JIMMA UNIVERSITY
INSTITUTE OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING
(MSc IN SUSTAIABLE ENERGY ENGNEERING)

ANALYZING ALTERNATIVE USES OF PHOTOVOLTAIC WATER PUMPING SYSTEM FOR SMALL SCALE IRRIGATION AND RURAL ELECTRIFICATION

(Case Study- West Hararghe Zone, Medhicho Kebele, Ethiopia)

A thesis report submitted to the School of Graduate Studies of Jimma University in Partial fulfilment of the requirements for the Degree of Master of Science in sustainable energy engineering

BY: MOHAMMED ALIYI AHMED

JULY, 2018
JIMMA, ETHIOPIA

Jimma University

Institute of Technology

Faculty of Mechanical Engineering

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July, 2018

Jimma, Ethiopia

Declaration

This thesis is my original work and has not been presented for a degree in any other university.

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Acronyms

PV ……………..Photovoltaic

LCC…………….Life Cycle Cost.

GIS…………….. Global International Satellite

DC…………….. Direct Current

IC……………… Initial cost

STC…………….. Standard Test Condition

NOCT…………….Nominal Operating Cell Temperature

MPP…………….. Maximum Power Point

M&O…………….. Maintenance and Operation

M & R …………….. Maintenance and Replacement

DG………………….. Diesel generator

GHG…………..….. Greenhouse gas

KW……………….….. Kilo watt

PVsyst......................photo voltaic system

W………………….. Watt

kWh…………...….. Kilo watt hour

NASA……………….. National Aeronautics and Space Administration

AC……………...….. Alternate current

V………………...….. Volt

P……………………….. Power

I…………………...….. Current

Temp……………..….. Temperature

AW……………………….. Annual worth

PW (DG)……………… Present worth of Diesel system

PW (PV)……………… Present worth of PV system

AW (DG)…………….. ….. Annual worth of Diesel system

AW (PV)……………..Annual worth of PV system

UWC………………..Unit water cost

PW………………….Present worth

A……………………Equal annual cost

i……………………. Discount rate

n……………………Economic life of project

F…………………….Future value

SV…………………..Salvage value

USD.............................US dollar

MPPT........................ Maximum Power Point Track

Acknowledgment

First of all I would like to gratefully acknowledge the Almighty of Allah to for His divine help. My deepest gratitude goes to my advisor **Prof. Dr.A.Venkata Ramayya** and my co advisor **Debela Geneti (MSc)** for all their limitless efforts in guiding me through my work and for providing me useful information and materials.

I would also like to thanks all of my friends and I also want to appreciate all of my instructors / colleague in School of Mechanical Engineering, Jimma Institute of Technology for their continuous encouragement..

Finally, I deeply and sincerely thank my wife Iman Hasen and my family for the unending confidence, constant support and endless love.

Abstract

Energy is one of the key factors for development of the country, and it can gain from different sources, but some of these sources are not environmentally friend, expensive and difficult to transport; like fossil fuel. Using solar energy is the best option to solve this problem. Ethiopia has huge potential for solar energy because it is located near the equator with an average daily solar radiation of 5.25kWh/m^2.Many researches are done on Photovoltaic water pumping technology which used for irrigation. But in Ethiopia, irrigation water is not required during the whole season. In Ethiopia irrigation season is starting from October up to May and in this season products has high value. The objective of this thesis is analyzing alternatively using solar PV energy and solves some energy problem in rural area at non-irrigating season using battery for store energy. Battery storage is one of the essential tools used for operating appliance. Especially battery is very required for the people who live in rural area for appliance during summer like LED light, fridge while during winter season no need of storage battery the pump is work directly to store water for purpose of irrigation. The people living in grid connected system use electric powered pumping or diesel generator for pumping water, but people living in rural off-grid area can't get electric powered pump. Therefore this problem would be solved when they use solar photovoltaic pumping. In this work Madhicho is study area of this thesis and it located at 9.14° latitude and 40.75° longitude. In this thesis analysis of PV water pump by using PVsyst or RETScreen Expert.

Most of the time the major problem of solar PV water pumping system technology has been the wastage of energy by made the system in idle manner without using energy which is only use for target of specific purpose and time but in this research when no need of irrigation time, the systems are required batteries to store the sun's energy for use during summer periods. Total quantity of water required for irrigation is 145125liter per day the Pump power that can able to pump water from well to storage tank is 20kw the number of PV module to satisfy pump power is 55 and total energy produced from solar panel 22kw.The initial cost of solar PV pump is 92,426.125USD and this cost would be obtained after three to five year. Solar PV water pumping system can be reliably used at where absence of continuous local grid available where as solar PV and battery storage need is critical

Keywords: Solar PV System; Water Pumping System; PVsyst; battery; irrigation, multi-purpose.

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CHAPTER ONE

1. INTRODUCTION

Energy is the ability to do work and essential to mankind as he makes use of it in his daily life. It is one of the indispensable factors for continuous development and economic growth. The demand of energy is increasing rapidly in the developing countries due to automation, industrialization and urbanization. The growing population and technological developments have shown that the present sources of energy in use are not adequate.. Some energy sources are not environmentally friendly, expensive and difficult to transport; like fossil fuel. Some energy sources are friendly with environment like wind energy, solar energy. Ethiopia has huge potential for solar energy because it is located near the equator with an average daily solar radiation of 5.25 kWh/m^2 *(Getachew B, Palm B, 2010) and (Wolde-Ghiorgis W, 2002).*Many researches done on Photovoltaic using for water pumping which used for drink, irrigation, livestock, wash and etc. but in Ethiopia water pumping requirement for irrigation is not constant in all season. As Ethiopia water pumping requirement for irrigation is start from November up to April and exchanging product also has high value in this season. The objective of this proposal is using solar energy for other purpose during no need water pumping requirement in summer (kiremt) season use battery storage of pv for multi-purpose such as milling , refrigerator, television.

The Ethiopian rural area demand water for crop irrigation and domestic water supplies is increasing due to weather change that has going in the country. Agricultural technology is changing rapidly. Farm machinery, farm building and production facilities are constantly being improved. Solar Photovoltaic water pumping system is one of the best technologies that utilize the solar energy to pump water from deep well underground water sources and to solve electricity problem in rural area.

Ethiopia has favourable solar energy resources to use for off-grid photo voltaic systems for rural population. The study also indicates that due to high prices of fuel oil, even larger photo voltaic systems are very competitive to diesel generator and village power supply *(S. Tsegaye, and W. Gashie, 2010).PV* water pumping systems may be the most cost-effective water pumping option in locations where there is no existing power line. When properly sized and installed, PV water pumps are very reliable and require little maintenance.

Agricultural applications suitable for photovoltaic solutions are numerous. Water pumping is one of the simplest and most appropriate uses for photovoltaic. From crop irrigation to stock watering to domestic uses, photovoltaic powered pumping systems meet a broad range of water needs.

1.1.PROBLEM STATEMENT

There are many systems of pumping water that are currently used including engine driven pump, grid powered pump, manual powered pump and use generator for drive pump. In rural area of Ethiopia use fuel for water pump, light, generator. However, there are inconveniences associated with these systems as follows:

- Due to the steady increase in the price of fuel for the past few years, most of these systems have become expensive leading to an increase in the price of water for domestic consumption and irrigation.
- There is low grid power coverage in the country; therefore grid powered pump cannot be used in most of the parts in the country particularly rural area. To overcome the inconveniences there is a need to design and construct a solar powered water pumping system.
- Due to fuel use for light cause air pollution from smoke therefore use storage battery for milling, Television, refrigerator and etc during non-irrigation season.
- Due to weather change ,Currently there is lack of rainfall in some rural area of country, to overcome these difficulty the available water should be need to safe for irrigation by using irrigation schedules by considering crop type ,soil type
- Due to lack of information about PV water pumping system in the study area so that the study can be provide awareness for community live with study area.

Research questions are:

1. What are advantages of rural community get from solar photovoltaic water pumping systems?
2. Can the system give power requirement and water demand adequately?
3. How the financial costs of both systems can be calculated?

1.2. GENERAL OBJECTIVE

The overall objective of this research paper is to study alternative use of photovoltaic power from PV the water pumping system for small irrigation during no rainfall but, when no need of water. use battery storage energy for multi- purpose and also to compare solar PV with diesel powered pumping system by making economic analysis to show system feasibility

1.3. Specific Objectives

The specific objectives include:

- To determine energy requirements, water demand and other design data;
- To system simulation by using PVsyst soft-wares or RETScreen
- To Analyze output data and interpret the results;
- To discuss economic evaluation of the system to show feasibility.

1.4.SIGNIFICANCE OF THE STUDY

The significance of the findings is to provide alternative use of photovoltaic power from PV water pumping system, From this, the study could be considered as a first for study area for solar energy utilization technology to pump water and for multi-purpose which is better solution to energy problem available in the study areas of the community.

Therefore the analysis of PV generators water pumping system for irrigation and other purpose for ruler area of country can be created good atmospheric environment due to using PV water pumping systems for small scale irrigation develop agricultural product and increase the value of the price of a small scale crop like vegetable ,fruit etc.

1.5.SCOPE OF STUDY

This research project is intended to analyze the alternative uses of photovoltaic water pumping system. In this study power requirement has been analysed using PVsyst software or RETScreen relating with the solar radiation energy from the solar panel for each monthly, daily and hourly solar radiation of selected study area. Analysis was goes up to the extent of storage tank and estimation of water requirement for irrigation system. Season limitation in this research project not considers pumping water for drink. The geographical limitation; water pumping for small scale irrigation require in study area and not reconsider grid-connect system area. The size of the farm to be propose is 10 acres (4 hector) and can be irrigated based on the type of crops like Vegetables (Pepper, Onion and Tomato) used at study area

CHAPTER TWO

2. LITERATURE REVIEW

The sizing of stand-alone photovoltaic systems is based on meeting electrical loads with lowest average daily solar insolation on the array surface usually during winter months. ***(Wagdy et al.1998)*** proposed a 'switched-mode' PV-powered pumping system. This system couples the pump to the PV array directly when the storage battery is fully charged, with the objective of maximum utilization of available solar radiation to minimize the cost by considering three basic parameters: PV array size, storage battery size and water tank size. Authors reported that the optimum solution is one that minimizes the PV array size because the array cost is the major item and found that increasing battery storage without increasing array size has little effect on system performance.

The power from solar PV can drive both AC and DC motors to power a mill, and with technological advancement and falling prices of PV technology, solar milling has become increasingly economically viable ***(GIZ, 2016b).*** Among the economic benefits of introducing a solar mill is the potential for savings on spending on alternative fuels, in cases where it replaces a diesel-powered mill. For example, 1,200 litres of diesel could be saved per year in Ethiopia through one solar mill. a solar mill was installed in a village in Senegal with power requirement of less than 100 Watts (W) ***(Beshada et al., 2006).*** However, following installation, the grain mill consumed more electricity than expected, resulting in a disappointing performance of the system. In addition, frequent repairs were required to keep the system running ***(Wegener, 2011)***

(Eyad and Al-Soud ,2004).studied the potential of solar water pumping in Jordan and selected 10 sites based on the availability of solar radiation data under three categories: adequate, promising and poor and suggested other water pumping alternatives for these sites.

(Edson et al. 2004).carried out a comparative study of four 3 kW grid-connected PV systems installed on the rooftop of a Test Centre in South Korea, for a period of 12 months exposure and concluded that the performance of PV system declined due to increased array losses, of about 14%, due to module deterioration and mismatch of PV sub-arrays.

(Rezae and Gholamian). carried out a technical and financial study of photovoltaic water pumping system for irrigation of Gorgan farm fields in Iran using RET Screen software and concluded that installation cost of PV water pumping project is very high but considerable savings are observed.

(Alawaji et al.1995) discussed components, basic operation and performance of water pumping and desalination in the remote areas of Saudi Arabia. The study reported that utilization of PV energy for water pumping and desalination is reliable and cost effective.

(Padmavathi and Daniel 2011).analyzed various photovoltaic water pumping options and domestic water requirements for Bangalore city in India and concluded that PV panels ranging from 60 Wp to 500 Wp are sufficient for residential buildings in Bangalore and suggested that government policies and regulations are required for the promotion of using PV water pumps in urban domestic sector

(Dunlop J.P.1988). presented three photovoltaic (PV) water-pumping systems, and then analyzed to develop techniques for optimizing system efficiencies and emphasized that tracking arrays can improve performance of direct-coupled systems over fixed arrays more than 26% of the insolation enhancement.

Photovoltaic (PV) technology is used for generating electricity from the incoming solar radiation. Several attempts have been made to evaluate, monitor and improve the performance of different components of a PV system: a PV module ***(Abdallah, 2004; Vick and Clark, 2004; Huang*** and Sun, ***2007; Hansen et al., 2000; Lorenzo, 1994)***, a controller ***(Hohm and Ropp, 2003)***, a battery ***(Gergaud et al., 2003; Achaibou et al., 2012)***,a pump ***(Vick and Clark, 2011)***, These, and similar studies have been effective for improving the efficiency of the PV system components. However , several factors need to be considered for an optimal PV system design to achieve the desired reliability of the system in a given environment. This involves a detailed investigation of all interacting physical (plant and soil type, irrigation system specifications, PV system sizing, site attributes), meteorological (solar radiation, air temperature, relative humidity, wind speed, precipitation , evapotranspiration) and managerial(irrigation scheduling) variables with the aim of achieving the desired reliability of the PV system.

