potential technology for sustainable power generation in the instance subject view.

Ever since the inception of Ethiopia Renwabel energy Policy progress in adoption in the urban land scape of Addis Ababa is minor as compared to the rural landscape as the grid reaches the entire urban population.

By view of Addis Ababa City Administration Strategic Plan, for Addis Ababa Strategic Development Frame work; though there is attitude for photovoltaic application, adoption is lesser due same above reason and less attention either on controlling actions that degrade the green city aims; competitive, livable , inclusive and sustainable views. CRGE aim to reduce 64 % of national green house gas emission by 2030 compared with business as susual scenario. However, bussiness as usual is continuing interms of use of electric from non renewable electric sources wherever applied. Also the business as usuall activity for getting energy infrastructure is more demanding than would have been in application of such small scale renewable energy in oposition to competitive, livble , inclusive and sustainable plans.

The role of solar energy to bridge the gap of energy supply and demand in Jemo area condominium residential in particular to CR, CC and BU₁ in general is thus significant in the researched demand scenario if not in the all demand scenarios.

Solar power technology has the tendency to bring energy security, provide socio economic benefits to the people dwellers, to immediate business cells. And most importantly in contribution to liveable and capital city standard for Addis Ababa if not with mitigating climate change by reducing GHG that is not found as significant in the current case. While securing self sufficiency to back up self need remain a paramount goal.

Thus, this research work highlight an immense need of policy framework, a market penetration strategy by concerned government agencies, by Addis Ababa City Administration, by private organizations, by society of condominium dwellers, by job seekers, by technology accustomed community, by electric utility agencies of the nations that would help promote further diffusion of PV in condominium areas as in the roof top solar PV application.

4.2.1 Economic Relevance of the Photovoltaic Systems.

- Economic capital outlay for CR: un-urban condominium housing block as discussed earlier holds 30 households, where an average of 4 people inside each house. Now in everyday life a refrigerator may contain a bucket of milk costing 40 Birr, which will be spared un-useful if the device for storing it loses electric power for a day and so the milk loses its freshness. Thus with local electric power availability index of 95 %, this implies 5% probability the device to not get power. And for 2 or 3 similar items to the milk being spared. Now the price of the service not found is 3 items costing 40 birr by multiplication factor of probability of losing electric power 0.05 equates to 6 birr per day per house hold and it equals 5,400.00 Birr per month per block roof top.

Similar assumption for a person having his meal of 100 birr at restaurant, showers his hand and may use toilet service. This implies if we assume 5% for toilet use service, it is 5 birr per person per day. Again coming to condominium house where there are 4 people average, 5 birr by 4 house hold family with 2 times a toilet service per day equates to a value of 16 birr; with 40 % of the time local water source not available. That was equal to 5,400.00 Birr per month per block roof top. Likewise with selling price of electricity 1kwhr per 2birr, a 9W working for 4 hour per day, costs 0.072 birr per day per a single house hold. And likewise it equals 64.8 Birr per month per block roof top. In total a building block can pay for cost of electric service as local power not available 19,864.00 Birr per month.

Now solar PV system cost; according to sizes predicted from shown in annual loss diagram and research demand scenario. First a solar panel module has an average cost of 0.7\$ to \$1.5 per watt and an average life cycle of 25 yrs. Second most common used type Lithium Ion Battery costs \$150.00 per kWhr and a life cycle 5yrs or equivalent to 4000 cycle of charging. Third an associated BOS including inverter charger and installation taken was to cost 2\$ per watt or as to accustomed methodology costs in excess of 20 % of system total cost.

Thus 163 Wp panel numbered 108 has an expense of \$17,496.00. A storage battery with 7.2 kWhr numbered to 2 also has an expense of \$2,160.00. And the BOS for this closes to 4,000.00\$. This in total present an upfront capital outlay cost 1,462,406.40 Birr at 62 exchange rate from USD.

- Business scenario of utility.

A grocer owner or an entrepreneur business man/woman on the ground floor of the housing complex may administer the power plant together with the compartments for energy transmission and balance of system. On contractual life cycle of equipment's period, to determine the pay back year and to check viability of the system; the calculation shows yearly gains and reimbursement of capital investment. As shown

monthly cleaning from aerosols, dust, bird effects and maintenance work 1000 birr which equate to 12,000 is needed. On the end of 5 year service battery replacement takes the initial it's sub amount for replacement On the 8th year it is shown a positive amount changed from negative value in the pay back column, implies debt is cancelled by gain with 214 694.00 profit. However, lifecycle operation is not reached, thus at least it should be checked for the next 5 or 7 years up to an estimated lifecycle end for capital investment. Thus, as shown on the third life cycle replacement of batteries system was able to pay for itself for the next years.

However, future value of present money analysis at interest rate of the common 7 percent, the following deduction is set for counter justification. If the first capital outlay amount 1,462,406.40 was saved for years at 7% interest it would pay to be 1,564,774.85 in the first year, consecutively it would increase to 1,674,309.09 in the second year to 2,512,686.47 birr, in the pay back year which was the 8th year, that was have a profit of 214,694. Showing profit gained from saved capital cost has not payed the capital outlay. Similarly, continuing to the supposes lifetime end period which was 15th year, the saved present money would have a future value of 4,034,825.38 but system life cycle has ended with less amount as a profit that is 1,656,418. That is Solar PV capital investment is with lesser profit of 0.41 times that of saved investment cost. That would be at interest gain of greater by more of 2,378,407.78 birr in general.

The difference between 4,034,825.38 and 1,656,418 is 2,378,407.78 at the 15th year, bringing it to the capital investment year; that is now, by factoring it by 1.07 fifteen times consecutively each amount, where 0.07 is the interest rate. The present value of the profit loss from investment on PV as compared to save equates to 805,649.00

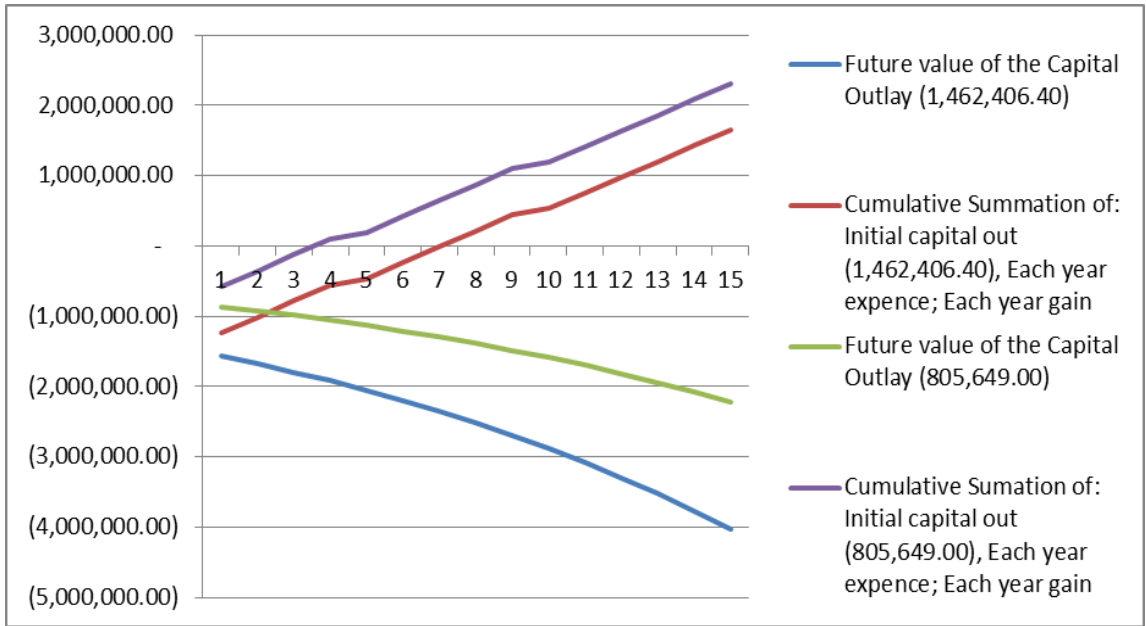


Fig 4.19: Economic Analysis for CR Block.

If initial capital outlay amount was 805, 649.00, as an economic potential for investment, at end of proposed lifecycle profit in-terms of gained utility and initial capital outlay with future worth at bank interest almost equates equal. Therefore this sets a basis by which specific to the research demand economic potential shall be mapped.

Accordingly, the size of system shall be curtailed to half from it's initial size according for a viable implementation.

- **Economic capital outlay for CC**

- Business scenario of utility:

In similar fashion for cost benefit analysis for total life cycle of 15 years and two times storage battery replacement consideration every five years and a balance of system component at the twelfth year. To determine pay back year and to check viability of the system; similar analysis shows gains and reimbursement of capital investment at 14th year. On the 14th year it is shown a positive amount changed from negative value in the

pay back column, implies debt is cancelled by gain with 33,640.80 profit. And at life cycle end period that is on additional one year total gain will reach 101,140.80.

However, future value of present money analysis at interest rate of the common 7 percent, the following deduction is set for counter justification. If the first capital outlay amount 894,139.20 was saved for years at 7% interest it would pay to be 2,305,568.46, in the pay back year which was the 14th year, that was have a profit of 33,640.80. Showing profit gained from saved capital cost has not payed the capital outlay. Similarly, continuing to the supposes lifetime end period which was 15th year, the saved present money would have a future value of 2,466,958 but system life cycle has ended with less amount as a profit that is 100,840.80 That is Solar PV capital investment is with lesser profit of 0.04 times that of saved investment cost. That would be at interest gain of greater by more of 2,366,117.45 birr in general.

The difference between (2,466,958.25) and 100,840.80 is 2,366,117.45 at the 15th year, bringing it to the capital investment year; that is now, by factoring it by 1.07, 15 times consecutively each amount, where 0.07 is the interest rate. The present value of the profit loss from investment on PV as compared to save equates to 857,589.85

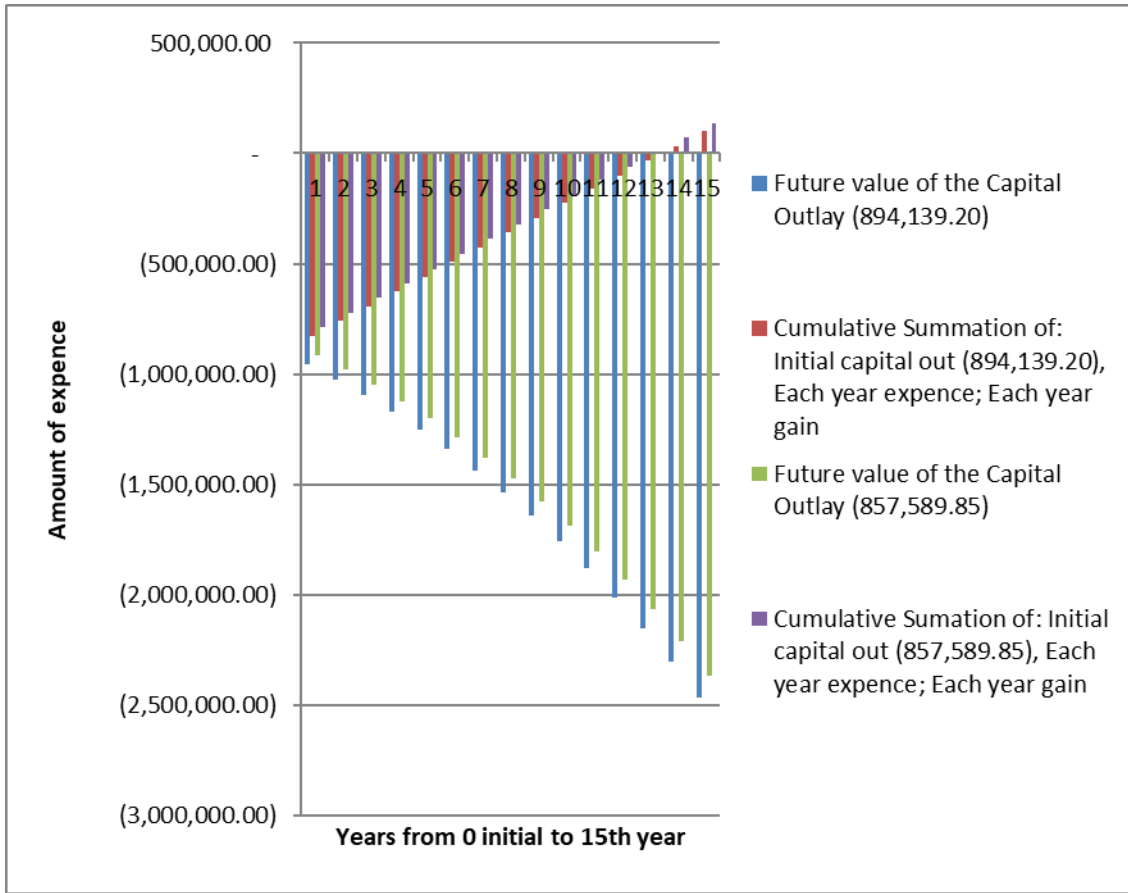


Fig 4.20 Economic Analysis for CC Block.