The PV systems can be operated as a stand-alone, hybrid or grid connected systems. Stand-alone schemes have found wide application in remote regions to meet small, but essential electric power requirement such as water pumping systems. Research work has also emphasized this aspect ***(Eker, B and A.Akdogan,2005***).In these proposal the study has been focused on electric power obtained from system provide for small scale irrigation water pumping during no rain fall (winter) and electric power for multipurpose during no need of irrigation(summer).

The performed reviews show that the previous approach to sizing the PV pumping irrigation system, which separately views the demands for hydraulic energy and possibilities of its fulfilment by PV pumping system from the available solar energy, is basically non-systematic and static, therefore is not optimal ***(Glasnovic, Z, Margeta, J., 2007).***So that, a systematic approach will be considered to problem solving, taking into account all relevant elements, from soil type, crops types and to irrigation system whether drip irrigation or sprinkle.

Most of the studies were system size-specific and location-specific. Studies focusing on systems with power requirements on the order of 1kW have been conducted for sites in Namibia, Jordan and India ***(Mahmoud, 1990; NAMREP, 2006; Meah et al., 2008).*** Most of the literature concluded that PV irrigation is both technically feasible for very small systems in the order of one acre ***(Kelley et al., 2010).***

Lead-acid battery technology is considered to be the most cost effective for many PV systems due to its relatively low cost and wide availability. In addition, batteries are able to satisfy transient surges of current that are much higher than the instantaneous current directly obtainable from a PV array ***(G. M. Masters, 2005).*** However, this process leads to extra power loss since approximately 15 -25% of the energy is lost during charging and discharging processes and the PV array must be oversized to cover the energy losses.

2.1.System-Sizing

Correctly sizing a solar PV system requires careful attention to detail and critical planning. Solar system sizing is a step-by-step process that accounts for facility energy needs and the local solar resource in order to determine the necessary size (in kWp) of the solar array. Photovoltaic panels, also called PV modules, are the basic building block of a PV system. The array of solar panels are normally sized to ensure that enough power is supplied to the photovoltaic solar water pumping systems. The power consumption varies by storage capacity and model. Countries experience varying weather conditions and solar radiation levels at different periods of the year depending on where they are located globally. Even within a country, different solar radiations, temperature and altitudes vary. These factors and elements influence the overall exercise of calculating the size of the solar array and the battery bank for optimum operation of the solar powered system.

2.2.Solar PV Installation Methods

Solar energy exploitation depends on the tracking system that mounts the PV panel. The tracking system is basically applied to direct the panel to the direction of the sun light which enhances the radiation that strikes the surface of the PV module. Most PV arrays are typically mounted with no tracking systems. There is possibility to track the radiation of the sun for the power output maximization. Solar tracking systems are basically categorized according the number of axes of tracking and the time with which the adjustment is to be made. Below are the techniques to be considered during the design of the PV system *(Dhanabal.R et al.2013).*

No tracking: Photovoltaic Panels are mounted at a fixed slope and azimuth; moreover it is the simplest and cheapest method. Preferable to orient the panel to the equator (south in the northern hemisphere) usually the angle of tilt is equal to the latitude of the specific site under study. A small increase and decrease from the latitude will be better for the winter and summer sun tracking respectively.

2.3.Solar Photovoltaic Systems

Photovoltaic system is the most well-known method of converting solar energy directly into electrical energy using semiconductor cells. Today's photovoltaic cells are mainly manufactured from a semiconductor material called crystalline silicon, which is available abundantly in the earth's crust and is free of toxicity. Modules made of by combining crystalline silicon cells are very durable, reliable; noise free and fuel free equipment's to produce electricity. Solar energy is the solitary source to power PV which is infinite. Photovoltaic cells have the capability of transforming 1/6 of solar resources into electric energy. PV systems are free of moving parts and are also environmental friendly. The life time of PV cells can end with greater than 30 years ***(Andrej Cotar, et al.2012).***PV systems provide electricity to remote areas where there is no access to utility grid, thus elevates the life value of the community. In a PV cell there are two doped semiconductor layers, P-type (hole) and N-type layer (electron) which is separated to each other by a junction. A spontaneous electric field is developed at the boundary which defines the direction of the current flow across the junction. In order to get electricity from a PV, the sunlight should penetrate a glass cover and antireflection coating. The model developed to harness solar energy was basically from the western, planed constructing centralized electricity generation and transmitting electricity by transmission wires to the consumers. Energy efficiency of solar photovoltaic is calculated as the power output from the PV divided by the solar radiation emitted to the solar array area.

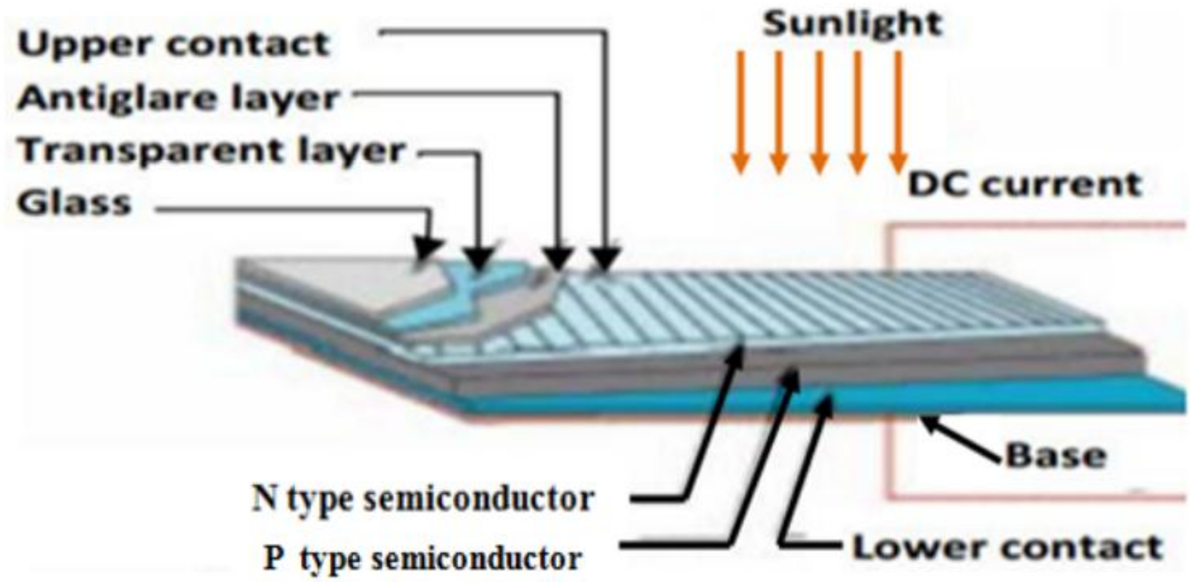

Figure 2-1: Typical PV cell ***(Wade Byrd.****2007)*

2.3.1. Types of Solar PV Cells

Different materials are used to make PV cells, with silicon obtained from sand is being the main material used for and it is available in the earth's crust. The electricity generation depends on the size of the PV cell, the conversion efficiency, and sunlight intensity of the local area. Based on ***(Wade Byrd.2007)*** the material from which it is made and the means of manufacturing, PV cells of silicon material are classified into the following.

Mono-crystalline PV Cells: are made from uncontaminated silicon single crystals, cut-off from ingots. It has a dark colour and along all its corners is trimmed; this is one clear difference from the poly-crystalline panels. This type of PV cell is the efficient one since it is made from one crystal but the most expensive too. It functions better in areas where low energy sources are required. This technology is the first generation of all PV cells and has high heat resistant ability. The disadvantage with this technology is that it consumes more time to manufacture. The means of production of mono-crystalline silicon is first heating high purity of silicon into super saturated state, second inserting seed crystal into the molten silicon. Then lastly slowly pulling the seed crystal out of the melted mono-crystalline with the aid of Czochralski mechanism to get silicon ingot; moreover, slicing the crystal in to pieces to make the cells then to modules and arrays. This technology has the ability to convert 1000W/m^2 solar radiation to around 140W of electricity in PV cell surface area of 1m^2 ***(Caisheng Wang.2006)***

Polycrystalline PV Cells: It is made from combination of smaller quantities of silicon crystal blocks. They are considered as the most widely used cells now a day. Such PV cells are inefficient than the single crystalline cells due to the reason that they are not grown from single crystals but from a combination of many crystals. They perform better than the mono-crystalline in slightly shaded conditions. This technology has the ability to convert 1000W/m2 solar radiation to around 130W of electricity in PV cell surface area of 1m^2***(Caisheng Wang.2006)***

The production of this type of cells is more efficient than mono-crystalline. Molten silicon has to be placed into blocks, which are then cut into slabs to make the crystals. Size of poly -crystalline solar panel is larger than mono-crystalline panel to get the same wattage because monocrystalline is more efficient per area than multi-crystalline. So when comparing the two PV panels in terms of size to get high power output, single crystalline is good in usefulness.

Thin Film PV Cells: These types of cells are not made from real crystals rather the silicon is deposited on stainless steel, plastics or glass to form the solar module. These types of PV cells are much less efficient than the above two but the production process costs less. The inefficiency shows that larger panels of this type required producing same power as the mono or polycrystalline panels. They have efficiency from 5% to 13% and their lifespan is about 15-20 years.

System controller Conditioner

Several electronic devices are used to control and modify the electrical power produced by the photovoltaic array. These include:

I. Battery charge controllers - regulate the charge and discharge cycles of the battery;

***II. Pump Controller* -** Matching device used so systems will operate at optimum power, matching the electrical characteristics of the load and the array.

***III. Inverter* - Is a** device that converts the direct current coming out of the PV into alternating current (AC). An inverter could be chosen to output in a variety of voltages, including **220 V** and **380V**, single and/or 3 phase for very large loads.

IV.Maximum power point trackers (MPPT) - maintain the operating voltage of the array to a value that maximizes array output. In a real field configuration, both factors take effect simultaneously,

2.4.Pumps

Pumps are also categorized as surface or submersible. Surface pumps have the obvious advantage of being more accessible for maintenance. When specifying a surface pump you must distinguish between suction and lift. A pump may be installed a few feet above the water level, with a pipe from the pump to the water. The maximum length of the pipe is determined by the suction capability of the pump. The pump may then lift the water to a storage tank above the pump. The elevation of the storage tank is determined by the **lift capability of the pump**. Most submersible pumps have high lift capability. They are sensitive to dirt sand in the water and should not be run if the water level drops below the pump. The **type of pump** will depend on the **water required**, the total dynamic head and the capability of the water source. Both rotating and displacement pumps can be driven by ac and dc motors. The choice of motor depends on **water volume** needed, **efficiency**, price, reliability and availability of support. DC motors are an attractive option because of their compatibility with the power source and because their efficiency is usually higher than that of ac motors. However, their initial cost is higher, the selection may be limited in some countries and the brush type motor requires periodic maintenance. Some brushless dc motors are available and promise improved reliability and decreased maintenance. AC motors require a dc to ac inverter, but their lower price and wider availability are advantages *(Chowdhury et al., 1993).*

For water pumping applications, several types of pumps may be used. They can be categorized according to their design type (rotating or positive displacement pumps), to their location (surface or submersible), or to the type of motor they use (AC or DC). Rotating pumps (e.g. centrifugal pumps) are usually preferred for deep wells or boreholes and large water requirements. The use of displacement pumps is usually limited to low volumes. Positive displacement pumps (e.g. diaphragm pumps, piston pumps and progressive cavity pumps) usually have good lift capabilities but are less accessible than surface pumps and are more sensitive to dirt in the water. Figure 2.2 which is adapted from (*Barlow et. al. (1993)*, suggests possible pump choices as a function of the head (total height the water has to be lifted) and the daily water requirement.

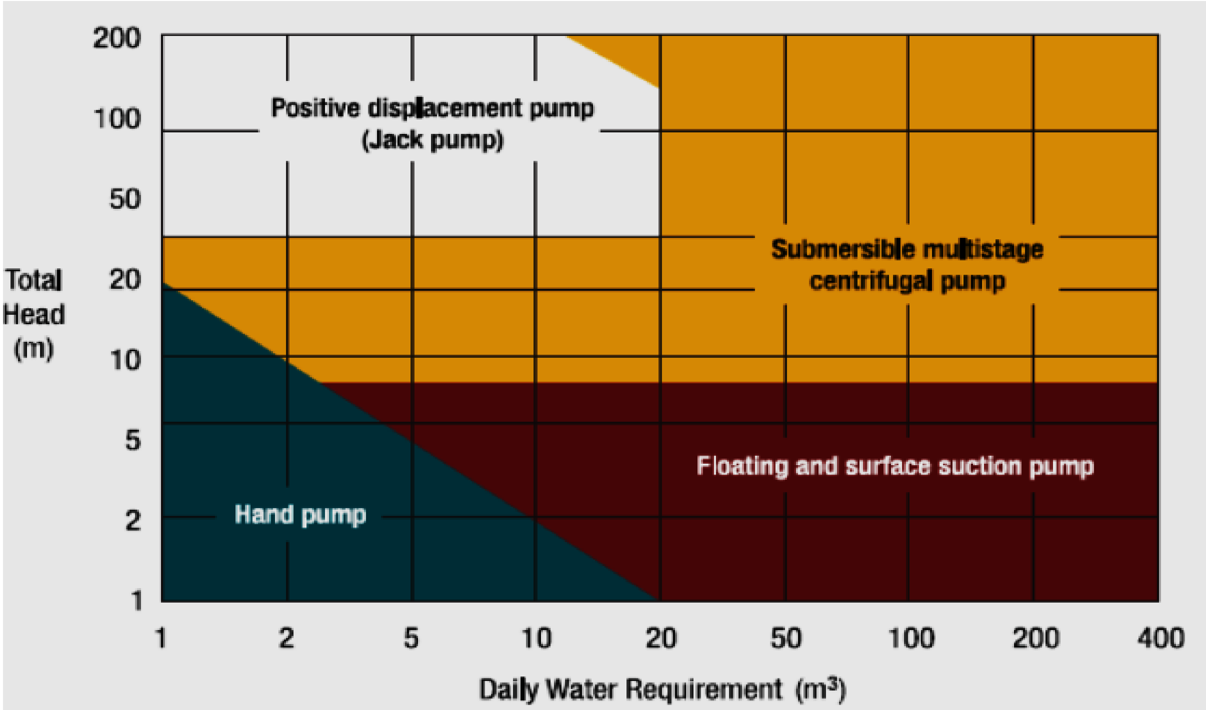

Figure 2-2 Pump type selection [adapted from Barlow et al., 1993]

2.5.Battery storage

The key difference between a grid connected system and an off-grid system is the need for a battery bank. Since sunlight is not available at night, and since we are most likely to require electricity at night for lights, entertainment devices, and so on, batteries are indispensable to any off grid system. Unfortunately, batteries are also often the most problematic and costly part of a system. Renewable energy systems, deep cycle batteries provide the energy storage for the system. Unlike car battery, deep cycle batteries that are used in renewable energy applications are meant to be discharged and recharged (cycled) repeatedly. To maintain healthy batteries and prolong battery life, most manufacturers suggest limiting the depth of discharge to about 20%. There is a different type of solar batteries. The most common one is flooded lead acid (FLA) batteries and sealed batteries (AGM or Gel cell).Flooded Lead Acid batteries require a bit of maintenance, however, they generally last longer than their sealed counterparts *(http://www.solarbuzz.com)*

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2.6. Summary Literature Review

The PV systems can be operated as a stand-alone, hybrid or grid connected systems. Stand-alone schemes have found wide application in remote regions to meet small, but essential electric power requirement such as water pumping systems. Research work has also emphasized this aspect.

Photovoltaic (PV) technology is used for generating electricity from the incoming solar radiation. Several attempts have been made to evaluate, monitor and improve the performance of different components of a PV system: a PV module, a controller, a battery respectively

The magnitude of solar irradiance which strike on the surface of the earth depends on latitude, climatologically location parameters like air pressure, cloudiness, state of atmosphere regarded as temperature wind and rain etc. Some of the direct applications of solar energy are to heat, to pump, and to desalinate water. Solar energy can be converted in to electricity using different conversion technologies, among which photovoltaic and solar thermal are the basics. Photovoltaic technologies convert the incoming solar insulation directly into electricity. This technology uses mirrors to concentrate the incoming solar energy, it captured in the form of heat.

Size of poly -crystalline solar panel is larger than mono-crystalline panel to get the same wattage because monocrystalline is more efficient per area than multi-crystalline. So when comparing the two PV panels in terms of size to get high power output, single crystalline is good in usefulness.

Proposed system

Many researchers write paper on solar PV using for water pumping which used for drink, irrigation, wash and etc. but in Ethiopia water pumping requirement for irrigation is start from October up to May particularly in study area. But from June to September for four months no water demand for irrigation this time used energy for other purpose, therefore in this research project for continuous operation of the system use power to solve the problem in community living nearby area. Therefore in those months use solar photovoltaic for milling, Refrigerator, television, mobile charge , etc

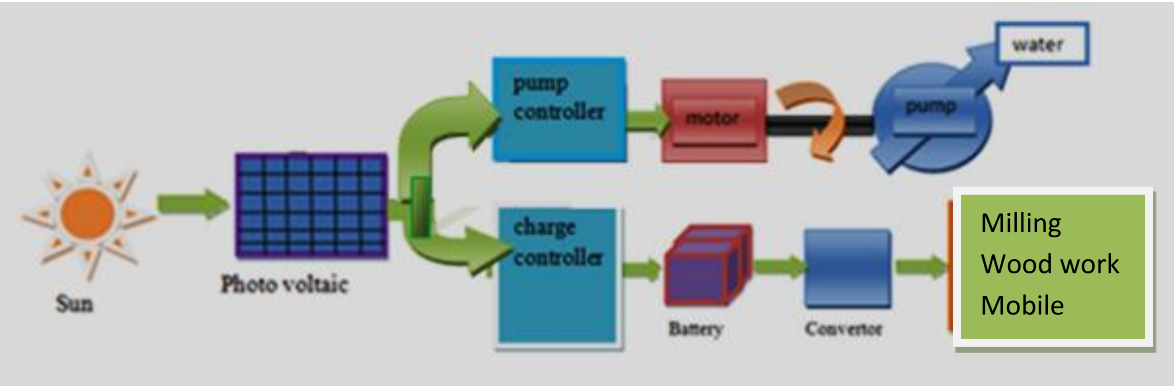


Figure 2-3: Energy flow schematic diagram of the proposed system

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Study area

3.1.1. Location

study area located onto it West Harerghe Zone at Medhicho kebele which located 20 kilometre from zonal capital town Chiro and 317 kilometres from regional and national capital city (Addis Ababa). The geographical location of this study area has latitude 9.14^0N and longitude of 40.867^0E and altitude of 1332m above sea level.

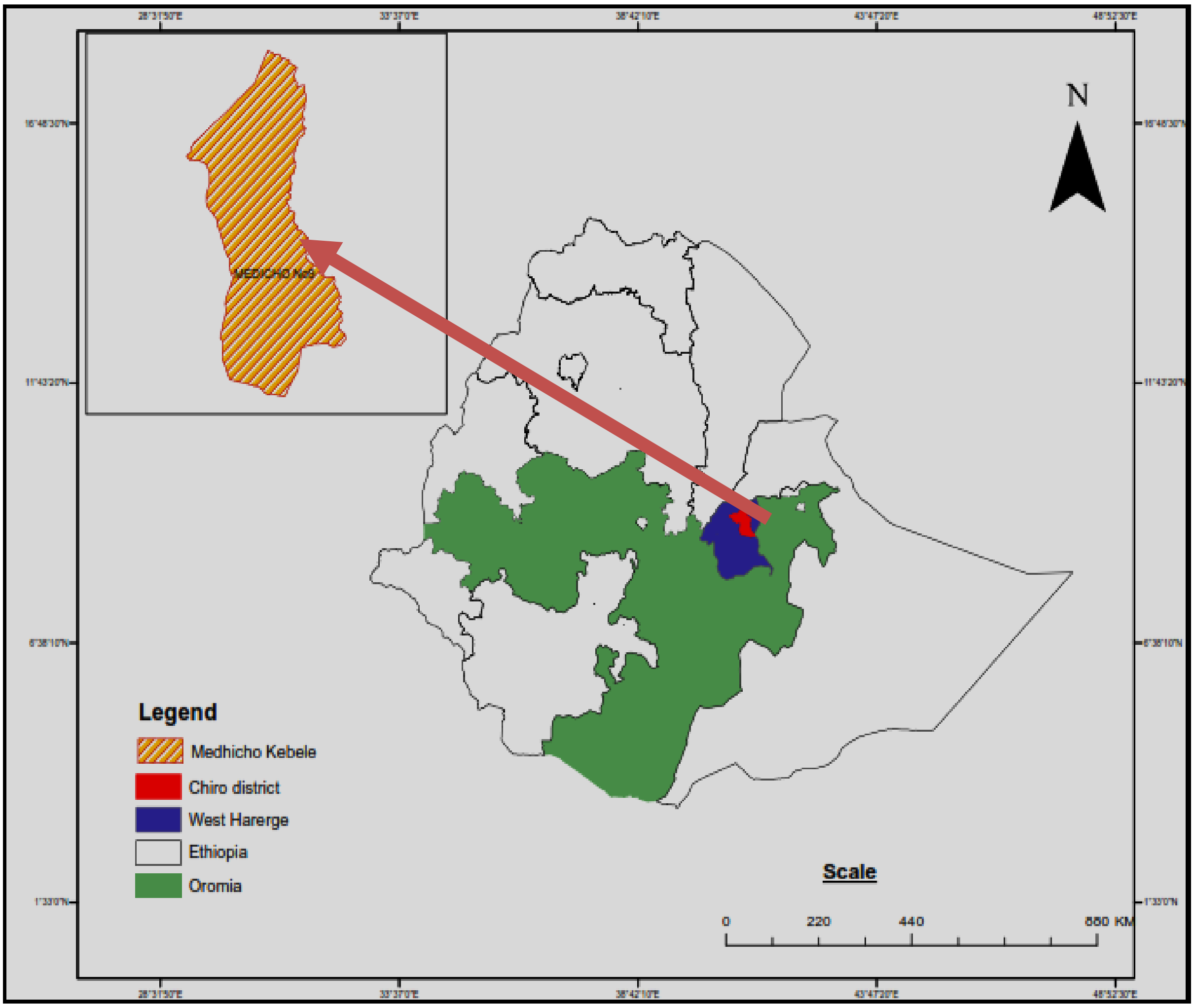


Figure 3-1: Location map of the study area

3.1.2. Topography

The study area located on the eastern escarpment of the country where mountain ranges and intermountain valley are characteristic land form Features. Project areas having situated on intermountain valley is bounded to the East, South East, South West and South by Chiro-kela, Jelo-Mukhtar and Chercher mountain ranges. Topographic differences gave rise to different climatic zones which correspond to the various physiographic features. The plateau areas get relatively high precipitation compared to the escarpment and the lowland areas.

3.1.3. Climate and Rainfall

The climate of the study area is temperate or "Badda Dare" as the average altitude fall between 1300-2300 m.a.s.l and mean annual temperature 15-20 ^{o}c.The area is characterized by two rainfall regimes having six rainy months with bimodal rainfall pattern. The rainy months extend from February to April (low rainy month) and June to September and about 53% of the annual rainfall amount occurs during latter four months. Very high concentration of rainfall in the months of July, August and September is markedly distinguished (MCE plc., 2010). The mean annual rainfall of the study area is estimated to be about 918mm.

3.1.4. Geology

Generally speaking, the rock types in the project area can be classified as Mesozoic Sedimentary rocks, Tertiary to Quaternary Volcanics and Quaternary deposits. In the Chercher massif which is the South West and south East of project area Basaltic lava flows overlain the sandstone and limestone rock units. In the valley colluviums and alluvial deposits that are the product of weathering are deposited. In the field observation specifically from quarry sites and along the road and river channel cuts it is investigated weathered and fractured ignimbrite, and basaltic rock subjected to spheroidal and columnar weathering in the rift valley escarpment are exposed. Yet, moderately to highly weathered ferrogenous vesicular basalt underlying the alluvium that comprises of clay, silt, sand, gravel, boulder, pebble and cobble along Medhicho and Chiro River channels are outcropping.

Lithological log data from three boreholes drilled from shallow up to 200m depths on the embankment of Chiro-Kela, Jelo, Ija-fara saro, Kololo and Medhicho rivers are also indicated that the colluviums and alluvial deposits, Scoraceous basalt, slightly fractured Ignimbrite and basalts of different composition and subjected to variable degree of weathering are the major rock strata in the study area. Geographically the area is border with East Harerghe in East, Arsi and East shewa in west, (Asebot and Mi'eso) districts of West Harerghe in North and Bale Zone in South.

3.1.5. Demographic Structure

3.1.5.1. Population

The population estimated to be 249,823, from which 128,892 are male and 120,931 are female. According to data from the woreda's Agricultural, development office the woreda has a total of 41 kebeles from which 4 are Urban and the rest 37 are rural kebeles. From the total population of the woreda 20,794 are urban population with 11,401 male and 9,393 female, where as the rural population accounts 229,027 with 117,491 male and 111,538 female .The Woreda has total Households of 37,830 with average family size of 4.9 person per household. Furthermore the physical assessment conducted during the socio economic study the proposed project is located in Madhicho kebele whose Population found to be total of 5862 with 2969 male and 2893 female with 1250 Households, from which 1,144 are male and 106 are female headed households. The average family size of the study area is nearly 4.81 people per household.

Table 3-1: Summary of population data of the project area

Woreda/Kebele/Beneficiary	Male	Female	Total
ChiroWoreda	128,892	120,931	249,823
Project Kebeles	2969	2893	5862

3.1.5.2. Crop Production

According to the information obtained from the Woreda Agricultural office 90% of the livelihood of the dwellers of the woreda and project area depends directly upon the production of crop, and livestock. Crop production is rain fed dependent and among the major crops widely grown includes cereals (Maize, Sorghum, teff, wheat and barley) and pulse crops and other seasonal crops like sugar cane.

Table 3-2: Types of Rained Major Crops Cultivated In Chiroworeda

Crop Type	Area Coverage (ha)	Total Production (Qt)	Average yield Qt/ha	Remark
Sorghum	14236	327428	23	
Maize	12375	309,375	25	
Teff	1277	15,324	12	
Coffee	9800	39,200	4	

Source: ChiroWoreda Agricultural office, May 2015

It is noted that the yield per ha of different crop types of cereals are different with different selected seeds and application of fertilizers. This means that with the application of selected seeds with fertilizers and application of local seeds with fertilizers, the yield increases at different rates, so that, we have taken the estimated average yield for all crops for the purpose of computation. As far as the irrigated agriculture in the woreda is concerned more or less the practice is exercised along the deepwel bank of Madhicho deepwel with traditional irrigation. The most farmers produce Maize, vegetables, banana, papaya and sugar cane for their own consumption and supply for market.