However, 857,589.85 at end of proposed lifecycle profit in terms of gained utility and initial capital outlay with future worth at bank interest not equates equal or approach.

Accordingly, the size of system saving obtained shall be analyzed shall be curtailed according to new business scenario for a viable implementation.

- **Economic capital outlay for BU₁**

Similar analysis for BU₁ building show, the initial customized demand load PV system energy. On the 14th year a pay back could obtained for the initial capital outlay 1,234,742.20. implies there is profit at fifteenth year by 98,107.20. But ratio between this profit and future worth of the capital outlay is only 2.88%. And this difference between PV system profit at 15 year and future worth of capital outlay is 3,308,586.03. The present value of this amount equates to profit loss from investment on PV as compared to

save equates to 1,199,183.84. However investment at this amount also pays back it does not equate to the future worth of this investments in the supposed consideration for the PV system.

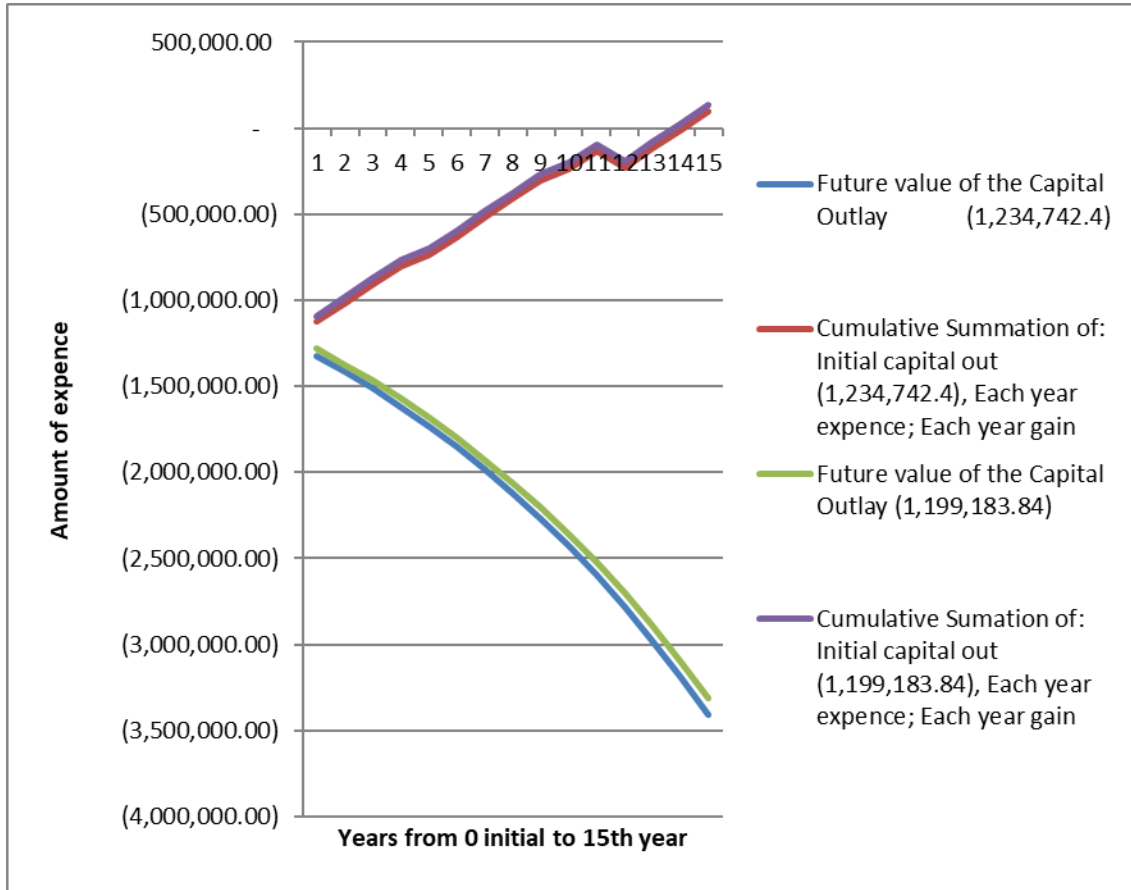


Fig 4.21 Economic Analysis for BU₁ Block.

- **Economic capital outlay for BU₂**

Similar analysis for BU₂ building show, the initial customized demand load PV system energy. Under the consideration, there is no pay back time under the life cycle of the system, the initial capital outlay 2,364,491.52 and supposed gained advantage in decreasing difference between future worth of initial cost and the advantage is at debt amount of (3,120,776.64). And if this amount taken to 15 years to present value and the

quantity taken for investment as (1,233,378.45) Ratio of PV profit to that of saved investment cost would only be 58%.

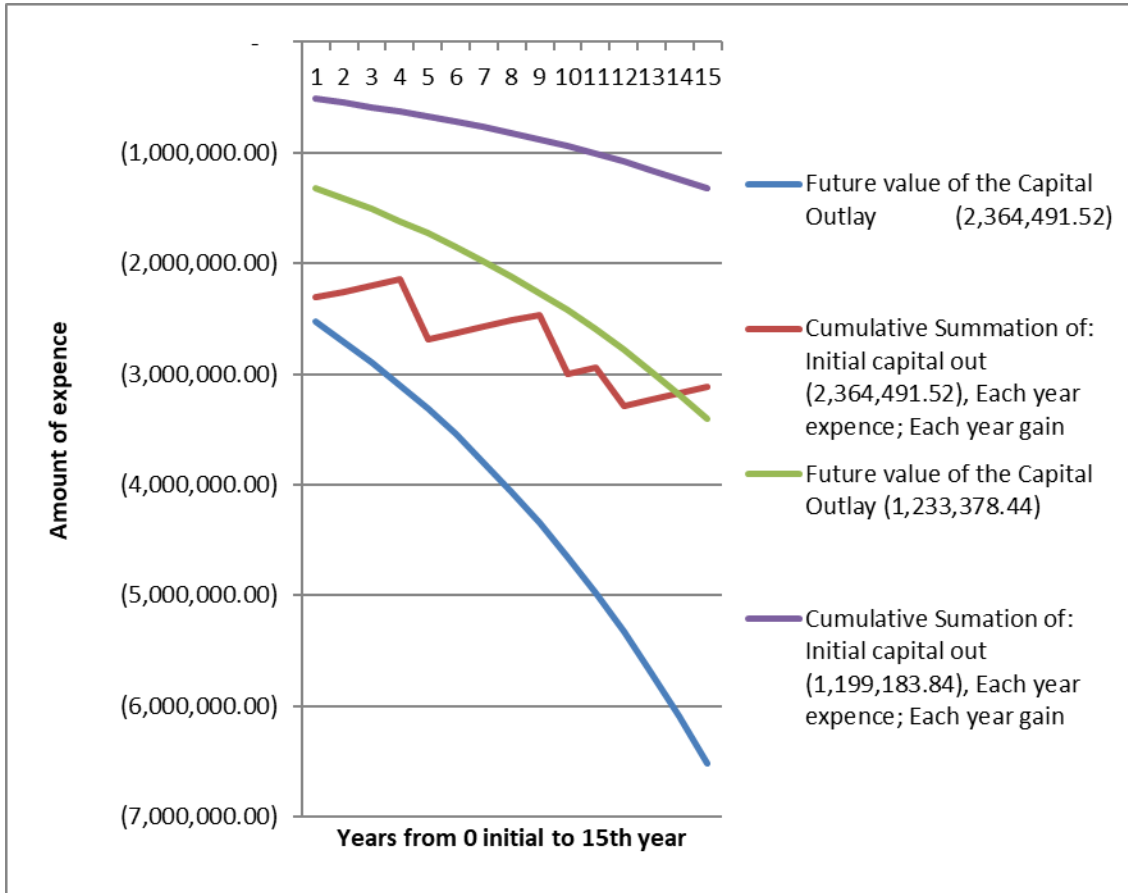


Fig 4.22 Economic analysis for BU₂ Block.

On the set scenario the result show that CR can get its self-sufficiency by almost equating its capital investments and gains in its life cycle economically. For CC buildings though self-sufficiency can be found capital investments and gains in its life cycle did not equate or balances.

This also holds true for BU₁ with but with more imbalances in the given life time of system application. In Contrary for BU₂ setting capital investments will not be feasible

4.2.2 Environmental Relevance of the Photovoltaic Systems.

GHG Reduction: As figure below show, throughout the entire year, monthly production of electricity from PV solar system for CR building would be enough to current regarding electric demand, ranging from being only 7.7 times on February to 5.71 times on July at the lowest set efficiency range. And it will be substantially enough to current regarding electric demand, ranging from being only 16 times on February to in 12 times on July to at the higher set efficiency range.

Using GHG emission reduction factor per unit of electricity for photovoltaic generated electricity and that of grid set as 0.03 and 0.3 respectively [36].

The comparison of same demand energy translated into GHG emission reduction range in terms of kg of CO₂ generated by local grid was found less by 77 % in February to 58 % on July in each month than from PV system.

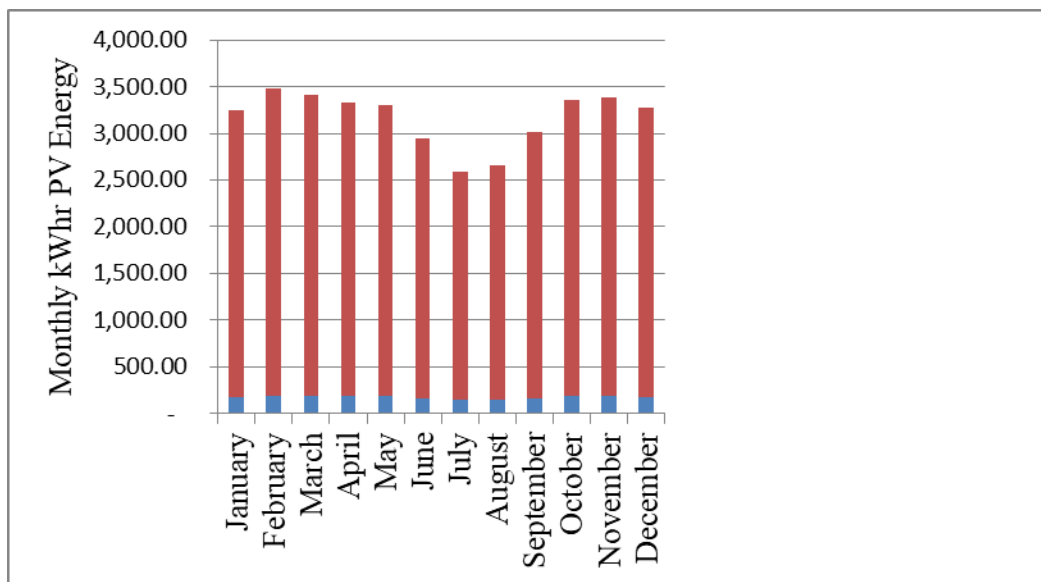


Fig 4.23 PV versus Conventional Grid out put view for CR Block

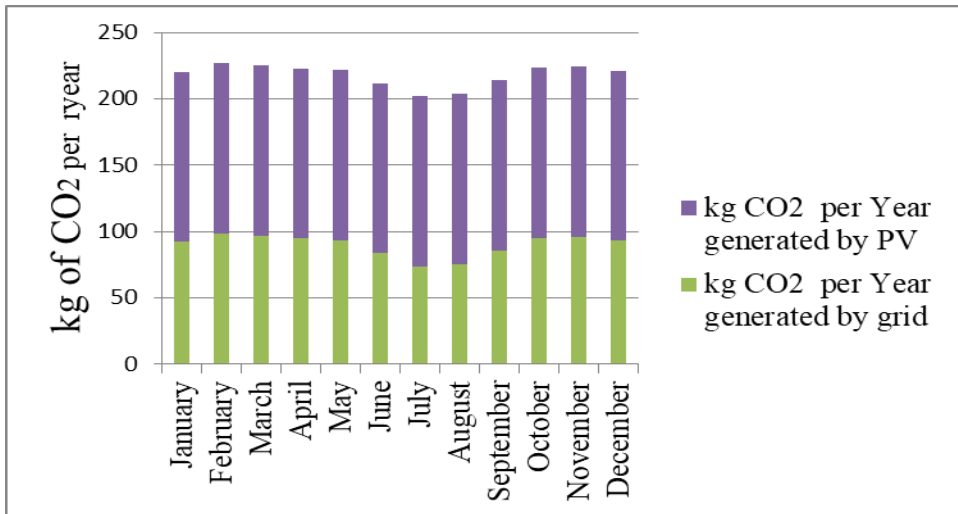


Fig 4.24: PV versus Conventional GHG mitigation comparison for CR Block

This gives the annual amount of 1,077 kg CO₂ from the grid and 1,540 kg CO₂ from PV system emission result annually using 12 % efficient system. When using PV system when extrapolate to entire building location of Jemo 1 which are 337 this will give 362,970.76 and 518,897.77 kg CO₂ equivalent per year.

Similar computation for CC:

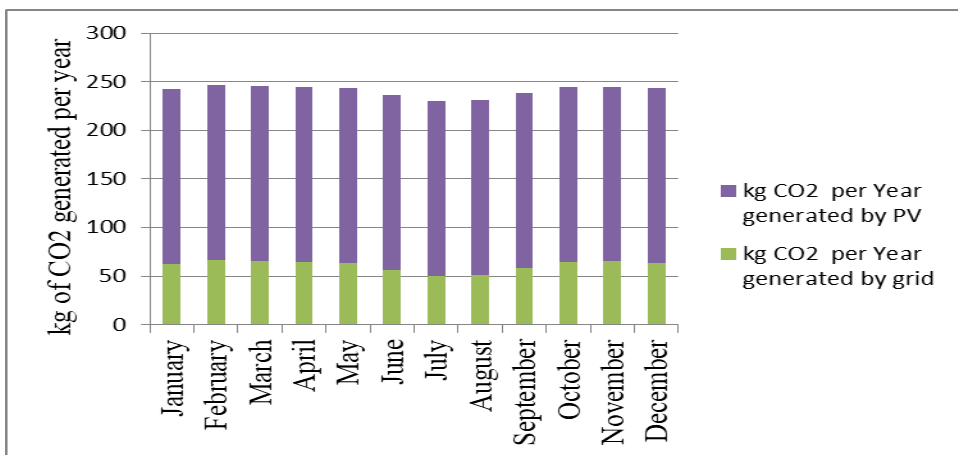


Fig 4.25: PV versus conventional grid output and GHG mitigation comparison for CC Block

This gives the annual amount of 732.10 kg CO₂ from the grid and 2,160.00 kg CO₂ from PV system emission result annually using 12 % efficient system. When using PV system when extrapolate to entire building location of Jemo 1 which are 50 communal this will give 36,605.13 and 108,000.00 kg CO₂ eq per year.

Similar computation for BU₁:

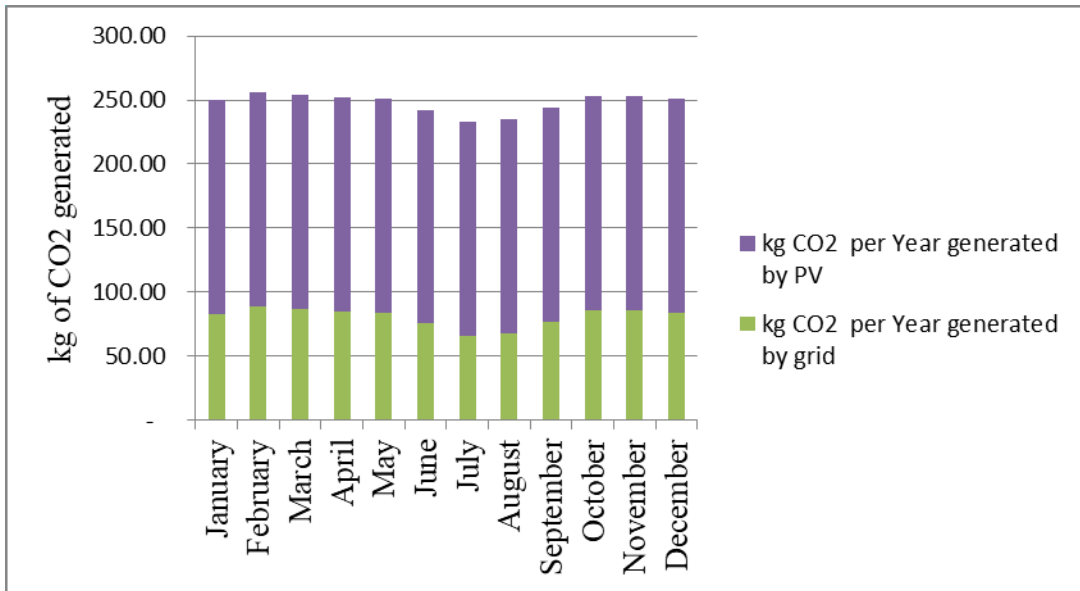


Fig 4.26: PV versus conventional grid output and GHG mitigation comparison for BU₁ Block

This gives the annual amount of 969.36 kg CO₂ from the grid and 2,003.76 kg CO₂ from PV system emission result annually using 12 % efficient system per year.

Similar computation for BU₂:

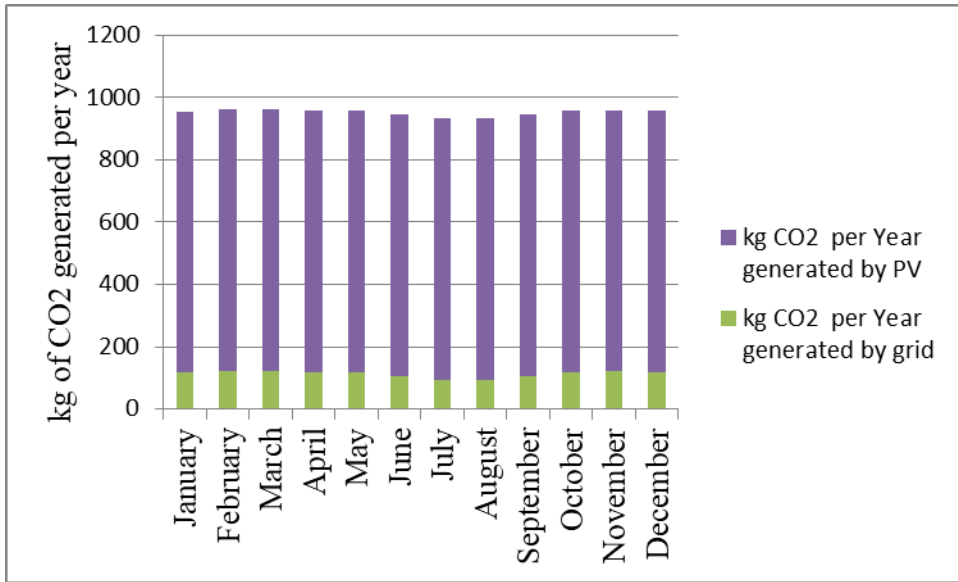


Fig 4.27: PV versus conventional grid output and GHG mitigation comparison for BU₂ Block

This gives the annual amount of 1,355.75 kg CO₂ from the grid and 10,065.60 kg CO₂ from PV system emission result annually using 12 % efficient system per year.

Coming to environmental relevance despite all four varieties of buildings did not attain self-sufficiency to cover the all demand and custom demand except the research demand case annually through the period year. Mitigation of GHG emission varies considerably between them depending on the amount in kilo gram of CO₂ and also in comparison with kilo gram of CO₂ from conventional grid as per predicted emission factor. For the condominium residential building that is CR the annual GHG emission per kwh of electric generated range from kg of 1,540 CO₂ per building foot print to 518,897.77 on Jemo 1 blocks lot which are 337 per Kilo watt hour generated with the proposed solar system to 1,077 kg CO₂ per building foot print to 362,970.76 in the blocks lot mentioned. This show capacity of the PV system will be only 70% as compared to the conventional grid.

Surprisingly this reduction can be compared weather it implicit a higher add up to the government co- promises in its nationally determined contribution NDCs in the frame of the Treaty of Paris regarding distribution of energy with photovoltaic panels by 2030 for the entire nations, which is 64%.

Similar assessment for the feasible communal building show the annual GHG emission per kwh of electric generated range from kg of 2,160 CO₂ per building foot print to 108,000 on Jemo 1 blocks lot which are 50 per killo watt hour generated with the proposed solar system to 732 kg CO₂ per building foot print to 36,605 in the blocks lot mentioned. This show capacity of the PV system will be only 34% as compared to the conventional grid.

Since the conventional electric grid is mainly from hydropower to the limit of 95% adding other renewable energy sources like wind and geo thermal make the limit of the resource 98%. Whereas fossil fuel powered energy service are not mixed in the grid energy currently and will not be in the far future; proposed system climatic change mitigation is un-preferable generally.

However, it should be noted that in the past years the use of fossil fuel to account for self-sufficiency service due growing interruption and to facilitate as usual business scenario has increased. For instance BU₁ building all reactions for countering sudden electricity interruption and to resume it's school activity is from energy source produced from fossil fuel source using generator, with GHG emission annually close to 1000 kg of CO₂ equivalent. If the different such private or government customer affiliated buildings are analyzed as BU₁ considering their location in urban areas as well as using the electricity demand availability, these other buildings will show same situation as BU₁ with their electricity consumption being nourished with fossil fuels. Therefore, despite the fact that the potential for photovoltaic installation in roof tops is less feasible on the building assessed, We argue that policy action in this direction would be increased interest in BU₁

purpose type of buildings area since the reduction in GHG emission are substantially higher than in CR buildings.

In fact, transportation, residential buildings and waste have been identified as most intensive sector in terms of GHG emission in Addis Ababa. However, it appears that implementation of decentralized photovoltaic technology in condominium building areas could imply reduction in emissions; especially targeting these sectors of urban high rise building area. Thus, considering residential application of CR, CC buildings and their relation of service to transportation sector can be a select application for roof top PV.

Beyond the GHG emission reductions detected within the system boundary considered in LCA, it is considered that environmental benefits of implementing decentralized photovoltaic will most likely affect other environmental aspects, including particulate matter from back-up generator including noise generated in city. Furthermore, land use is an important credit in the proposed system, since the use of spaces in urban roof top implies an inherent optimization of urban land resources. Interestingly, the balance system to store energy at night or whenever needed did not create significant emissions. Nevertheless, it should be noted that these batteries weather Lithium ion or lead acid can cause important environmental burden in terms of human toxicity, eco-toxicity or metal depletion. And a technology wise administration is also of paramount importance either in recycling, storing, eliminating or using its salvage value.

As result suggest PV solar energy obtained from roof top areas would allow attaining full coverage of the self sufficient determined energy demand. Nevertheless, it should be noted that these medium economy sized location in emerging situation have below average per capita consumption of electricity. In fact electricity demand in the buildings is not high, if data are compared to more city centers where demand for electricity is higher and also taking the before said factor; livable, resilient, green and sound capital city. We hypothesize that the energy self-sufficiency factor would be significantly higher than that obtained in less economic location. While these less economic residential

location are still absorbing and expanding urban growth through a steady sprawl, they are experiencing two simultaneous phenomenon; an increase in the vertical profile of the building, together with formal urban planning, along the city residential route thanks to the escalated urbanization going on and chaotic migration to it as a result of relocation through resettlement action plan from developing woreda's or less urbanized location cities of the nation. In other words, larger economic building will require more complex, multi approach policy to achieve tangible feasible solar PV installation potential.