Table 3-3: Types of irrigation cultivated crops in Chiroworeda

No	Crops	Area Hec	Total production(Qt)	Av.Yield kun/hec
1	Maize	65	2600	40
2	Onion	2	350	175
3	Pepper	3	45	15
4	Tomato	4	200	50
	Total	74		

Source: Chiro Woreda Irrigation Development office, Mayl 2015 and also other perennial like Banana & papaya etc

As far as the specific project area is concerned the data gathered from the kebele assigned development agents shows that the type of crops are common yield per hectare differs relatively depending on the climate and type of soil and agricultural extension services.

3.1.5.3. Land holding

Discussion was made with development agents and kebele administration on the existing land holding size. In addition to the data gathered from DA of the kebele the household survey conducted reveals that about 10% of the household estimated to be landless and less than 0.5 ha, about 36% of the household posses 0.5-1ha, about 23% of the households in the kebele posses equally about 1-1.5ha and 18% of the households owns 1.5-2ha of plot of land and further 13% of the household do have 2ha and above. Land holding size of the household in project kebele estimated in the range of 0.5ha – 4ha per HH and the average 1.5ha per household.

3.1.6. Study period

The study has been conducted from April, 2017 to July 2018 GC.

3.1.7. Study design

Observation and design document would be used to collect, generate and analyze relevant data on the existing PV water pumping system with proposed PV water pumping system and analyse simulate and interpret the result

3.1.8. Data type

Data was collected and generated at Primary and secondary level through personal observation, structured interview, design document and reviewing of archived data.

3.1.9. Data collection process

To achieve the objective of the study data was collected at primary and secondary level

3.1.9.1.Primary data collection

Primary data is collected by Visual inspection, assess the current condition of the study area, field survey would consist of looking for where the material found. The survey help to -get information about the sources of data Such as characteristics of the water source (depth, quality, drawdown) and irrigation size, land available by hectare, the number of people live by area ,bar land for panel, and Anything that shades the array Interview within woreda water expert and the beneficiaries within the command area.

3.1.9.2.Secondary data collection

Secondary data was conducted design data on existing scenario and which have already been collected by someone else and which have already been passed through the statistical process.

- ❖ Analysis of PV water pumping system which is a task that involves gathering of relevant information from a variety of sources.
- ❖ Description of parameter in irrigation system such as soil type, crop type, irrigation period, from design document.
- ❖ Journals, reports, and internet.

3.2. Data processing and analysis

PVsyst software or RETScreen Expert was used to simulate the solar photovoltaic water pumping system for small scale irrigation before using software first identified inputs parameter, independent and dependent variable.
Following methodology can be adopted for present feasibility study

One method to analysis is to identified independent variable such as pump selection, size of photovoltaic module, land available and water required on command area, discharge from well and total head etc.dependent variable like output parameters which are obtained from software such as energy at operating pump, array output energy, water needs to user and water pumped. From the source by inputting Weather data of selected site to software energy required was determined that can be used for irrigation (bega season) and energy required for other purpose during no need of irrigation (keremt season).

During simulation analysis using PVsyst software the following points should be considered. The initial point is determining the global effective irradiation and the maximum power point (MPP), once irradiation and MPP determined, the simulation is dependent on the Pumping Type and Configuration *(SA, 1994-2012).*

Total irrigation water requirement for the crop was calculated using net-irrigation requirement of the crop, irrigated areas.
Input parameter in to RETScreen expert like average temperature, relative humidity, precipitation showed that the effect of those weather data on monthly solar radiation

3.3. Materials

The following materials have been used during the study.

- PVsyst software
- RET Screen expert
- Microsoft Excel and etc.

3.4. Climatic Data

After compare collected Recorded data and NASA, then we take a minimum solar radiation of nearby area of a site the reason if it applicable for the minimum value as well as it might be possible for maximum solar radiation. The climatic data location is Mi'eso which is near by the specific site of my study area of Madhicho. Madhicho is found between Chiro and Mi'eso the data was taken from Mi'eso station because no recorded weather data at Chiro station.

3.5. Analysis of Photovoltaic Energy for the Selected Site

The solar radiation is very important in calculating the amount of electricity generated by PV modules. The long term statistical data of solar sunshine hour is also very important in deriving an equation to calculate the solar radiation, and use in the design of the PV energy generation system. However, the solar radiation could be generated by the mathematical model which is developed based on the meteorological sunshine hour data.

The analysis follows from extra-terrestrial solar radiation calculation, monthly average terrestrial solar radiation determination up to daily solar radiation on the plane of solar module for the site.

3.6. Solar Resource and Photovoltaic System

The main electrical generator of the proposed system is photovoltaic panel which converts solar irradiation directly into Electricity. Since the solar radiation varies daily, hourly and seasonally the electricity produced by the PV array vary accordingly. Since the selected site has been very good solar irradiation throughout the year and battery storage is incorporated in the system to handle.

3.7. Demand Assessment

For the selection of source & designing of the delivery of water supply project, it is necessary to determine the total quantity of water required for various proposes by the beneficiaries.

3.7.1. Water Resource Potential

Surface water

1. River= there is a seasonal flow river

2. Rain =Roof catchment harvesting is practical to use in the area during rainy season and there is pond during summer.

Ground water: There are many Hand dug wells which have low discharge found around area. Based on physical study the area is promising for ground resource at deeper depth. Existing water supply source the communities of Madhicho kebele are using water obtained from rain flood and pond.

The hydrological, hydro geological and geological condition of the area is promising for the ground water exploitation at an estimated depth of 250m.

3.7.2. Water Source

The configuration of the water system has been defined primarily by the type of water source used, as well as by the local topography and the location(s) of the delivery point(s). The water source may be either subsurface (a well) or surface (a pond, stream, or spring).If the water source is a well, the following items was determined.

- The static water level,
- The pumping rate
- The water quality.

Information on water levels and well production can be obtained from the well log. The drawdown value obtained from the well log should be used to determine the production potential of the well to ensure that the well can be able to supply the operation’s estimated water needs.

Table 3-4: monthly average precipitation mm/day and solar radiation $MJ/m^2/day$ weather data from NASA

Month	10 year average PCP	10 year average solar radiation
Jan	18.7	20.21
Feb	28.3	20.91
Mar	92.3	21.26
Apr	278.5	20.36
May	157.4	21.38
Jun	93.1	19.71
Jul	216.3	19.03
Aug	267.1	19.61
Sep	238.6	18.06
Oct	79.8	20.58
Nov	31.4	20.83
Dec	29.8	18.75

A day with maximum water demand in winter season which is start from the month of October ,November, December, January ,February ,march ,April and may ,providing that on a day available solar irradiation followed by sufficiently high evapotranspiration $E_{T(i)}$ and insufficiently low precipitation.

3.7.3. Ratio of Water Requirement to Solar Radiation (Wr/Sr)

Table 3-5: Ratio of Water Requirement to Solar Radiation (for first irrigation season)

Month	Irrigation requirement (irr_r) mm/dec	Solar radiations available (s_r) ($kwh/m^2/day$)	Ratio of water requirement to solar radiations (Irr_r/s_r)
Nov	31.0	5.80	5.34
Dec	29.8	**5.21**	5.72
Jan	18.7	5.61	3.33
Feb	28.3	5.81	4.87

From Table 3-5 its show that for December the ratio of water requirement to solar radiations was largest(5.72) to compare remain value, therefore daily solar radiation of $5.21kWh/m^2$ and water requirement of 29.8mm/dec were considered for optimum PV array sizing.

3.7.4. Water Requirement

For the selection of source & designing of the delivery of water supply project, it is necessary to determine the total quantity of water required for various proposes by the beneficiaries.

Actually, the determination of the quantity of water depends up on the size of the command irrigable area and the purpose for which it is needed.

For determining the total quantity of water required, the following items should be determined first.

3.7.4.1. Duty of crops

Madhicho Deep well has main source of water for irrigating this project site. The area farmers used effective irrigation system of water for 6 hour a day. The duty of the highest Crop Water Requirement which is need for this project in December month it is 1.68 Lit/sec/ha. 0.028lit/minutes/hac at (appendix-E)

Well yield is 9l/s=0.15lit/min.

The well can give the amount of water about 194,400lites/day

Volume of water =194,400*3=583,200liters

To calculate the daily possible irrigated area (m^2) is dividing the daily volume of water pumped ($195m^3$) by the desired depth of irrigation (m), by assuming a standard irrigation depth is 0.005 m per day. $A=V/D_{irrigation} = 195m^3/0.005m = 39{,}000m^2 = 4hac$

Now we can calculate the amount of water needed for area (peak scheme water required).The amount of water needed for vegetable crop particularly Tomato plant on 4 hectare of land. The amount of water needed = peak daily crop water requirement *cropped area. For irrigation system where the irrigation area 4ha was calculated and pumping will take place peak sun hours for 6 hours each day during the peak demand period

The total quantity of water required (flow rate requirement) =1.68 l/s/ha*4ha=6.72l/s=$24m^3$/h

Daily total quantity of water required = 6.72 litre/s*60*60s/h*PSH h/day

= 6.72*60*60*6h/day = 145,152liters/day

We need a water pumps that can provide 145,152litres of water each day.

Bore hole discharge

Well yield is =0.15lit/min.

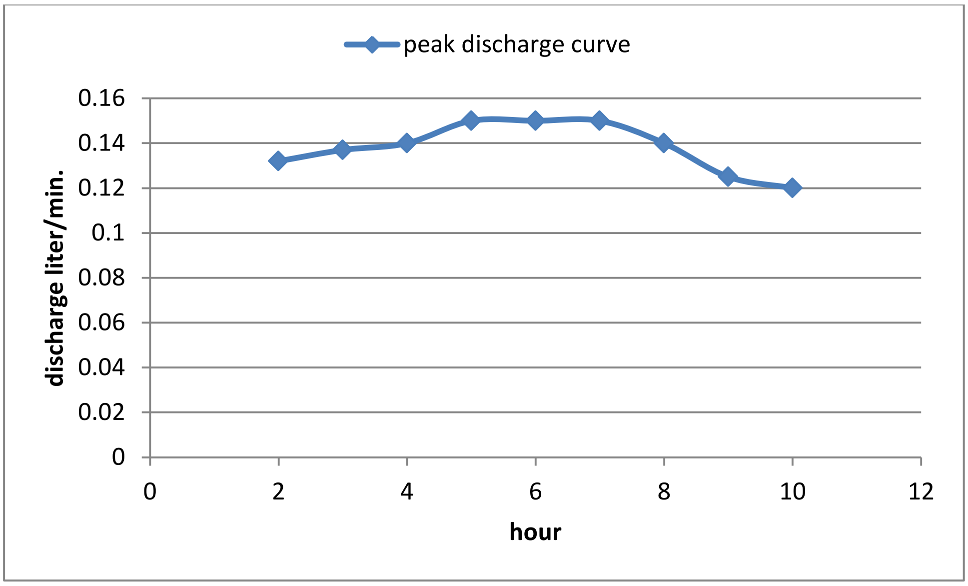


Figure 3-2: discharge flow curve

the figure 3-2 show that the bore hole discharge potential and pumping rate its worked on intensity of solar radiation pump start to pump water from 3:00h to 9:00h the maximum pumping rate

storage time=583m3/0.009m3/s= 64,700sec*1h/60*60s=18h

The area farmers used effective irrigation system of water for 18 hour a day

Velocity through transmission line to tank=Q/A_{cress}=4*0.009/$(0.065m)^2$*3.14=2.7m/s

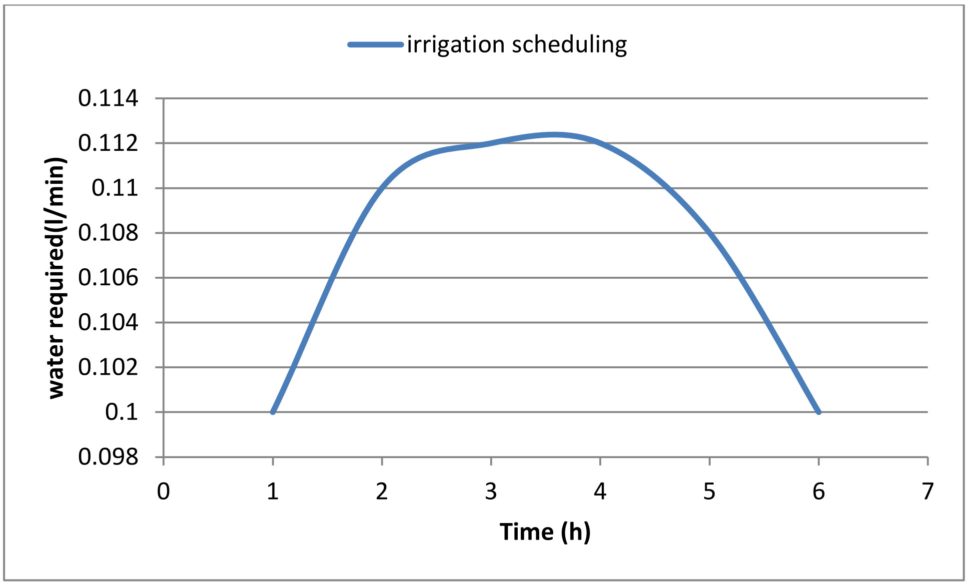


Figure 3-3: irrigation Time

The fig.3-3 indicate that the irrigation time required for crop is morning and evening at this time evaporation is decreasing but at noon time because of high evapotranspiration presented on a field more water loss.