Buildings in the study urban location do not tend to show high carbon emissions per capita for several reasons, including lower income per capita than other comparative urban residential building of the city. However, they do need to shift from carbon locked self sufficiency fulfillment in order to elude similar trends to those class of society where vulnerability to energy security is counter acted. Although it is an understood fact and observably global warming does not have a significant relevant space in the practiced policy agenda in Addis Ababa, it is fair to say that the current situation is changing due to the capital city commitment as can be attested in day to day changes for better habitat in terms of sound environment. Recent times attention may related to the so called treaty of Paris as by government of the nation and the city likewise in greenification works. In contrast, recently events in Addis Ababa are glared with successive tap water shortage on one hand in connection with electric power shortage to water pumps. And on the other hand in connection with greenification demand for electricity lighting both in decorative and lighting purpose increases the management associated in delivery of grid power. This shows the challenges that are presented to the centralized water and energy system to more constrained supply cases.

Hence, we venture that if decentralized urban renewable energy systems are brought into the market with sufficient penetration capability both in terms of installation and up keeping they could be seen as an attractive option to foster urban resilience and energy security.

4.2.3 Sensitivity Analysis

The sensitivity analysis that was performed has the main objective of determining the robustness of the results computed in the study.

- In the first place, the current urban morphology of the Jemo building location, the residential population density would still have room for substantial increases in dwellers per family by percentage of 1.5 to 2 % annually. Thus for 10 years range the population per building shall reach 144 from 120. Thus, in the scenario of demand at customized condition the demand was 14.26 kWhr/m^2 for the increase in population in dweller aspect according to demand there will be increase demand. Thus self sufficiency factor is affected. In addition, in regard to geographic potential for PV application trends of solar radiation, monthly averaged temperature values for the specified 10 or 15 years year range have the trend of increasing, and all system rated values will also face de-ratings; these will in total to lead to a decreased in performance of efficiency of module.
- Secondly, an increase from 12 to 25 % in the efficiency of solar modules would also increase the electricity self sufficiency factor by 2 with respect to the base line scenario. While the result may be fairly evident, it demonstrates that under a ceteris paribus situation, the capabilities of these building location to obtain their electricity from solar module would improve thanks to optimistic technological innovation that will happen at same cost of the lower efficiency.
- When the previous scenarios are combined in third condition; residential density could be allowed to be increased further as compared to suggested first case. In other words, technological innovation in photovoltaic energy would progressively allow a shift to socio economic wider, more inhabited buildings and appropriate for customized self sufficient need.

- As fourth step, which assumes a steady growth of per capita electricity demand and residential population density. This depicts a situation in which condo locations would have self sufficient capacity in self generated electricity with solar modules to power the said self sufficient need. This shows that the proposed installations are an interestingly way to mitigate current GHG emissions, while improving energy security and resilience in these areas. However, long term policies should aim at keeping the infrastructure energy sources in these urban environments beyond the first capital invested solar modules system and the central grid system shall be supported to avoid its magnanimous pressure of financing shortage whenever new plant is built. In addition complex and redundant network of transmission lines along road side routes or in landscapes shall be optimized.

Nevertheless, it is important to consider that urban planning is continuously subject to technological and social changes. Hence, although the scenarios modeled provide interesting projections for the future, the influence of novel technology and behavioral changes in society are not accounted for in the sensitivity analysis descriptions.

- Finally, as fifth step; PVSyst TRIAL Version 7.4.5 ; PVSyst - Simulation report Standalone system Project: DEMO - Stand alone system at Dakar Variant: 2.2 kWh/day, 480 Wp, slightly undersized Standalone system with batteries System power: 480P [Annex 3.0].

Simulation report was used as the sensitivity analysis.

❖ Main data and comparison:

- Geographic Location:
 - Latitude: 14.48° N
 - Longitude: -17.01° W (Dakar, Senegal)
 - Global Horizontal Solar Irradiation:
 - Annual: 2,256.5 kWhr/m²
 - Solar Energy Available: 767.77 kWhr/year

Maximum Irradiation: 224 kWhr/m² (April)
Minimum Irradiation: 150 kWhr/m² (December)
Daily Total Radiation Average: Not available
Daily Hours and Monthly Max/Min Temperature: Not available

- System Installation:

Orientation:

Polar Direction: South

Azimuth Degree: 0°

Population Density: Not available

Interference Factor: -2.6

Orientation Factor: +3.6%

Shading Factor: 0

Roof Surface Correction Factor: Slope (15°)

Cleaning: -0.3

Tilt: 0

Potential Area Size: 4 m²

- System Specifications:

Nominal Power:

Peak Power per Module: 60 Wp (Eight units = 480 Wp)

Area Module: 4.5 m²

Test Condition: 1000 W/m² and 25°C

Peak-Power Voltage: 15V

Peak-Power Current: 3.5A

Short-Circuit Current: Not available

Energy Demand:

Daily Demand: 2.2 kWhr/day

Annual Demand: 804 kWhr

Annual Electricity Production: 974 kWhr (at 10.79% efficiency)

- Storage:
 - Size: 6 units (12V battery, 160 Ahr)
 - Configuration: 2 in series, 3 in parallel (480 Ahr)
 - State of Charge (SOC): Discharging 20%
 - Stored Energy: 9.2 kWhr

❖ Analysis similar to RTPVEPM:

- “The angle of incidence for the average day of each month of the year was analyzed for azimuth classes at 0 degrees (oriented south) and for a 15-degree slope at various hour angles throughout the day.”

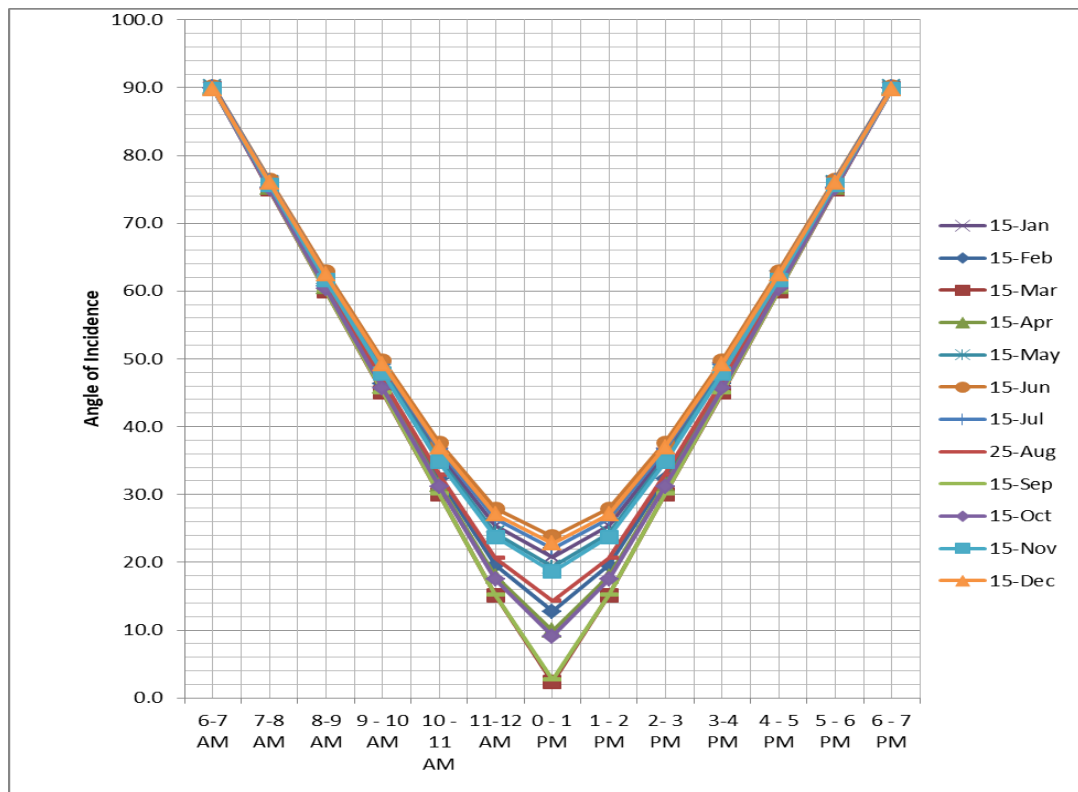


Fig 4.28: Incidence Angle versus Hour of the Representative Day of the Month of the Year for Dakar-Senegal Project as Jemo CR Standalone PV Analysis, Incidence angle View.

- “A smaller incidence angle, as low as 2 degrees, was observed at or near zero hour angle in September, and around 24 degrees in June. When the incidence angle was low in September, the corresponding monthly kWhr/m² from the demo was not at its maximum. Similarly, in June, when the incidence angle was comparatively higher, the corresponding kWhr/m² from the demo was not the lowest.”
- “To define the azimuth angle, it is essential to find the optimum slope for a better incidence angle, which should be smaller for most of the time.”

Table. 4.17 Dakar-Senegal Project as Jemo CR Standalone PV Analysis, Slope View Results.

| Day of month | Hour | Slope in Deg. | | | | | | | | | |
|--------------|------|---------------|------|------|------|------|------|------|------|------|------|
| | | 0 | 5 | 10 | 15 | 20 | 25 | 45 | 60 | 75 | 90 |
| 15-Jan | 0 | 35.7 | 30.7 | 25.7 | 20.7 | 15.7 | 10.7 | | 24.2 | 39.2 | 54.2 |
| | | 5 | 5 | 5 | 5 | 5 | 5 | 9.25 | 5 | 5 | 5 |
| 15-Feb | 0 | 27.7 | 22.7 | 17.7 | 12.7 | | | 17.2 | 32.2 | 47.2 | 62.2 |
| | | 7 | 7 | 7 | 7 | 7.77 | 2.77 | 3 | 3 | 3 | 3 |
| 15-Mar | 0 | 17.3 | 12.3 | | | | | 27.7 | 42.7 | 57.7 | 72.7 |
| | | 0 | 0 | 7.30 | 2.30 | 2.70 | 7.70 | 0 | 0 | 0 | 0 |
| 15-Apr | 0 | | | | | 14.9 | 19.9 | 39.9 | 54.9 | 69.9 | 84.9 |
| | | 5.07 | 0.07 | 4.93 | 9.93 | 3 | 3 | 3 | 3 | 3 | 3 |
| 15-May | 0 | | | 14.3 | 19.3 | 24.3 | 29.3 | 49.3 | 64.3 | 79.3 | 94.3 |
| | | 4.31 | 9.31 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 15-Jun | 0 | | 13.8 | 18.8 | 23.8 | 28.8 | 33.8 | 53.8 | 68.8 | 83.8 | 98.8 |
| | | 8.83 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

| Day of month | Slope in Deg. | | | | | | | | | | |
|--------------|---------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | Hour | 0 | 5 | 10 | 15 | 20 | 25 | 45 | 60 | 75 | 90 |
| 15-Jul | 0 | 7.04 | 12.04 | 17.04 | 22.04 | 27.04 | 32.04 | 52.04 | 67.04 | 82.04 | 97.04 |
| 25-Aug | 0 | 0.70 | 4.30 | 9.30 | 14.30 | 19.30 | 24.30 | 44.30 | 59.30 | 74.30 | 89.30 |
| 15-Sep | 0 | 12.26 | 7.26 | 2.26 | 2.74 | 7.74 | 12.74 | 32.74 | 47.74 | 62.74 | 77.74 |
| 15-Oct | 0 | 24.08 | 19.08 | 14.08 | 9.08 | 4.08 | 0.92 | 20.92 | 35.92 | 50.92 | 65.92 |
| 15-Nov | 0 | 33.63 | 28.63 | 23.63 | 18.63 | 13.63 | 8.63 | 11.37 | 26.37 | 41.37 | 56.37 |
| 15-Dec | 0 | 37.82 | 32.82 | 27.82 | 22.82 | 17.82 | 12.82 | 7.18 | 22.18 | 37.18 | 52.18 |
| Sum | | 17.8 | 16.1 | 15.2 | 14.8 | 15.3 | 16.3 | 30.4 | 45.4 | 60.4 | 75.4 |
| Average | | 8 | 0 | 5 | 7 | 3 | 1 | 8 | 8 | 8 | 8 |