Table 3-6: Well loge data information

parameter	Value in m
Hg	85m
Hs	45m
Tank depth	6m
Discharge	0.009m^3/s
Gravity line	1054m
Total Static head estimated well depth well diameter	130m 250m 0.067m
Distance b/w PV panel to village	500m
Distance b/w PV panel to Pump	350m

Source: [Chiroworeda Water, Mineral and Energy Office, Mayl 2015]

g –acc. Due to gravity	g	9.81
Hazen-williams friction factor for riser pipe	C	150
Diameter of riser pipe, mm	D	65
Length of riser pipe, meter	L	46
Hazen-williams friction factor for transmission pipe	C	150
Diameter of transmission pipe,(mm) from BH to Tank	D	100
Length of transmission pipe, meter (from BH to Tank)	L	1000

Source: [Chiroworeda Water, Mineral and Energy Office, Mayl 2015]

the distance between Bore hole to minimum Tank is 948m and length of riser pipe 46m height of tank is 6m then total length of pipe is 1000m

Calculate Total head H

Hazen William's formula

h_f(friction headloss)=10.675*L*($Q^{1.852}$) / (($C^{1.852}$) * ($D^{4.87}$))

Where L is length of transmission pipe, Q is flow rate C Hazen Williams friction factor D pipe diameter

Headloss transmission pipe, meter=hftr

h_{ftr} =10.675*1000*((9/1000)^$^{1.852}$)/((150^$^{1.852}$)*((0.1/1000)^$^{4.87}$) =14.41m

Headloss riser pipe, meter= hfr

h_{fr} =10.675*120*((9/1000)^$^{1.852}$)/((150^$^{1.852}$)*((0.065/1000)^$^{4.87}$)) =11.774m

Total headloss pipe, meter=Thf =hftr + hfr =26.15m

Total head H=total static head+ Total headloss pipe

Total head H=130m + 26.18m=146.184=162.18m

Pump power=$Q*H_T*\rho*g/\eta_{mp}$=0.009*162*9810/0.70=20kw

Pump power that can able to pump water from well to storage tank is **20kw** it's must be put exactly with standard YQS**200-22 kw submersible pump but in this case the required power having capacity of 20kw.**Therefore, for Medhicho bore hole scheme a submersible pump having a power Capacity of 20 kW must be required.

Now the main point that must be focused in this research is to find the energy required from solar PV the PV panel which can able to **satisfy** pump power during winter season and PV panel power used for multipurpose (Appliance) period of summer season when the amount of power output is low.

METHODS OF IRRIGATION

There are three methods of irrigation commonly used on small schemes

Irrigation Methods:

- Surface irrigation
- Sprinkler irrigation
- Trickle irrigation

The main objectives of these methods are to:

- Apply an adequate amount of water to meet crop needs
- Apply water uniformly across the field
- Ensure there are no long-term problems (e.g., soil erosion, salinization).

Trickle irrigation is selected depending energy consumed

Trickle irrigation is potentially a very efficient method of applying water to crops. Field application efficiency can be as high as 90%, but like any other method it relies very much on the skill of the irrigator to achieve this. Field measurements on trickle systems have shown application efficiencies as low as 25%. This was the result of poor system management rather than design. The farmers had not fully understood the concept of partial wetting of the root zone and so they wasted a lot of water trying to wet up the entire area. Because of the potentially higher efficiency and the operating pressure of only 1-2 bar this method can use less energy than sprinkler irrigation and in some cases less than surface irrigation.

CHAPTER FOUR

4. SYSTEM ANALYSIS

4.1. Solar Radiation Data Collection and Solar Resource Assessment of Selected Site

4.1.1. Recorded Data at Mi'eso Station

Data of selected site solar radiation is collected from recorded data at Mi'eso station.

Table 4-1: Average Monthly Solar radiation recorded data at station MJ/m^2/day from 2003-2012

Lat.9.23 Long.40.75	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10-year average	20.30	21.05	21.28	20.28	21.56	19.76	18.99	19.53	19.16	20.64	20.90	18.89

Source: from the existing data prepared by MOA in1990. (Miesoo metrology station & LocClim climate estimator)

4.1.2. Collected site data from NASA

Latitude 9.23 / Longitude 40.75 was chosen

Table 4-2: Average Monthly Insolation Incident on a Horizontal Surface (MJ/m^2/day) (2003-2012)

Lat.9.23 Long.40.75	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10-year average	20.21	20.91	21.26	20.36	21.38	19.71	19.03	19.61	18.06	20.58	20.83	18.75

(Source NASA website data at http://eosweb.larc.nasa.gov

4.2. Method of solar energy determination on the plane of PV panel

The solar radiation is very important in calculating the amount of electricity generated by PV modules. The long term statistical data of solar sunshine hour is also very significant in deriving an equation to calculate the solar radiation, and to know amount of energy generate by solar array. However, the solar radiation could be generated by the mathematical model which is developed based on the meteorological sunshine hour data. The analysis follows from extra-terrestrial solar radiation calculation, monthly average terrestrial solar radiation determination up to daily solar radiation on the plane of solar module for the site.

The algorithm used to calculate the radiation on the plane of the solar array would be shown as follows:

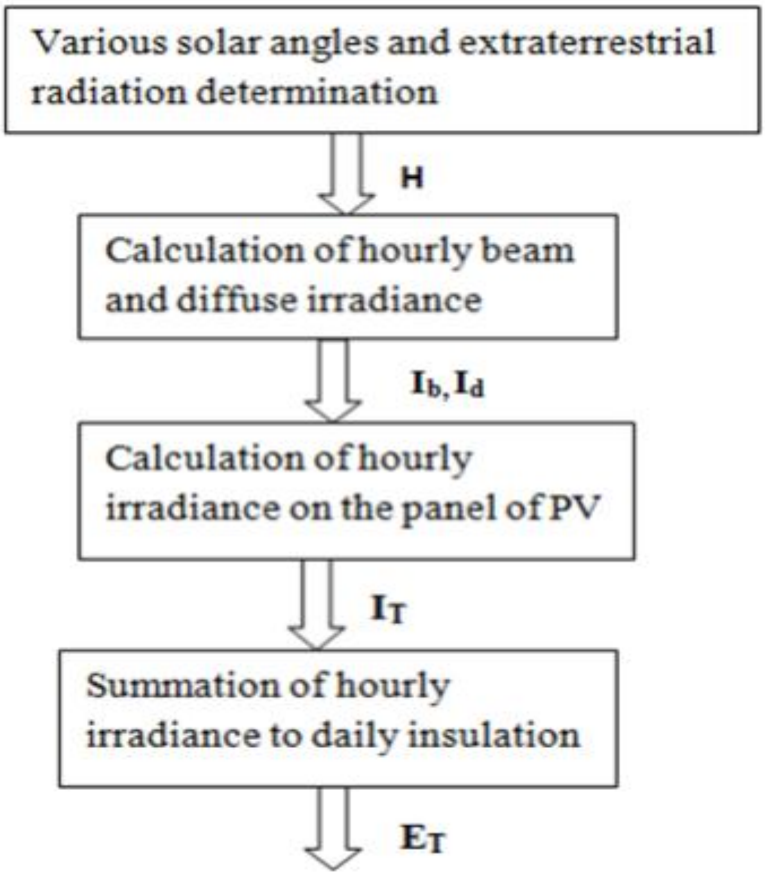


Figure 4-1: Flow Showing the Determination of Solar Energy on the Plane of PV Panel

4.3. Sizing of Solar PV system

Sizing of photovoltaic system is based on the worst operating condition. For the purpose of the solar PV system design, solar data is available but check by **numerically analysis** in this method use the minimum monthly solar irradiation. Since, December month is minimum solar irradiation as shown in table **4-2** assuming December 10 at [appendix A-1] i.e. N=**344** is chosen for PV sizing, and the **declination angle** can be calculated using equation (4-1).

$$\delta = 23.45\sin[\frac{360}{365}(284+N)] \qquad \text{-- (4-1)}$$

Where N is day of year

δ =23.45.sin [360/365(248+344)] = -23^0

Hour angle **ω** and solar time ST in hour is related as equation (4-2).

Assuming 1:15PM for the selected site:

$\omega = (ST-12)* 15^0=13.15-12*15=17.25^0$-- (4-2)

For horizontal surface, zenith (θz) can be calculated using equation (4-3)

$\cos \varphi \times \cos\delta \times \cos\omega + \sin \varphi \times \sin d = \cos z$ ……….. (4-3)

$\cos\theta z=\cos 9.14\times\cos -23\times\cos 17.25+\sin -23 \times\sin 9.14=36.11^0$

Where, the latitude ϕ of the site is 9.14^0

$\Theta z=36.11^0$

The relationship for the angle of incidence of surfaces sloped due north or due south can be derived from the fact that surfaces with slope β to the north or south have the same angular relationship to beam radiation as a horizontal surface at an artificial latitude of $(\phi - \beta)$.
Slope β for all year $\beta = \phi$
for summer $\beta = \phi - (10^0- 15^0)$ and for winter $\beta = \phi + (10^0- 15^0)$.............................. (4-4)
$\cos\theta = \cos\delta \times \cos\omega \times \cos\ (\phi - \beta) + \sin\delta \times \sin(\phi - \beta)$……………………… (4-5)
Where: δ is the declination (°) calculated from **(4.1**) and ϕ is the site's latitude (°)
$\cos\theta = \cos\ (-23) \times \cos 17.25 \times \cos\ (9.14 - 9.14) + \sin(-23) \times \sin(9.14 - 9.14) =$
0.88
$\theta = 28.4^0$

4.3.1. Estimation of Solar Radiation

The solar radiation passing through the atmosphere and reaching the earth's surface is classified into two components:

- **Beam radiation I_b**: is the solar radiation propagating along the line joining the receiving surface and the sun. It is also referred to as direct radiation.
- **Diffuse radiation I_d**: is the solar radiation scattered by aerosols, dust and molecules. It does not have a unique direction.

The total radiation I: is the sum of the beam and diffuse radiation and is sometimes referred to as the global radiation

4.3.2. Estimation of Clear Sky Radiation on Horizontal Surface

Hottel, et. al. (1976) presented a simple model for the estimation of the transmittance of beam radiation in clear sky conditions. The inputs needed are the altitude of the location A in km above. Mean sea level, day number of the year N and the zenith angle (θz). Combined with the Liu and Jordan's model for the transmittance of diffuse radiation through clear skies, the clear sky beam and diffuse radiation can be easily computed.

The clear sky beam radiation on a horizontal surface is:

$I_{b=}I_n\tau_b\cos\theta_z$... (4-6a)

Where: $I_n = I_{sc}[1.0 + 0.033\cos\left(\frac{360\ N}{365}\right)]$

$= 1367 w/m^2[1.0 + 0.033\cos\left(\frac{360\ (344)}{365}\right) = 1409\ w/m^2$

$\tau_b = a_0 + a_1 e^{(-k/\cos\theta_z)}$ .... (4-6b)

$a_o = a_o^* r_o, a_1 = a_1^* r_1, k = k^* r_k$

Where,

$a_o^* = 0.4237 - 0.00821(6 - A)^2$

$a_1^* = 0.5055 + 0.00595(6.5 - A)^2$

$k^* = 0.2711 + 0.01858(2.5 - A)^2$

$r_o = 0.95, r_1 = 0.91, r_k = 1.02$, A= altitude in (1.332km) =1332m

A is altitude of the location in km above mean sea level

$a_o^* = 0.4237 - 0.00821(6 - 1.332)^2 = 0.2448$

$a_1^* = 0.5055 + 0.00595(6.5 - 1.332)^2 = 0.6644$

$k^* = 0.2711 + 0.01858(2.5 - 1.332)^2 = 0.296$

Therefore,

$a_o = a_o^* r_o = 0.2448 \times 0.95 = 0.2326$

$a_1 = a_1^* r_1 = 0.6644 \times 0.91 = 0.605$

$k = k^* r_k = 0.296 \times 1.02 = 0.3019$

Substitute the values into equation 4.6(b) gives:

$$\tau_b = 0.2326 + 0.605e^{(-0.3019/\cos 36.110^0)} = 0.70$$

Then using equation 3.23(a) to calculate beam radiation

$I_b = 1409 w/m^2 \times 0.7 \times \cos 36.11^0 = 800.17 w/m^2$

The transmittance of diffuse radiation through clear skies can be estimated from the beam radiation transmittance based on the study of ***Liu and Jordan:***

$\tau_d = 0.271 - 0.2939\tau_b = 0.271 - 0.2939 \times 0.7 = 0.080$

The clear sky diffuse radiation is:

$I_d = I_n \tau_d \cos\theta_z$…………………………………………………………......... (4.7)

$I_d = 1409 \times 0.080 \times \cos 36.11^0 = 91.30 w/m^2$

So, the total clear sky radiation on a horizontal surface can be estimated as:

$I_T = I_b + I_d$………………………………………………………..………………. (4.8)

$I_T = 738.77 + 91.30 = 892\ w/m^2$

4.3.3. Estimation of Solar Radiation on Inclined Surface

The following formula was given by **Liu** and **Jordan** (1962), for evaluating the total radiation on a surface of arbitrary orientation from knowledge of beam and diffuses radiation on horizontal surface.

$I_T = I_b R_b + I_d R_d + r R_r (I_b + I_d)$…………………………….……………………….. (4.9)

Where:

r = reflectivity of the ground = 0.2.

Rb, Rd and Rr are known as conversion factors for beam, diffuse and reflected components respectively.

The expressions for these are as follows:

Rb: is defined as the ratio of flux of beam radiation incident on an inclined surface to that on a horizontal surface. The flux of beam radiation incident on a horizontal surface (Ib) is given by: $R_b = \frac{\cos\theta}{\cos\theta_z} = \frac{\cos 28.4^0}{\cos 36.11^0} = 1.08$

Rd: is the ratio of the flux of diffuse radiation falling on the tilted surface to that on the horizontal surface. This conversion factor depends on the distribution of diffuse radiation over the sky and on the portion of sky seen by the surface.

$R_d = \frac{1+\cos\beta}{2} = \frac{1+\cos 9.14^0}{2} = 0.994$

Rr: The reflected component comes mainly from the ground and other surrounding objects.

$R_r = \left(\frac{1-\cos\beta}{2}\right) = \left(\frac{1-\cos 9.14^0}{2}\right) = 6 \times 10^{-3}$

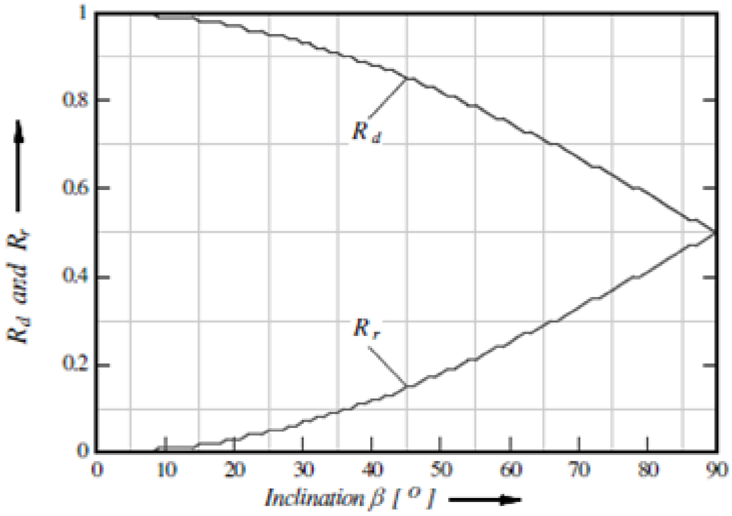


Figure 4-2: **Variation of Rd and Rr with inclination**

In this case ($\beta = 9.14^0$), Rd=0.994 and Rr = 6×10^{-3}

This indicates that small slop planes receive little reflected radiation and more deflection radiation.

Using equation 4.9 to determine solar radiation on inclined surface:

$$I_T = I_b R_b + I_d R_d + rR_r(I_b + I_d)$$

$$I_T = 800 * 0.94 + 91.30 \times 0.994 + 0.2 \times 6 \times 10^{-3}(800 + 91.30)$$

$$I_T = 844 W/m^2$$

December month is minimum solar radiation in selected site, but the calculated total solar radiation above that taken from data collection, therefore, the solar radiation of selected site enough for this system.

4.3.4. Peak Sun Hours

For the purpose of the solar PV system design, the minimum monthly solar irradiation is used in determining the peak sun shine hours. This approach is usually required for the design of solar PV systems (designing for worst conditions).

Performance of solar PV system depends largely on the peak sun hours of the location of application. The peak sun hour(s) of an area is determined form the available solar irradiance of the location. The peak sun hours and total irradiation are related by Equation 4-10

After compare collected data of **Recorded** and **NASA**, then we take a minimum solar radiation of nearby area of a site. Now by definition Peak Sun hour is equivalent to calculated irradiance 844 [w/m2], the number of peak sun hours can be obtained by equation 4-10 using minimum monthly solar irradiation data in December 5.21 kWh/m^2/day from **Table 4-2.**

$$PSH= \frac{Irrigation[wh/_{m^2/day}]}{Peak\ sun[W/_{m^2}]} \qquad (4\text{-}10)$$

$=5.21*1000Wh/m^2/day/831.061w/m^2=6.27h/day$

PSH=6.27h/day (This peak sun hour is minimum value available in December)

Peak sun hour is the time period of pump can be operated daily its value is 6.27h/day

4.4. System sizing

4.4.1. Determining of Solar PV Panel

Now the main point that must be focused in this research is to find expected energy required from solar the PV panel which can able to satisfy pump power during winter season and another aspect during summer season due to different environmental factor like cloud wind temperature etc the amount of power output is become low at this time the PV panel power used for multipurpose (Appliance). The required power of the solar panel depends on the amount of energy demand to operate pumping. The Power requirement to operate Pump has power capacity around 27.5 kWp it's determined in section 4.4.2 and power requirement for other purpose 132262Wh per day shown in table 4-7. It is used as supplementary power for other purpose has to be considered. The minimum solar radiation of site is 5.21kwh/m^2. The efficiency of maximum power point of module is 12.5-15% as shown in **Table 4-3.** A type of motor pump power has been selected based on flow rate capacity and pump head. It's called Submersible pump **Submersible Motor Specification (YQS200-22) at [Appendix-B]**

4.4.2. Array size

Daily horizontal solar radiation strike on tilted surface of Solar PV panel can provide energy demand. Array size can be obtained based on energy requirement and actual sunshine hour. By considering system

Electrical power needed for pump power is 22kw
Energy Requirement= Electrical power required* 6hr=1320, 000Wh/day.

Now determine sizing of solar array

$$\text{Array size (total wattage of PV panel)} = \frac{\text{Energy Requirement}}{\text{PSH}} \quad (4\text{-}11)$$

Assuming, actual sunshine hours or PSH peak sun hours =6.27h/d and energy needed $= \frac{132{,}000\text{Wh/d}}{6.27\text{h/d}} = 22\text{W}$

Total wattage of PV panel= 22000kW =22kw.Now calculate number of PV panel

$$N^{\underline{o}}_{\text{PV panel}} = \frac{\text{Capacity of plant}}{\text{PVmodule selected}}$$

=22,000W Wp/400Wp=55

But, the solar panels must also have additional capacity to account for any potential reduction in power due high heat, dust, age, etc. Many PV manufacturers recommend increasing the minimum peak power value by 25% to account for these environmental factors. Therefore, the PV panels can be sized to provide a minimum output of 22,000Wp*1.25 = 27,500Watts peaks. So that, the selected PV panel can produces above required power. Therefore the design is safe.
Therefore Number of solar PV panel to satisfy energy required is around 55W

Power loss

There are different loss presented during power PV power producing

wiring loss(1.5 %) at STC

series diod loss(0.1 %) at STC

module quality loss (1.5 %)

module mismatch losses (1.0 %) at MPP

total pv arry loss =1.5+0.1+1.5+1=4.1%

Solar PVpower= 25*0.959=23.97kw

4.4.3. Module Selection

Candidate Modules for the System

1. Generic: - model: 190 Wp 54 cells, nominal power 190.0 Wp technology: Si poly ISc 7.820A, Impp 7.250A, Voc 32.80v, Vmpp 26.2v, temperature coefficient=0.05 %/^{o}c, module efficiency 12.92%
2. BP Solar: -model: BP7180 S, nominal power 180 Wp, technology crystalline silicon, ISc 5.3A, Impp 5A, Voc 44.2V, Vmp36V, temperature coefficient 0.05%/^{o}c, module efficiency 14.3%.
3. Mitsubishi: -model: PV-UD180mfs, nominal power: 180 Wp, technology: Si poly, ISc 8.03A, Impp 7.45A, Voc 30.4V, Vmpp24.2V, temperature coefficient 0.03%/^{o}c, module efficiency 13.6%.
4. Helios:-model: 9T6 400Watt nominal power 400Wp technology: Mono-crystalline silicon, 8.82A, Impp 8.26A, Voc 59.8V v, Vmpp 48.43v, temperature coefficient=0.03 %/^{o}c, module efficiency 15%

Candidate number four i.e. Helios Solar 9T6 400W technology module, is selected for this purpose because of its best efficiency and better temperature coefficient. It provides reliable photovoltaic power operating DC loads directly or, in an inverter-equipped system. With 400 watts of nominal maximum power, the 9T6 400 is used in utility-grid supplemental systems for residences, commercial buildings, and centralized power generation and in remote systems for applications including telecommunications, pumping and irrigation, remote villages and homes, and land-based aids to navigation.

Source: https://www.gogreensolar.com/pages/orange-county-solar-company

Table 4-3 : Electrical and mechanical characteristics of the selected PV module.

Electrical characteristics	Helios 9T6 400
Maximum power (P_{max})	400W
Power tolerances	-3%/+5%
Number of cell	96
Voltage at P_{max} (V_{mp})k	48.43 V
Current at P_{max} (I_{mp})	8.26A
Open-circuit voltage (V_{oc})	59.8V
Short-circuit current (I_{sc})	8.82A
Temperature coefficient of I_{sc}	0.03%/^{o}c
Temperature coefficient of V_{oc}	-0.32mV/^{o}c
Temperature coefficient of power	-0.41%/^{o}c
NOCT	47±2^{o}c
efficiency	12.5-15%
Mechanical characteristics	
Type	Mono (96 Cell)
Frame colour	Clear
Thickness	40mm
Width	1,976 mm
Depth	1,310 mm
Weight	31.30 kg
Area:	2.58 m^2
80% power output warranty period 25 years	

4.4.4. Battery

Batteries are one of the most sensitive equipment of a PV system and expensive too, accountings for nearly **20% to 40%** of the total cost of the PV system for stand-alone applications. Battery is mostly used for purposes of solar power which during nights and cloudy days, we need to store the energy produced during the daytime, however in this research the purpose of using battery storage is that the time no need of irrigation and during low water demand from command area. The most commonly used batteries in the PV systems are the lead-acid and nickel cadmium batteries. But we use the Deep cycle battery, on account of its low cost and simple charging process.

4.4.4.1. Summer Season Battery Storage

The size of solar storage battery used in summer time required would be based on the appliance load energy demand the energy required of appliance such as florescent, mobile battery, TV, grain milling etc. And also depend on Weather condition available at study area. When the storage battery to be installed its coupled with system in summer season irrigation is not required the reason to attach battery storage to the system is considered in order to solve scarcity of series problem of rural electricity faced people live nearby area, however in winter season due to water demand increase no need of battery storage the system can be coupled directly so battery storage should be removed from the system at this time battery become wait to sleep the most benefit to kept sleep battery at winter(bega) season is to increase the service life of battery. Having too much energy and storage capacity will increase cost ,however to design the solar PV water pumping system may need high initial cost but after a given period of time the system could be more advantage. The system mostly focused on irrigation time consequently temporary energy needed as supplementary power can supply to other purpose.

In the summer season Solar PV panels can be generate less energy at the study area, so the system may not generate enough solar electricity as winter to fully charge the battery during the summer months. Service lifetime of battery can be affected by long periods discharging battery. This is specifically the case for Deep cycle batteries so that to maintain battery health, the system may have a ‘winter mode’ setting that is during the winter by putting the battery to sleep. to stop the discharge from it or charges it from the mains.

In this research battery only worked for appliance that critical in the rural community that can consume energy for small time therefore, this time a battery sleeping time is greater than discharging time.

Types of Selected Battery at Appendix –D: Battery Selection

The specification of the battery that we use is **1875ah**

- Calculation for the number of batteries that we use in our project
- Generally the sun gives 1000W/m^2

A solar panel is 40% efficient so we get 400 W (40% of 1000)

Theoretically we use 55 panels each of 400 watts (400*55=22,000w) practically summer output power is 4049 kW from (table:4-10)

The size of the appliance that we uses are 132262Wh per day) from (table:4-9)

132262*30=3,967,860w-hr =3,967.86kwh/month

132262wh needed

Usually battery is specified in amp-hr

The specification of the battery that we use is1875Ah

We use 12v battery so 132262wh/12V= 11,000A-h

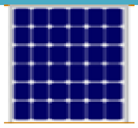
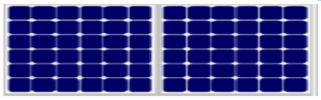
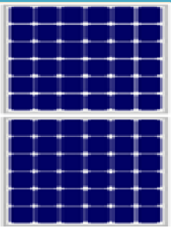
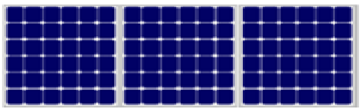
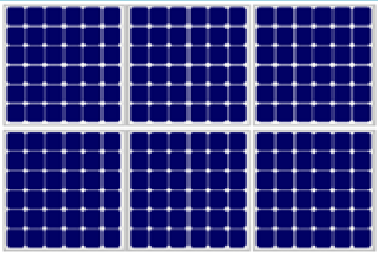
- No of Battery energy stored= 11000/1875*.7=8 assuming (Since battery is 70% efficient) battery loss is 30%
- We require 8 batteries to supply power

The useable storage capacity in kilo-watt hours (kWh)

Useable storage capacity=A-h*voltage =1875ah*12V=22.5kwh. DOD) allowable depth of discharge, typically 80% for deep cycle batteries (lead acid battery)

Stored energy (80%)=0.80*22.5=19.125kwh

Table 4-4: Module connections in parallel and series

Panel connection	Connections	Voltage	Current
	None	59.8	8.82
	Series	119.6	8.82
	Parallel	59.8	17.64
	Series	179.4	8.82
	Parallel and series	179.4	17.64

55 panels are required to meet the pump's power requirement. They were wired in series to provide the necessary voltage for the pump power needed.

4.4.5. Electrical Connection of Modules

Solar panels have a negative (-) and a positive terminal (+) similar to the terminals on a battery. PV panels are wired in series by connecting the negative terminal of one panel to the positive terminal of the next panel as shown in Figure 4-3. When panels are wired in series, the panel voltages are added.