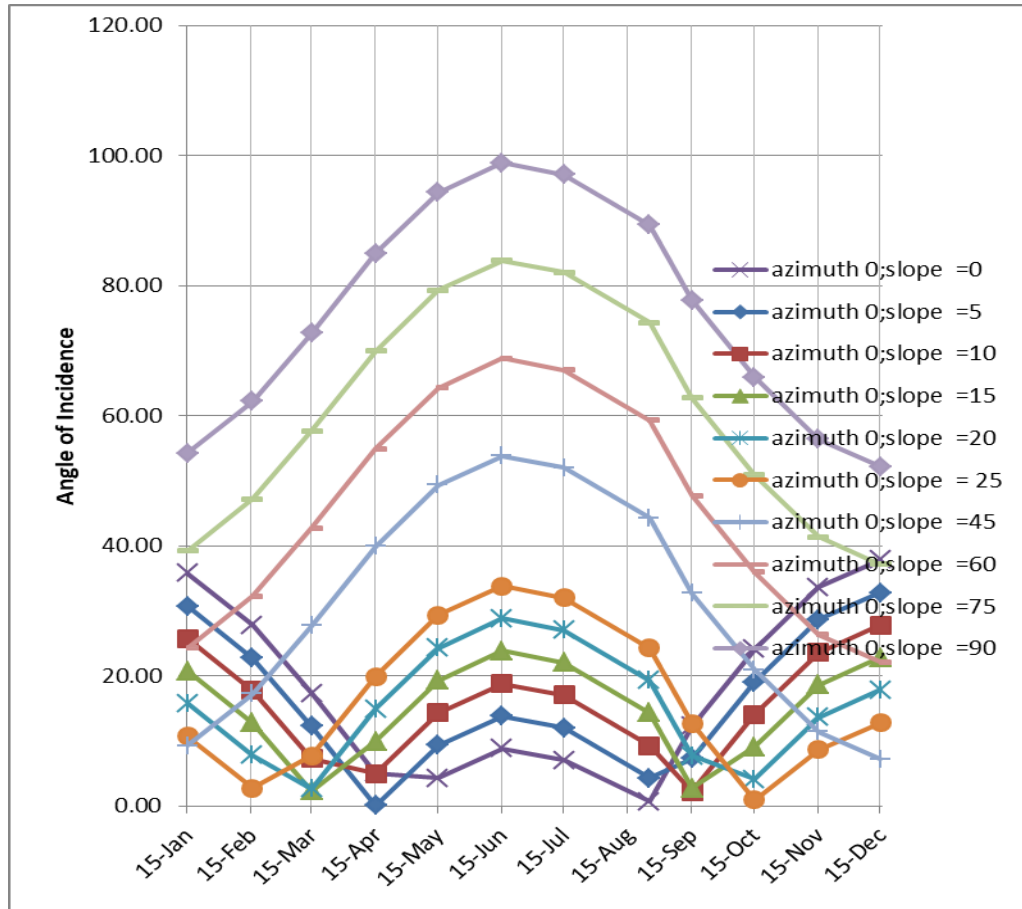


Fig 4.29: Incidence Angle versus Representative Day of the Month of the Year for Dakar-Senegal Project as Jemo CR Standalone PV analysis, Slope View

- “Indeed, the 15-degree angle is more optimal for reducing the incidence angle, as shown by the average results.”
- “The 15-degree slope is characterized by a lower average incidence angle, indicating that the azimuth direction with the lowest incidence angle is the next best option.”
-

Table. 4.18 Dakar-Senagal Project as Jemo CR standalone PV analysis, Azimuth View Results

| | | Azimuth Degree | | | | | | | | | | |
|---------|---|----------------|------|------|------|------|------|------|------|------|------|------|
| hour | | -180 | -145 | -120 | -90 | -45 | 0 | 45 | 90 | 120 | 145 | 180 |
| 15-Jan | 0 | 50.7 | 48.7 | 44.9 | 38.3 | 27.0 | 20.7 | 27.0 | 38.3 | 44.9 | 48.7 | 50.7 |
| | | 5 | 0 | 0 | 8 | 2 | 5 | 2 | 8 | 0 | 0 | 5 |
| 15-Feb | 0 | 42.7 | 40.9 | 37.4 | 31.2 | 19.9 | 12.7 | 19.9 | 31.2 | 37.4 | 40.9 | 42.7 |
| | | 7 | 0 | 0 | 8 | 6 | 7 | 6 | 8 | 0 | 0 | 7 |
| 15-Mar | 0 | 32.3 | 30.7 | 27.9 | 22.7 | 12.4 | | 12.4 | 22.7 | 27.9 | 30.7 | 32.3 |
| | | 0 | 7 | 0 | 5 | 0 | 2.30 | 0 | 5 | 0 | 7 | 0 |
| 15-Apr | 0 | 20.0 | 19.3 | 18.0 | 15.8 | 11.9 | | 11.9 | 15.8 | 18.0 | 19.3 | 20.0 |
| | | 7 | 6 | 6 | 1 | 5 | 9.93 | 5 | 1 | 6 | 6 | 7 |
| 15-May | 0 | 10.6 | 11.7 | 13.3 | 15.5 | 18.3 | 19.3 | 18.3 | 15.5 | 13.3 | 11.7 | 10.6 |
| | | 9 | 3 | 6 | 9 | 0 | 1 | 0 | 9 | 6 | 3 | 9 |
| 15-Jun | 0 | | | 13.0 | 17.3 | 22.1 | 23.8 | 22.1 | 17.3 | 13.0 | | |
| | | 6.17 | 9.24 | 1 | 6 | 3 | 3 | 3 | 6 | 1 | 9.24 | 6.17 |
| 15-Jul | 0 | | 10.0 | 12.9 | 16.5 | 20.5 | 22.0 | 20.5 | 16.5 | 12.9 | 10.0 | |
| | | 7.96 | 6 | 7 | 3 | 7 | 4 | 7 | 3 | 7 | 6 | 7.96 |
| 25-Aug | 0 | 15.7 | 15.5 | 15.3 | 15.0 | 14.5 | 14.3 | 14.5 | 15.0 | 15.3 | 15.5 | 15.7 |
| | | 0 | 8 | 6 | 2 | 2 | 0 | 2 | 2 | 6 | 8 | 0 |
| 15-Sep | 0 | 27.2 | 25.9 | 23.5 | 19.2 | 10.6 | | 10.6 | 19.2 | 23.5 | 25.9 | 27.2 |
| | | 6 | 9 | 9 | 9 | 6 | 2.74 | 6 | 9 | 9 | 9 | 6 |
| 15-Oct | 0 | 39.0 | 37.3 | 34.0 | 28.1 | 16.9 | | 16.9 | 28.1 | 34.0 | 37.3 | 39.0 |
| | | 8 | 1 | 0 | 3 | 5 | 9.08 | 5 | 3 | 0 | 1 | 8 |
| 15-Nov | 0 | 48.6 | 46.6 | 42.8 | 36.4 | 25.0 | 18.6 | 25.0 | 36.4 | 42.8 | 46.6 | 48.6 |
| | | 3 | 2 | 9 | 6 | 9 | 3 | 9 | 6 | 9 | 2 | 3 |
| 15-Dec | 0 | 52.8 | 50.7 | 46.8 | 40.2 | 28.9 | 22.8 | 28.9 | 40.2 | 46.8 | 50.7 | 52.8 |
| | | 2 | 2 | 6 | 6 | 2 | 2 | 2 | 6 | 6 | 2 | 2 |
| Sum | | 29.5 | | | | | | | | | | |
| Average | | 2 | 28.9 | 27.5 | 24. | 19.0 | 14.8 | 19.0 | 24.7 | 27.5 | 28.9 | 29.5 |

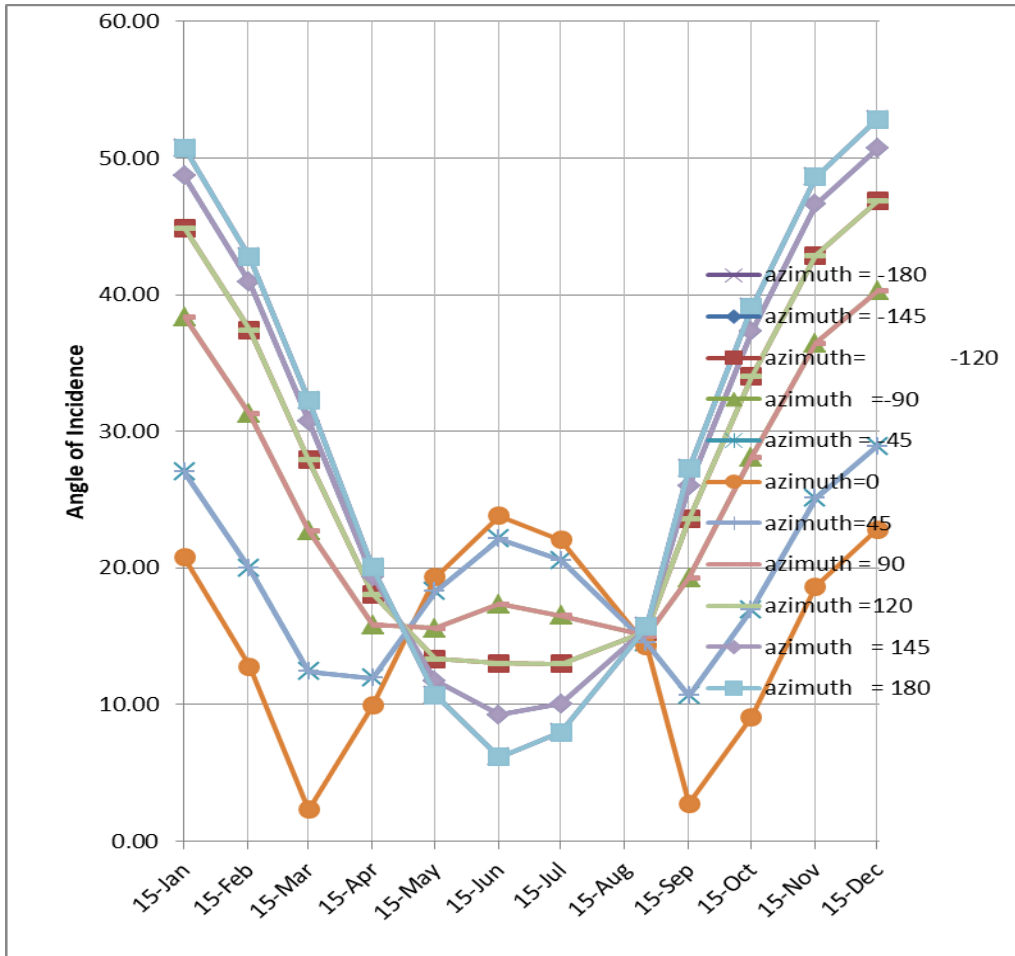


Fig.4.30: Incidence Angle versus Representative Day of the Month of the Year for Dakar-Senagal Project as Jemo CR Standalone PV Analysis, Azimuth View.

- “At an azimuth angle of 0 degrees, a lower average value is observed, as depicted in the graph.”
- “The data set for April was selected due to higher solar radiation, while December was chosen for its lower solar radiation.”