If the panel has the characteristics shown in Table 4-3, the resultant voltage output for panels shown in Table 4-4 is: - $59.8 + 59.8 = 119.6v$. The current output would be the same as for an individual panel or 8.82 A.

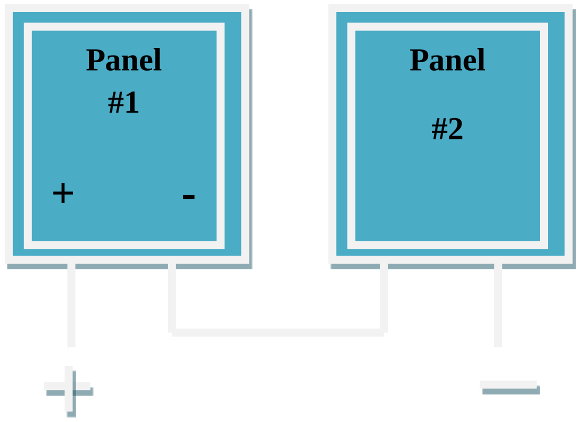


Figure 4-3: Solar panels wiring in series

Now we need to input power that can able to start to move pump power which is to satisfy water demand at command area. We can obtain input power from solar PV module watt peak that obtained by inputting daily, monthly and yearly horizontal solar radiation But it can be fluctuated due to weather changing from period to period once time increase or decrease such as morning, noon and evening whether the power produced might be maximum or minimum it is based on those time these power requirement should be satisfy or greater than water power delivered by the pump.

4.5. System Simulation

4.5.1. Simulation using by PVsyst Software

From the below figure can be observe irradiance of site and describe loss factor of energy on solar array and by using this irradiance can be calculate peak sun hours.

PVsyst software is able to import meteo data from many different sources as well as personnel data. The software consists of three main design steps. The preliminary design option allows evaluating grid-connected, stand-alone and pumping systems, and using monthly values to perform a quick evaluation of system yield. For each project the location and the system to be used has to be specified. The program includes predefined values of locations of different parts of the world. The second one is project design option allows to create full-featured study and analysis of grid connected, stand-alone, pumping, and dc-grid systems with accurately system yields computed using detailed hourly simulation data. Different simulation variants, horizon shadings, detailed losses, and real components can be added to make economic evaluations. Reports can be generated after the completion of the project and information can be exported to the clipboard. The last option includes meteorological data, components, solar toolboxes, and the analysis of actual data.

Source: ***(http://www.pvsyst.com***)

4.5.2. Input parameter for software

Table 4-5: **Solar PV water pumping system parameter**

Parameter	Values
Water required for command area	6.72l/s
Water yield from the well	9l/s
Total head	162.5m
Pump power	20kw
Pump motor efficiency	0.70
Pumping rate (peak sun hour)	6.27hour/day
Duty	1.68l/s/ha
Irrigated land by hectare	4ha
Piping length	1000m
Pipes types	PVC

Table 4-6: Pump characteristics

Manufacturer	Hebei,china
Model	YQS200-22
Pump Technology	Centrifugal multistage
Power	20 kw
Motor	Asynchronous motor

Stand Alone System: Detailed User's needs

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Stand Alone System: Simulation parameters

Project :	**PV water pumping in madhicho area**			
Geographical Site	**Madhicho**		Country	**Ethiopia**
Situation	Latitude	9.14° N	Longitude	40.75° E
Time defined as	Legal Time	Time zone UT+3	Altitude	1332 m
	Albedo	0.20		
Meteo data:	**Madhicho**	NASA-SSE satellite data, 2003-2012 - Synthetic		

Simulation variant :	**New simulation variant**			
	Simulation date	01/04/18 18h08		

Simulation parameters				
Collector Plane Orientation	Tilt	25°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
PV Array Characteristics				
PV module Si-mono	Model	**9T6 400**		
Original PVsyst database	Manufacturer	Helios USA		
Number of PV modules	In series	11 modules	In parallel	5 strings
Total number of PV modules	Nb. modules	55	Unit Nom. Power	400 Wp
Array global power	Nominal (STC)	**22.00 kWp**	At operating cond.	19.74 kWp (50°C)
Array operating characteristics (50°C)	U mpp	478 V	I mpp	41 A
Total area	Module area	**142 m²**	Cell area	126 m²
PV Array loss factors				
Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	193 mOhm	Loss Fraction	1.5 % at STC
Serie Diode Loss	Voltage Drop	0.7 V	Loss Fraction	0.1 % at STC
Module Quality Loss			Loss Fraction	1.5 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP

Table 4-7:output energy required of Winter season

	Number	Power	Use	Energy
irrigation purpose	1	3667 W tot	6 h/day	22002 Wh/day
Total daily energy				22002 Wh/day

Table 4-8: Daily energy consumptions in Summer season

Daily consumptions

Number	Appliance	Power		Daily use		Hourly distrib	Daily energy
100	Lamps (LED or fluo)	18	W/lamp	4.0	h/day	OK	7200 Wh
98	TV / PC / Mobile	75	W/app.	3.0	h/day	OK	22050 Wh
89	Domestic appliances	200	W/app.	1.0	h/day	OK	17800 Wh
85	Fridge / Deep-freeze	1.00	kWh/day	24.0	h/day	OK	85068 Wh

Appliances info

Total daily energy 132262 Wh/day
Total monthly energy 3967.9 kWh/month

Consumption definition by: Year
Week-end or Weekly use: Use only during
Display Values of: Summer

load curve for community

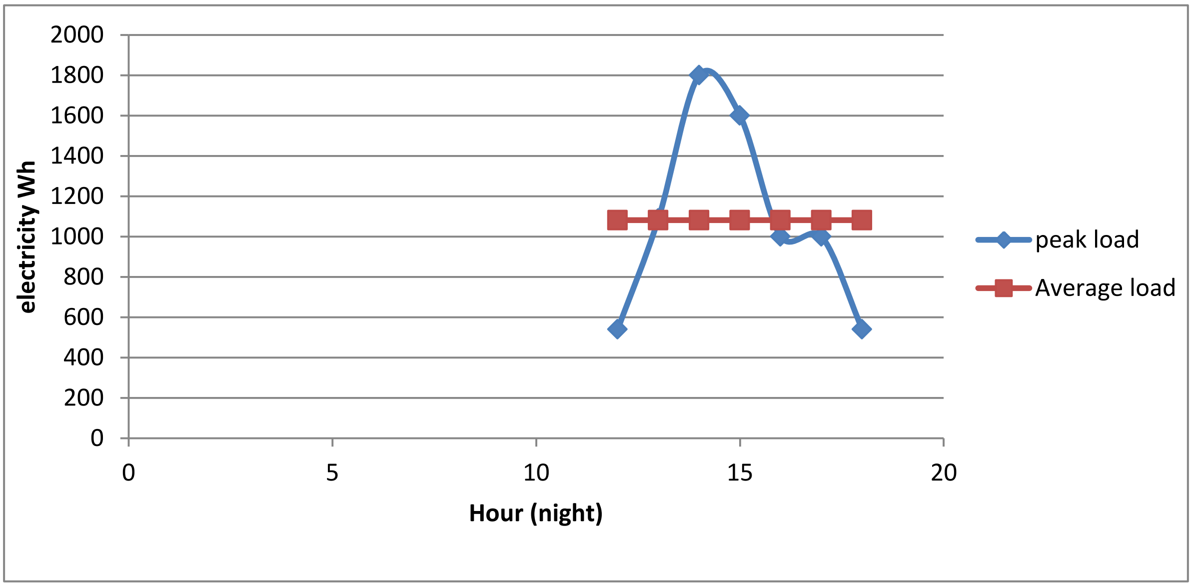


Figure 4-4:load curve for community- Lamp

the figure 4-4 shows that the people live in rulal area required light only night time from 12:00-5:00hour most of people swith on Lamp from 1:00h upto 4:00h however after 5:00h more of switch of the Lamp.

Lamp

hour	peak load(W)	average load
12	540	1081W
13	1089	1081W
14	1800	1081W
15	1000	1081W
16	1600	1081W
17	1000	1081W
18	540	1081W
	7569	

Average load=total peak load/No of hour=7569/7=1081W

at 12 hour

100 No of Lump 30 lamp becom opened

30*18w=540w*1h=540wh

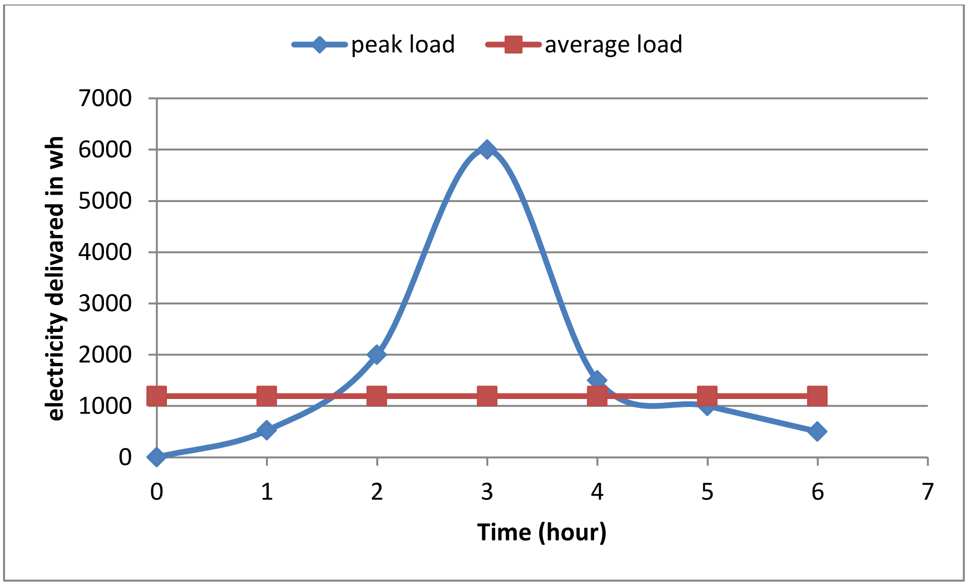


Figure 4-5:load curve for community- TV

Figure 4-5 indicate that the load curve for rural community TV user the most of people live rural area used TV at night time rather than day time they can be start to open TV 12:00 up to 6:00h but most of user at the same time use from 2:00h-4:00h then decreased.

Time	peak load	average load
7	750	2,813
8	6000	2,813
9	1,500	2,813
10	3,000	2,813
	Av.load=2813	

battery power supply system(control system) used by control unit Controller Model Universal controller with MPPT converter

Technology MPPT converter Temp coeff. -5.0 mV/°C/elem.

Converter Maxi and EURO efficiencies 97.0/95.0 %

Table 4-9: Output energy required and Water demand

New simulation variant

Balances and main results

	GlobEff kWh/m²	EArrMPP kWh	E PmpOp kWh	ETkFull kWh	H Pump meterW	WPumped m³	W Used m³	W Miss m³
January	202.4	5822	3916	1587	162.7	4741	4495	0.000
February	176.9	5066	3379	1423	162.6	4067	4060	0.000
March	181.3	5152	3736	1126	162.6	4491	4495	0.000
April	154.2	4441	3564	566	162.6	4332	4350	0.000
May	154.1	4443	3672	449	162.5	4453	4495	0.000
June	132.9	3919	3586	45	162.5	4340	4350	0.000
July	136.1	4049	3673	36	162.5	4457	4495	0.000
August	148.5	4379	3733	301	162.5	4511	4495	0.000
September	143.6	4160	3545	264	162.6	4268	4350	0.000
October	185.1	5261	3788	1141	162.7	4601	4495	0.000
November	197.0	5594	3595	1671	162.7	4418	4350	0.000
December	191.2	5522	3684	1537	162.7	4495	4495	0.000
Year	2003.3	57806	43871	10145	162.6	53174	52925	0.000

Legends:
- GlobEff — Effective Global, corr. for IAM and shadings
- EArrMPP — Array virtual energy at MPP
- E PmpOp — Pump operating energy
- ETkFull — Unused energy (tank full)
- H Pump — Average total Head at pump
- WPumped — Water pumped
- W Used — Water drawn by the user
- W Miss — Missing water

the result in the tabel 4-9 obtained from PVsyst software.