Table 4.19 Dakar-Senagal Project as Jemo CR Standalone PV Analysis, Data set Generated Sample.

| | | April | | | December | | |
|------|--------|--------------|----------|----------------------------|--------------|----------|----------------------------|
| Hour | Li(wh) | IT(MJ) | Ei(wh) | Energy available to demand | IT(MJ) | Ei(wh) | Energy available to demand |
| 12-1 | 50.00 | (482,500.86) | 2,147.28 | 4295% | (309,911.81) | 2,420.14 | 4840% |
| 1--2 | 50.00 | (497,929.15) | 1,815.59 | 3631% | (350,030.24) | 2,066.75 | 4133% |
| 2--3 | 50.00 | (506,933.02) | 1,228.68 | 2457% | (403,522.27) | 1,442.74 | 2885% |
| 3--4 | 50.00 | (472,869.98) | 585.19 | 1170% | (425,154.52) | 739.84 | 1480% |
| 4--5 | 50.00 | (356,458.79) | 93.44 | 187% | (365,431.10) | 170.36 | 341% |
| 5--6 | 50.00 | (129,603.78) | (63.15) | -126% | (186,834.08) | (75.65) | -151% |
| 6--7 | 50.00 | 213,036.54 | 241.19 | 482% | 122,476.28 | 127.01 | 254% |

| Hour | Li(wh) | IT(MJ) | Ei(wh) | Energy available to demand | IT(MJ) | Ei(wh) | Energy available to demand |
|---------------|---------------|------------------|---------------|-----------------------------------|------------------|----------------|-----------------------------------|
| H 7-- 8 | 50.00 | 648,111. 81 | 1,002.3 9 | 2005% | 541,420.9 9 | 798.92 | 1598% |
| 8-- 9 | 50.00 | 1,125,17 1.07 | 2,082.8 7 | 4166% | 1,017,438. 82 | 1,803.05 | 3606% |
| 9-- 10 | 50.00 | 1,575,67 4.63 | 3,264.9 8 | 6530% | 1,476,501. 97 | 2,926.35 | 5853% |
| 10-- 11 | 50.00 | 1,927,31 8.82 | 4,202.3 0 | 8405% | 1,839,304. 36 | 3,828.03 | 7656% |
| 11-- 12 | 250.0 0 | 2,120,11 0.79 | 4,537.0 5 | 1815% | 2,039,533. 62 | 4,152.57 | 1661% |
| 12-- -1 | 50.00 | 2,120,11 0.79 | 4,341.6 8 | 8683% | 2,039,533. 62 | 3,964.63 | 7929% |
| 1-- -2 | 50.00 | 1,927,31 8.82 | 3,758.2 9 | 7517% | 1,839,304. 36 | 3,404.31 | 6809% |
| 2-- -3 | 80.00 | 1,575,67 4.63 | 2,829.3 9 | 3537% | 1,476,501. 97 | 2,518.17 | 3148% |
| | | | | | | | |

| Hour | Li(wh) | IT(MJ) | Ei(wh) | Energy available to demand | IT(MJ) | Ei(wh) | Energy available to demand |
|--------|--------|--------------|----------|----------------------------|--------------|----------|----------------------------|
| 3--4 | 80.00 | 1,125,171.07 | 1,771.81 | 2215% | 1,017,438.82 | 1,521.78 | 1902% |
| 4--5 | 80.00 | 648,111.81 | 823.21 | 1029% | 541,420.99 | 649.25 | 812% |
| 5--6 | 80.00 | 213,036.54 | 143.03 | 179% | 122,476.28 | 70.58 | 88% |
| 6--7 | 80.00 | (129,603.78) | (15.38) | -19% | (186,834.08) | (6.78) | -8% |
| 7--8 | 190.00 | (356,458.79) | 224.83 | 118% | (365,431.10) | 305.06 | 161% |
| 8--9 | 190.00 | (472,869.98) | 737.70 | 388% | (425,154.52) | 876.97 | 462% |
| 9--10 | 190.00 | (506,933.02) | 1,392.17 | 733% | (403,522.27) | 1,572.89 | 828% |
| 10--11 | 190.00 | (497,929.15) | 1,953.24 | 1028% | (350,030.24) | 2,163.51 | 1139% |
| 11--12 | 190.00 | (482,500.86) | 2,302.90 | 1212% | (309,911.81) | 2,520.09 | 1326% |

- Taking April, a month with good radiation, the hourly average daily demand is almost never in shortage but in excess by 8380% from 10 to 11 AM.
- The available energy for April and December from the demo was 74.04 kWh and 57.16 kWh, respectively. According to RTPVEPM, the energy supplied monthly for April is 1,242.02 kWh and for December is 1,198.9 kWh.

Table 4.20: Balances and Main Result from Dakar- Senegal Stand Alone Project Report.

| Balances and main results | | | | | | | | |
|---------------------------|-------------------|-------------------|--------------|------------|-------------|-------------|-------------|----------------|
| Month | Global Hor KWh/m2 | Global Eff KWh/m2 | E_Avail KW h | E_Used KWh | E_Mis s KWh | E_Use r KWh | E_Loa d KWh | SolFra c ratio |
| Jan | 165.90 | 183.80 | 63.53 | 0.00 | 8.50 | 67.23 | 75.73 | 0.89 |
| Feb | 181.60 | 192.70 | 66.46 | 0.00 | 5.84 | 62.56 | 68.40 | 0.92 |
| Mar | 211.10 | 209.70 | 72.77 | 0.00 | 0.00 | 67.73 | 67.73 | 1.00 |
| Apr | 223.90 | 208.10 | 74.04 | 3.16 | 0.00 | 65.54 | 65.54 | 1.00 |
| May | 218.70 | 192.30 | 68.48 | 3.50 | 0.00 | 67.73 | 67.73 | 1.00 |
| | | | | | | | | |

| Month | Global Hor KWh/m2 | Global Eff KWh/m2 | E_ Ava il KW h | E Unused KWh | E_Mis s KWh | E_Use r KWh | E_Loa d KWh | SolFra c ratio |
|----------|----------------------|----------------------|----------------------------|--------------------|----------------|----------------|----------------|-------------------|
| June | 196.40 | 169.50 | 58.4 4 | 0.00 | 0.00 | 60.05 | 60.05 | 1.00 |
| July | 184.70 | 162.00 | 55.6 6 | 0.00 | 8.04 | 54.02 | 62.06 | 0.87 |
| Aug. | 180.30 | 164.30 | 56.6 1 | 0.00 | 5.99 | 56.07 | 62.06 | 0.90 |
| Sept. | 175.40 | 168.90 | 58.1 8 | 0.00 | 10.39 | 55.15 | 65.54 | 0.84 |
| Oct / | 198.00 | 204.40 | 71.2 4 | 0.00 | 0.00 | 67.73 | 67.73 | 1.00 |
| Nov. | 170.40 | 186.70 | 65.2 1 | 0.00 | 0.00 | 65.54 | 65.54 | 1.00 |
| Dec. | 150.10 | 166.60 | 57.1 6 | 0.00 | 20.16 | 55.57 | 75.73 | 0.73 |
| Yr. | 2256.50 | 2209.00 | 767. 78 | 6.67 | 58.92 | 744.92 | 803.84 | 0.93 |

Table. 4.21: Dakar-Senagal Project as Jemo CR Standalone PV analysis, Solar Fraction Result.

| Month | (Fraction of load by PV with out battery) Δfo | load carried by PV without battery; Whr | (Fraction of load carried by battery storage, Δfs | load carried by battery, Whr | fraction by PV; fs | load carried by PV system, Whr |
|-------|--|--|--|---------------------------------|-----------------------|-----------------------------------|
| Jan | (5.7734) | -12,990.26 | 6.87 | -15,467.96 | (12.65) | -28,458.22 |
| Feb | (7.45) | -16,765.62 | 8.90 | (20,020.46) | (16.35) | (36,786.08) |
| March | (8.44) | -18,999.85 | 10.23 | (23,008.22) | (18.67) | (42,008.06) |
| April | (7.60) | -17,091.26 | 9.01 | (20,276.94) | (16.61) | (37,368.20) |
| May | (5.76) | -12,954.69 | 6.79 | (15,277.70) | (12.55) | (28,232.40) |
| June | (4.53) | -10,187.87 | 5.45 | (12,272.57) | (9.98) | (22,460.44) |
| July | (4.92) | -11,068.77 | 5.87 | (13,209.67) | (10.79) | (24,278.45) |
| Aug | (6.47) | -14,546.32 | 7.61 | (17,118.77) | (14.07) | (31,665.08) |
| Sept | (7.78) | -17,497.19 | 9.27 | (20,865.30) | (17.05) | (38,362.49) |
| Oct | (7.52) | -16,913.03 | 8.97 | (20,184.27) | (16.49) | (37,097.30) |
| Nov | (6.05) | -13,620.36 | 7.19 | (16,185.37) | (13.25) | (29,805.74) |

| Month | (Fraction of load by PV with out battery) Δf_o | load carried by PV without battery; Whr | (Fraction of load carried by battery storage, Δf_s | load carried by battery, Whr | fraction by PV; fs | load carried by PV system, Whr |
|--------------|--|--|--|---|-------------------------------|---|
| Dec | (5.20) | -11,707.22 | 6.24 | (14,032.26) | (11.44) | (25,739.48) |
| Sum | | -174,342.43 | | -207,919.50 | | -382,261.94 |

The table presenting the monthly average daily PV system results shows:

The annual energy need of the user equals 803.84 kWhr. The energy supplied to the user is 745 kWhr, as reported from the simulation. The RTPVEPM sensitivity check indicates that the load carried by the PV system is 378,820 Whr, excluding the negative sign. However, there is a difference of 366.2 kWhr compared to the demo result.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this research paper, an attempt has been made to assess the RTPVEPM casing condominiums in Addis Ababa city, Ethiopia. Based on the evidence gathered, the following conclusions are presented:

- The proposition is supported by demonstrating that potential mapping addresses geographic, physical, technical, and economic constraints while evaluating GHG mitigation potential.
- The prediction of PV energy potentials is assessed through stages of geographic, physical, technical, and economic criteria.
- Firstly, geographic potential is essential to identify the amount of solar insolation and other climatic characteristics useful for assessment.
- Secondly, physical potential is expressed by the orientation of the roof cover and the available size, along with other nearby physical characteristics.
- Thirdly, technical potential is predicted from two perspectives: the needed demand and the available power from the quantified geographic and physical potential.
- Fourthly, economic potential examines the forecasted cost with the sized technical and physical potential, dictating a possible potential, setting either limitations or expandable size according to stated economic sizes.
- From the assessed Jemo 1 residential blocks and the associated communal buildings, a customized demand scenario was set. The building rooftop also serves as a control, with

various other habitats such as a school compound and a warehouse rooftop from the Jemo surroundings.

- For CR buildings, an economic potential assessment sets the feasibility and worthiness of investment for nearly halved initial capital investment cost or its predecessor stage, which is technical potential demand satisfaction further customized by specific limits. Likewise, technical potential to the limit of one-fifth is achieved considering a customized research demand size.
- For this building block type, capital investment was 1,462,406.40 birr for a demand size of 14.26 kWhr/day or 5,205 kWhr annual customized demand. This was based on a rooftop area of 143 m² on a block. An additional 7.2 kWhr of power from storage equipment is cited for system size fulfillment. From a selected 1.31 m² sized solar panel module, 108 panels were found to be needed. Characterized economic potential using life cycle and future worth assessment dictates a capital investment amount of 805,649.00 birr.
- However, satisfying this potential depends on the parameter utilizability. Thus, all varieties of efficiency stages and best operating points are adjusted together with this parameter, finding specific limits to utilities like the economic potential prediction. The physical size area taken as average has a corresponding direct relation to economic worthiness and technical operation, as it is just a rooftop where operational limits and sizes cost are factors.
- Understanding the roof area with PV potential and energy outputs has been developed, which is significant for policy frameworks to shift Addis Ababa towards a livable city on a resilient path. This will be considered not only according to the goal of CRGE but also the city administration's strategic dreams for its citizens.

5.2 Recommendations

- The research gap or knowledge should be addressed using recent papers or similar topics. Novelty and new findings should be highlighted in the subject research for discussion and summarized in the conclusion. Similarly, the influence of novel technology and behavioral changes should be accounted for in the sensitivity analysis description.
- The slope predicted as 45 degrees and slope variation from 0 to 95 degrees in graphical analysis should be better justified. The type of orientation, including slope and tilt angle selection, should be more thoroughly justified. The comparison of incidence angle versus hour of representative days of the month for the sensitivity location (Dakar) and the original location (Jemo) should be clarified.
- The selected storage battery size and payback period analysis are imperfect and should be rectified. Considering most household loads are AC, inverter design should be included. And if households use Mitad simultaneously, the power requirement in 30 houses of a block will be high. How this consideration supports the research objective is a supportive idea to work on.
- Environmental sensitivity and GHG reduction potential expressed lack clarity and should be clarified. Baseline energy sources such as kerosene, LPG, and biomass were not applied, which otherwise would show the possibility of emission reduction comparison results.
- The solar radiation value of 1000 W/m² used to estimate peak power demand is ambiguous and should be rectified. Annual meteorological solar radiation data was used.
- The energy balance analysis results and the numerical data shown in tables should be better described.

REFERENCES

- 1) Kassahun M. and Bishu S. The Governance of Addis Ababa City Turn Around Projects: Addis Ababa Light Rail Transit and Housing, 2017.
- 2) Getnet E. Assessment on the perceived needs of condominium residents on the functional uses and values of neighborhood open spaces: the cases of Jemo one condominium site, Addis Ababa. 2016.
- 3) Seife N. Condominium Buildings Versus Environmental Sustainability In the case of Addis Ababa. 2014.
- 4) Wikipedia (2013). "Renewable energy in Ethiopia." Nov 18, 2019.
- 5) MOWIE (2018). National Energy Policy, Ministry of Water Irrigation and Electricit: 52.
- 6) Tsefaye Y. Assessment of Power Interruptions in Addis Ababa. 2015.
- 7) AACPPO. Addis Ababa City Structure Plan, DRAFT FINAL SUMMARY REPORT. 2017.
- 8) Luque, A. and S. Hegedus, Eds. (2003). Handbook of Photovoltaic Science and Engineering, WILEY.
- 9) Behailu, N., Study and Review on the Design and Performance Aspects of III-V Semiconductor Solar Cells; (Case Study: Comparison on GaAs, Ge, and Si substrate). 2016.
- 10) Bekele, C., TEMPERATURE DEPENDENCE OF THE OPTICAL PROPERTIES OF a-Si:H THIN FILMS FOR SOLAR CELLS 1996.
- 11) Liu, Y.W.D.W.Y., Study on Comprehensive Energy Saving of Shading and Photovoltaics of Roof Added PV Module. 2017.
- 12) Bazan, J., et al. (2017). "Low-carbon electricity production through the implementation of photovoltaic panels in rooftops in urban environments: A case study for three cities in Peru. " Science of the Total Environment: 15.
- 13) Aboushal, E. A. (2018). "Applying GIS Technology for optimum selection of Photovoltaic Panels "Spatially at Defined Urban Area in Alexandria, Egypt" Alexandria Engineering Journal: 10.

- 14) Bergamasco, L. and P. Asinari (2011). "Scalable methodology for the photovoltaic solar energy potential assessment based on available roof surface area: Application to Piedmont Region (Italy)" Science Direct: 15.
- 15) Gagnon, P., et al., Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment, in National Renewable Energy Laboratory. 2016.
- 16) (wikipedia,2023)"Köppen_climate_classification"
https://en.wikipedia.org/wiki/Köppen_climate_classification; Accessed March 2023
- 17) Duffie, J. A. and Beckman W. A. (2013). Solar Engineering of Thermal Process. New Jersey, Canada, WILEY.
- 18) B.P. Verma (1980), Civil Engineering Drawing and House Planning, Khanna Publisher
- 19) Jibrán Khan , M.H.A., 2016 Estimation of rooftop solar photovoltaic potential using geo-spatial techniques: A perspective from planned neighborhood of Karachi Pakistan. 2016.
- 20) Bruno Gaiddon, Henk Kaan, Donna Munro, (2009). Photovoltaics in the Urban Environment. (Earthscan) UK & US.
- 21) MacDonald, S.W. (2014), Quantifying Rooftop Solar Power for the City of Waterloo, Ontario.
- 22) Yohanes, A.T., Optimizing the Technical and Social Benefits of Solar Photovoltaic Technologies in Ethiopia. Energy Center. 2016, AAU. p. 92."
- 23) Woldeyes S. Assessment of Stand-Alone Solar Photovoltaic Power Systems Performance and Reliability for Rural Electrification in Ethiopia Energy Center, (2017) AAU: 145.
- 24) Kacoba S. A. et al. Cost and Energy Analysis of PV Battery Grid Back Up System for a Residential Load in Urban India (2017).
- 25) Gardner T. ETHIOPIANS ADJUST TO LIFE IN AFRICA'S MOST AMBITIOUS SOCIAL HOUSING PROJECT. Thomson Reuters Foundation; <https://www.reuters.com/article/ethiopia-landrights-cities-idINKCN12P1T9/> Accessed 2023.

- 26) https://unfccc.int/sites/default/files/ethiopia_climate_resilient_green_economy.pdf Accessed 2023.
- 27) <https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC?locations=ET>. Accessed 2024.
- 28) Mekonnen A. ASSESSMENT OF THE WATER DEMAND MANAGEMENT OF CONDOMINIUM HOUSES CONSIDERING GREY WATER REUSE- THE CASE OF MICKEY LELAND AND JEMO GARA ADDIS ABABA, ETHIOPIA. (2015). P. 118.
- 29) www.mofed.gov.et/programmes-projects/crge.facility. Accessed 2023
- 30) (Google inc. 2023) <https://earth.google.com>
- 31) ILIC (2014). Integrated Land Information Center,. A. A. C. Administration.
- 32) <https://www.worldbank.org/en/topic/energy/publication/solar-photovoltaic-power-potential-by-country>
- 33) Köppen climate classification - Wikipedia; Accessed 2023,
- 34) Kebede A. Rainwater harvesting for Addis Ababa city; a Case of Jemo Condominium site. (2015) AAU. Pp. 87
- 35) LIBEN S. ASSESSMENT OF ROOFTOP SOLAR PHOTOVOLTAIC POTENTIAL AND ITS CONTRIBUTION FOR GREENHOUSE GAS EMISSION REDUCTION ON MAJOR CONDOMINIUM SITES OF ADDIS ABABA, ETHIOPIA. (2018). P 75
- 36) <https://documents1.worldbank.org/curated/en/694951613157481232/pdf/Project-Information-Document-Access-to-Distributed-Electricity-and-Lighting-in-Ethiopia-P171742.pdf>. Accessed 2023

APPENDIX 1.0

Table data set, for graphical depiction instance and for further analysis generated numerical result; when azimuth is at 90 degree, slope at 45 degree and hour angle -60.

APPENDIX 2.0

House Hold electric demands of residents around Jemo condominiums

Informant -1

| | | | | | |
|---|--|-----------------------|------|---------------|----------------|
| House type 1. | Two children's and a mother aged from 5 to 45 yrs. old, a government worker with monthly gain greater than 30,000.00 | No | | | |
| 1 | Number of People in the house hold | 3 | | | |
| 2 | No of House hold in a block | 40 | | | |
| 3 | Conventional grid electric power unavailability per day; hours | - | | | |
| 4 | Conventional grid electric power unavailability per week, day | 0.072 | | | |
| 5 | Electricity from Conventional Electric power rate per month, ETB | 400 | | | |
| Electric Utility Equipment's in the house | | No | watt | hours per day | Per Month days |
| 6.1 | Lighting (NO. and watts per hour) | (2*9w and 2*60); 4 | 129 | 6 | 30 |
| 6.2 | Refrigerator (No. and watts per hour) | 1 | 350 | 12 | 30 |
| 6.3 | Cloth Washing Machine | 1 | 800 | 1 | 2 |
| 6.4 | Boiler or water heater | 1 | 750 | 2 | 6 |
| 6.5 | Electric Mitad for Enjira backing | 1 | 1500 | 0.5 | 5 |
| 6.6 | Electric Stove (Cooker and Oven) | 1 | 850 | 2.5 | 20 |
| 6.7 | Iron for clothes | 1 | 800 | 0.25 | 1 |
| 6.8 | Electronic Utilities (LCD Televisions, Mobile Chargers..) | (80 and 20W) 2 | 100 | 6 | 26 |

Informant 2.

| | | | | | |
|---------------|---|-----------|------|---------------|----------------|
| House type 2. | Three children's and their parents and a house maid; aged from 5 to 50 yrs. old, a private school teacher worker, and a government worker as transport sector management; with monthly gain 60,000.00 | | | | |
| 1 | Number of People in the house hold | 6 | | | |
| 2 | No of House-holds in a block | | | | |
| 3 | Conventional grid electric power unavailability per day; hours | 0 | | | |
| 4 | Conventional grid electric power unavailability per week, day | 0.014 | | | |
| 5 | Electricity from Conventional Electric power rate per month, ETB | 1000 | | | |
| 6 | Electric Utility Equipment's in the house | No | watt | hours per day | Per Month days |
| 6.1 | Lighting (NO. and watts per hour) | (4*9w and | 276 | 6 | 30 |

| | | | | | |
|-----|---|----------------|------|------|----|
| | | 4*60); #8 | | | |
| 6.2 | Refrigerator (NO. and watts per hour) | 1 | 500 | 12 | 30 |
| 6.3 | Cloth Washing Machine | 1 | 1200 | 1 | 4 |
| 6.4 | Boiler or water heater | 1 | 1200 | 2 | 25 |
| 6.5 | Electric Mitad for Enjira backing | 1 | 1500 | 0.5 | 5 |
| 6.6 | Electric Stove (Cooker and Oven) | 1 | 1200 | 2.5 | 30 |
| 6.7 | Iron for clothes | 1 | 800 | 0.25 | 4 |
| 6.8 | Electronic Utilities (LCD Televisions, Mobile Chargers..) | (80 and 20W) 2 | 100 | 6 | 28 |

Informant 3.

| | | | | | |
|---------------|---|---|--|--|--|
| | | | | | |
| House type 3. | Three children's and their parents and a house maid; aged from 1/2 to 55 yrs. old, a house wife. House maid, children, baby, man, and a government worker as communication sector management; with monthly gain 35,000.00 | | | | |
| 1 | Number of People in the house hold | 5 | | | |
| 2 | No of House-holds in a block | | | | |
| 3 | Conventional grid electric power | 6 | | | |

| | | | | | |
|---|---|-------|------|---------------|----------------|
| | unavailability per day; hours | | | | |
| 4 | Conventional grid electric power unavailability per week, day | 0.500 | | | |
| 5 | Electricity from Conventional Electric power rate per month, ETB | 700 | | | |
| Electric Utility Equipment's in the house | | No | watt | hours per day | Per Month days |
| 6.1 | Lighting (NO. and watts per hour) | 4 | 129 | 6 | 30 |
| 6.2 | Refrigerator (NO. and watts per hour) | 1 | 500 | 12 | 30 |
| 6.3 | Cloth Washing Machine | | 0 | | |
| 6.4 | Boiler or water heater | 1 | 750 | 2 | 12 |
| 6.5 | Electric Mitad for Enjira backing | 1 | 1200 | 0.5 | 5 |
| 6.6 | Electric Stove (Cooker and Oven) | 2 | 1400 | 5 | 28 |
| 6.7 | Iron for clothes | 1 | 800 | 0.25 | 1 |
| 6.8 | Electronic Utilities (LCD Televisions, Computer, Mobile Chargers..) | 2 | 100 | 6 | 30 |

Informant 4.

| | | | | | |
|--------------|---|-------|--|--|--|
| House type 4 | An adult aged from 40s old, a government worker as; with monthly gain 30,000.00 | | | | |
| 1 | Number of People in the house hold | 5 | | | |
| 2 | No of House-holds in a block | 30 | | | |
| 3 | Conventional grid electric power unavailability per day; hours | 0.5 | | | |
| 4 | Conventional grid electric power | 0.143 | | | |

| | | | | | |
|-----|--|----|------|---------------|----------------|
| | unavailability per week, day | | | | |
| 5 | Electricity from Conventional Electric power rate per month, ETB | - | | | |
| | Electric Utility Equipment's in the house | No | watt | hours per day | Per Month days |
| 6.1 | Lighting (NO. and watts per hour) | 5 | 104 | 6 | 30 |
| 6.2 | Refrigerator (NO. and watts per hour) | 1 | 396 | 12 | 30 |
| 6.3 | Cloth Washing Machine | 1 | 1200 | | 4 |
| 6.4 | Boiler or water heater | | | | |
| 6.5 | Electric Mitad for Enjira backing | 1 | 3000 | 0.5 | 5 |
| 6.6 | Electric Stove (Cooker and Oven) | 2 | 2000 | 5 | 30 |
| 6.7 | Iron for clothes | 0 | 0 | 0 | 0 |
| 6.8 | Electronic Utilities (LCD Televisions, Computer, Mobile Chargers...) | 3 | 150 | 3 | 30 |

Informant -5

| | | | | | |
|--------------|---|-------|--|--|--|
| House type 5 | An adult aged from 40s old, a government worker as; with monthly gain 30,000.00 | | | | |
| 1 | Number of People in the house hold | 1 | | | |
| 2 | No of House-holds in a block | 30 | | | |
| 3 | Conventional grid electric power unavailability per day; hours | 0.5 | | | |
| 4 | Conventional grid electric power unavailability per week, day | 0.071 | | | |

| | | | | | |
|-----|---|-----|------|---------------|----------------|
| 5 | Electricity from Conventional Electric power rate per month, ETB | 150 | | | |
| | Electric Utility Equipment's in the house | No | watt | hours per day | Per Month days |
| 6.1 | Lighting (NO. and watts per hour) | 4 | 44 | 7 | 30 |
| 6.2 | Refrigerator (NO. and watts per hour) | 1 | 264 | 12 | 30 |
| 6.3 | Cloth Washing Machine | 1 | 1000 | | 1 |
| 6.4 | Boiler or water heater | | 0 | | |
| 6.5 | Electric Mitad for Enjira backing | | 0 | | |
| 6.6 | Electric Stove (Cooker and Oven) | 1 | 500 | 1.5 | 26 |
| 6.7 | Iron for clothes | 0 | 0 | 0 | 0 |
| 6.8 | Electronic Utilities (LCD Televisions, Computer, Mobile Chargers..) | 2 | 65 | 5 | 30 |

Informant 6.

| | | | | | |
|--------------|--|-------|--|--|--|
| House Type 6 | An adult aged from in 30's, a private organization and a government worker woman ; with monthly gain 40,000.00 | | | | |
| 1 | Number of People in the house hold | 2 | | | |
| 2 | No of House-holds in a block | 32 | | | |
| 3 | Conventional grid electric power unavailability per day; hours | 2 | | | |
| 4 | Conventional grid electric power unavailability per week, day | 1.429 | | | |

| | | | | | |
|-----|--|-----|-------|---------------|-----------------------------|
| 5 | Electricity from Conventional Electric power rate per month, ETB | 200 | | | |
| | Electric Utility Equipment's in the house | No | watts | hours per day | Per Month hours per days |
| 6.1 | Lighting (NO. and watts per hour) | 5 | 104 | 6 | 30 |
| 6.2 | Refrigerator (NO. and watts per hour) | 1 | 176 | 12 | 30 |
| 6.3 | Cloth Washing Machine | | 0 | | |
| 6.4 | Boiler or water heater | | 0 | | |
| 6.5 | Electric Mitad for Enjira backing | 1 | 120 | 0.25 | 3 |
| 6.6 | Electric Stove (Cooker and Oven) | 1 | 400 | 2 | 22 |
| 6.7 | Iron for clothes | 0 | 0 | 0 | 0 |
| 6.8 | Electronic Utilities (LCD Televisions, Computer, Mobile Chargers..) | 3 | 600 | 3 | 30 |

Informant 7.

| | | | | | |
|-----|---|-------|------|---------------|----------------|
| | An adult aged from in 30's, a private and a government worker woman ; with monthly gain 28,000.00 | | | | |
| 1 | Number of People in the house hold | 3 | | | |
| 2 | No of House-holds in a block | | | | |
| 3 | Conventional grid electric power unavailability per day; hours | 2 | | | |
| 4 | Conventional grid electric power unavailability per week, day | 2.000 | | | |
| 5 | Electricity from Conventional Electric power rate per month, ETB | 340 | | | |
| | Electric Utility Equipment's in the house | No | watt | hours per day | Per Month days |
| 6.1 | Lighting (NO. and watts per hour) | 3 | 82 | 6 | 30 |
| 6.2 | Refrigerator (NO. and watts per hour) | 1 | 396 | 12 | 30 |
| 6.3 | Cloth Washing Machine | 1 | 0 | | 4 |
| 6.5 | Electric Mitad for Enjira backing | 1 | 0 | 0.5 | 5 |
| 6.6 | Electric Stove (Cooker and Oven) | 2 | 2000 | 5 | 30 |
| 6.8 | Electronic Utilities (LCD Televisions, Computer, Mobile Chargers..) | 3 | 150 | 3 | 30 |

Informant 8.

| | | | | | |
|--|---|--|--|--|--|
| | An adult aged from in 30's, a private and a government workers; with monthly gain 40,000.00 | | | | |
|--|---|--|--|--|--|

| | | | | | |
|-----|--|-------|------|---------------|----------------|
| 1 | Number of People in the house hold | 2 | | | |
| 2 | No of House-holds in a block | 32 | | | |
| 3 | Conventional grid electric power unavailability per day; hours | 2 | | | |
| 4 | Conventional grid electric power unavailability per week, day | 1.429 | | | |
| 5 | Electricity from Conventional Electric power rate per month, ETB | 1000 | | | |
| | Electric Utility Equipment's in the house | No | watt | hours per day | Per Month days |
| 6.1 | Lighting (NO. and watts per hour) | 5 | 104 | 6 | 30 |
| 6.2 | Refrigerator (NO. and watts per hour) | 1 | 396 | 12 | 30 |
| 6.3 | Cloth Washing Machine | 1 | 1200 | | 4 |
| 6.5 | Electric Mitad for Enjira backing | 1 | 3000 | 0.5 | 5 |
| 6.6 | Electric Stove (Cooker and Oven) | 2 | 2000 | 5 | 30 |
| 6.7 | Iron for clothes | 0 | 0 | 0 | 0 |
| 6.8 | Electronic Utilities (LCD Televisions, Computer, Mobile Chargers, coffee grinders..) | 3 | 1100 | 3 | 30 |

Informant -9

| | | | | | |
|---|---|---|--|--|--|
| | A small business owner in 40's, with a studio type work place | | | | |
| 1 | Number of People in the house hold | 5 | | | |

| | | | | | |
|-----|--|-------|------|---------------|----------------|
| 2 | No of House-holds in a block | 32 | | | |
| 3 | Conventional grid electric power unavailability per day; hours | 2 | | | |
| 4 | Conventional grid electric power unavailability per week, day | 1.429 | | | |
| 5 | Electricity from Conventional Electric power rate per month, ETB | 1200 | | | |
| | Electric Utility Equipment's in the house | No | watt | hours per day | Per Month days |
| 6.1 | Lighting (NO. and watts per hour) | 5 | 82 | 6 | 30 |
| 6.2 | Refrigerator (NO. and watts per hour) | | | | |
| 6.3 | Cloth Washing Machine | | | | |
| 6.4 | Boiler or water heater | 3 | | | |
| 6.5 | UV sterilizers | 2 | 40 | 12 | 30 |
| 6.6 | Electric Stove (Cooker and Oven) | | | | |
| 6.7 | Iron for clothes | 1 | 800 | 2 | 22 |
| 6.8 | Electronic Utilities (LCD Televisions, Computer, Mobile Chargers..) | 2 | 70 | 3 | 30 |

Informant 10.

| | | | | | |
|---|--|-------|--|--|--|
| | A business Owner | | | | |
| 1 | Number of People in the house hold | - | | | |
| 2 | No of House-holds in a block | 32 | | | |
| 3 | Conventional grid electric power unavailability per day; hours | 2 | | | |
| 4 | Conventional grid electric power | 1.429 | | | |

| | | | | | |
|-----|---|---------|------|---------------|----------------|
| | unavailability per week, day | | | | |
| 5 | Electricity from Conventional Electric power rate per month, ETB | 4,000.0 | | | |
| 6 | Electric Utility Equipment's in the house | | | | |
| | | No. | watt | hours per day | Per Month days |
| 6.1 | Lighting (NO. and watts per hour) | 5 | 104 | 6 | 30 |
| 6.2 | Refrigerator (NO. and watts per hour) | 3 | 484 | 12 | 30 |
| 6.3 | Cloth Washing Machine | | | | |
| 6.4 | Boiler or water heater | 2 | 800 | 6 | 30 |
| 6.5 | Electric Mitad for Enjira backing | 2 | 3000 | 4 | 10 |
| 6.6 | Electric Stove (Cooker and Oven) | 4 | 4000 | 10 | 30 |
| 6.7 | Electronic Utilities (LCD Televisions, Computer, Mobile Chargers..) | 2 | 150 | 3 | 30 |

APPENDIX 3.0

Data set generated to observe solar fraction of PV system under research demand case for months January,.....December.

ANNEX 1.0

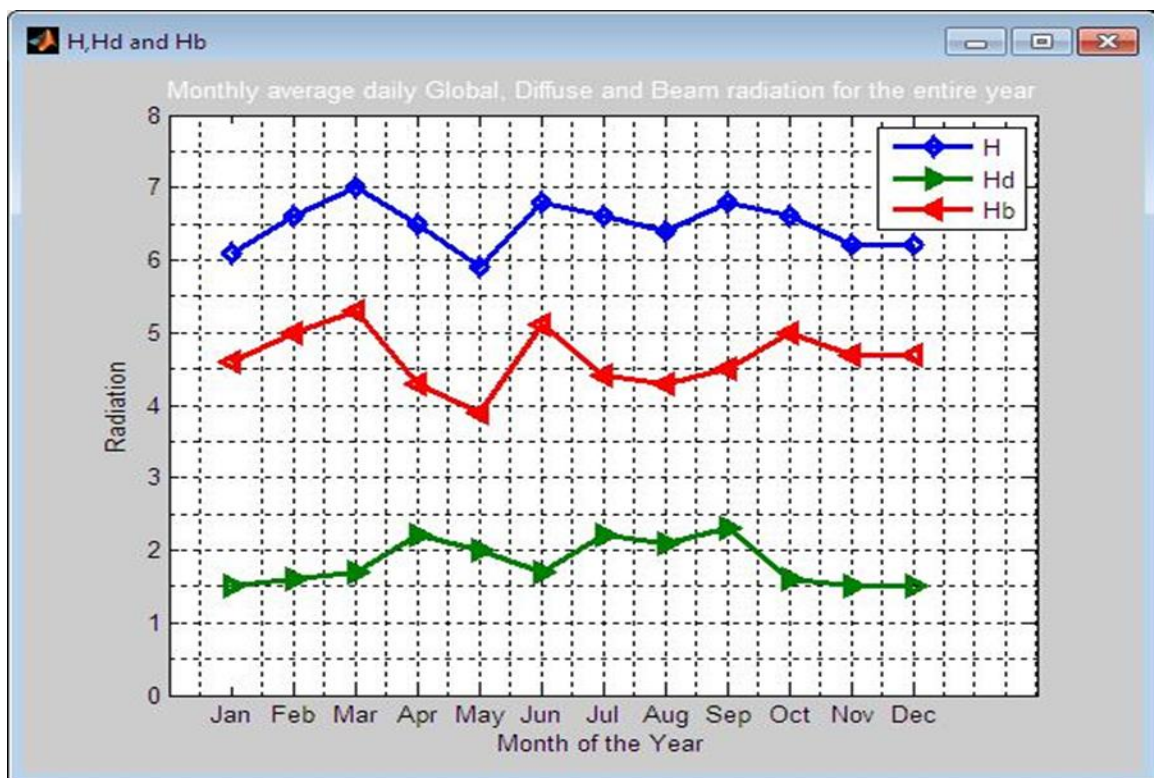
NASA Surface meteorology and Solar Energy: RETScreen Data Ethiopia

| NASA Surface meteorology and Solar Energy: RETScreen Data Ethiopia, Latitude 8, Longitude 38, Elevation 2324 m | | | | | | | | | |
|--|------|-------------------|-------------------------|------|-----------------|---------------|-------------|-------------|--|
| month | | relative humidity | kWh/m ² /day | kPa | wind speed(m/s) | earth temp °C | heating deg | cooling deg | |
| January | °C | 42.00% | 5.97 | 79.4 | 3.5 | 22.4 | 18 | 241 | |
| February | 18 | 37.70% | 6.38 | 79.3 | 3.2 | 24.4 | 3 | 257 | |
| March | 19.4 | 41.90% | 6.26 | 79.3 | 3 | 25.6 | 1 | 315 | |
| April | 20.5 | 54.80% | 6.12 | 79.2 | 3.1 | 24.1 | 5 | 288 | |
| May | 19.8 | 65.50% | 6.05 | 79.3 | 2.9 | 21.8 | 8 | 266 | |
| June | 18.6 | 76.80% | 5.41 | 79.4 | 3 | 18.6 | 29 | 213 | |
| July | 16.9 | 79.50% | 4.75 | 79.4 | 2.6 | 16.9 | 59 | 187 | |
| August | 15.8 | 79.50% | 4.87 | 79.4 | 2.3 | 16.8 | 54 | 192 | |
| September | 15.8 | 76.10% | 5.54 | 79.4 | 2.3 | 17.3 | 41 | 197 | |
| October | 16.1 | 63.00% | 6.17 | 79.4 | 2.8 | 17.8 | 49 | 197 | |
| November | 16.3 | 48.40% | 6.2 | 79.4 | 3.2 | 19.3 | 38 | 202 | |
| December | 16.9 | 46.00% | 6.02 | 79.4 | 3.4 | 20.5 | 33 | 215 | |

ANNEX 2.0

Monthly average daily global diffuses and beam radiation for the entire year.

(<https://www.homerenergy.com/>)



ANNEX 3.0:

PVSyst Demo simulation Project Report for Dakar, Senegal.