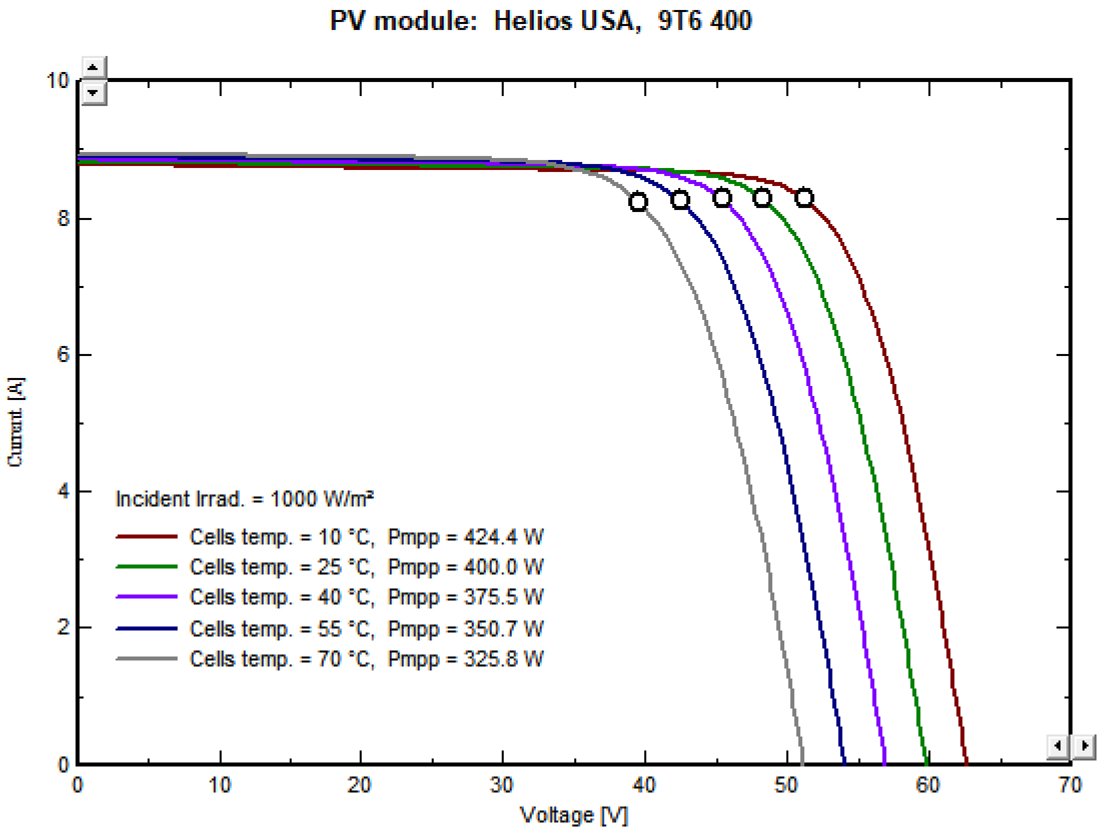


Figure 4-6: **The effect of cells temperature on maximum power point at constant irradiance**

This fig. Indicated that at different level available cells temperature increase the PV power produced conversely decrease. The required output power obtained perfectly at 25^0c cell temperature and also it obtained the result from the process of combining voltage and current.

P_{mpp}=45*8.89=400.05W

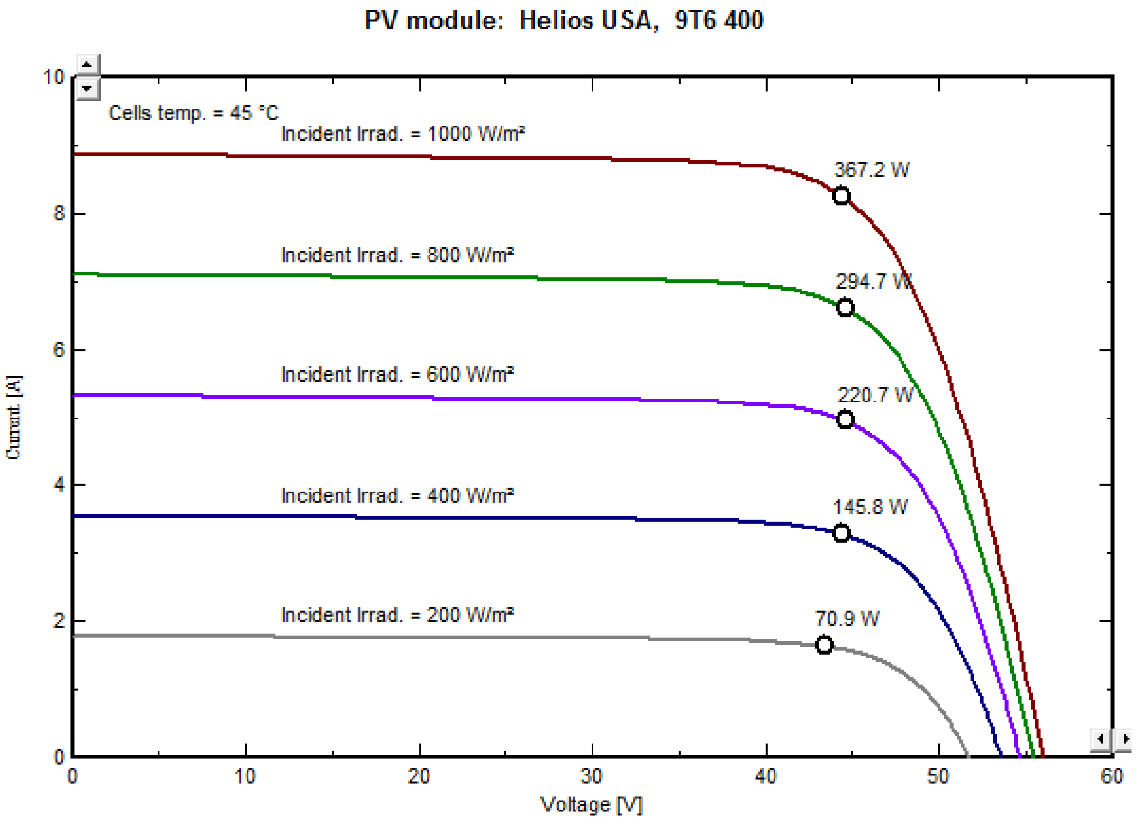


Figure 4-7: PV power at different irradiance by PVsyst software

The inputs of PVsyst software for this work are latitude, Altitude, Time zone and longitude of Site, power requirement types of PV panel and etc. As shown in above figure as irradiance of site increase, power produced by PV panel is increase. The power required for solar powered pumping is about 20kW can be getting this power at irradiance of 1000W/m^2.At 1000W/m^{2}irradiance can be produce power.

P= V (V)* I(A) = 41.23V*5.9A = **367.2W**

PV power at different irradiance by PVsyst software at 1000w/m^2 is 367.2W while to satisfy power required for solar powered pumping about 20kW which is required number of PV panel about 55 which is 367.2W* Panel array 22,020W. But these powers reduce by different

In this case due to maximum cell temperature available on the site the power output is low cause to increase number of PV panel to satisfy power required so that its clear effect on the cost of solar module.

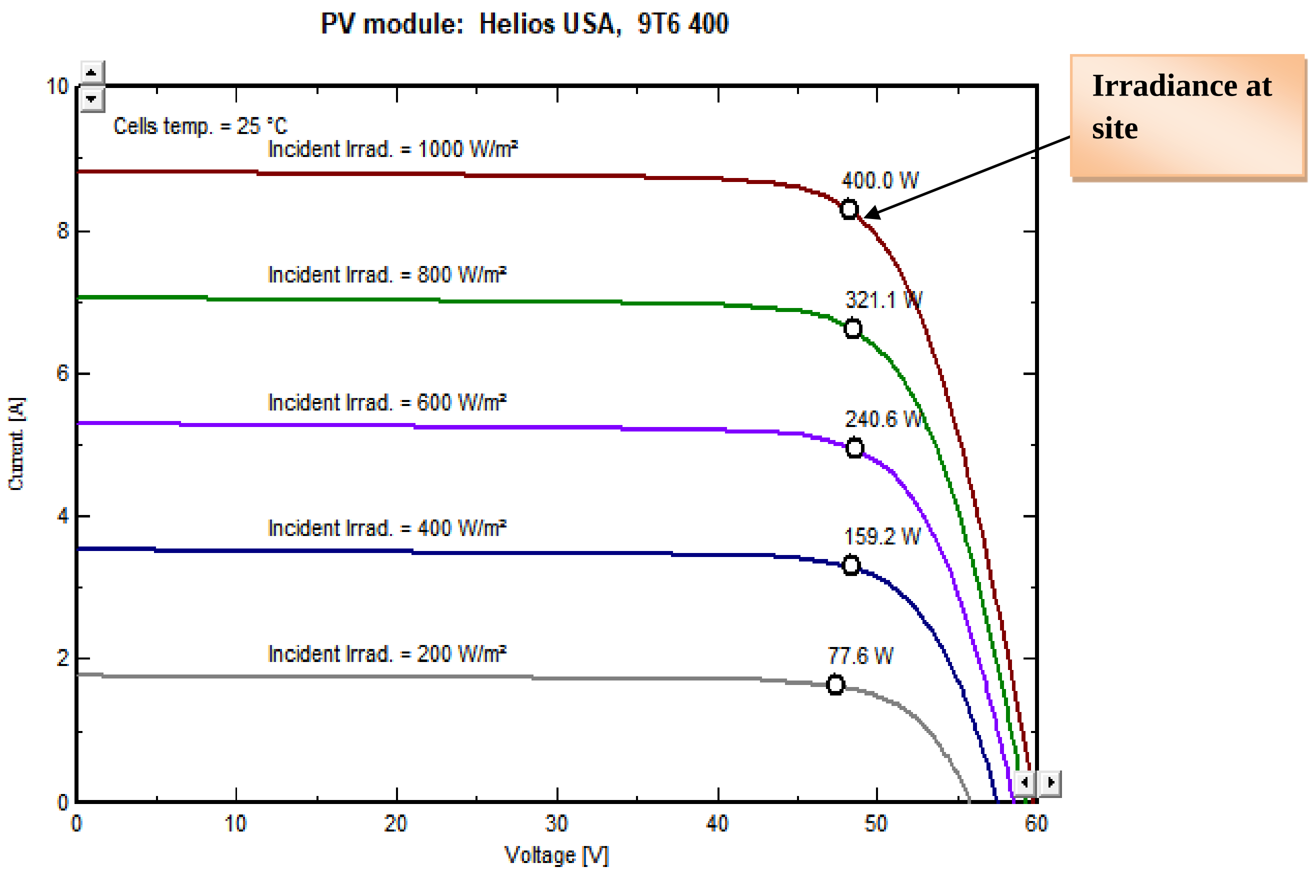


Figure 4-8: The effect of different irradiance on PV power at constant cell temperature.

What is observed from the graph as the cell temperature increase maximum power point decrease. As cell temperature 25^0c MPP become 400W.In my case to satisfy the energy needed we can get selected power based on 25^0c.

For moving solar pumping power 20,000W PV solar pane capacity has required can be getting this power at irradiance of 1000 W/m^2.At 1000W/m^{2}irradiance can be produce power.

P= V (V)* I (A) = 45V*8.9A = 400W.

In this case during moderate cell temperature presented in site study the power output is high it cause to decrease number of PV panel to satisfy power required so that it has significant benefit to decreasing the cost of solar module. Therefore to satisfy the power demand in the system the number of photovoltaic panel required in this research is about fifty five (55).

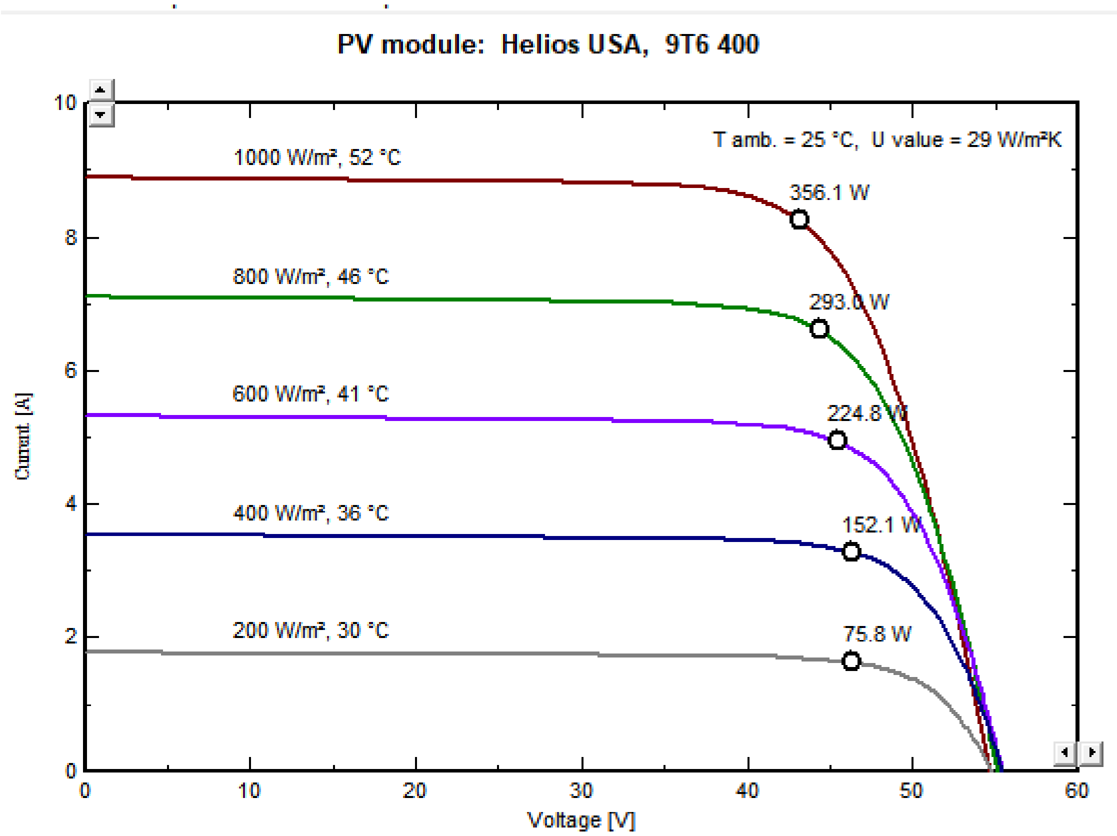


Figure 4-9: Effect of ambient temperature at different irradiance on PV power output.

From the above fig. Shows that the effect of ambient temperature at different irradiance has significant effect on maximum power output is meaning that as ambient temperature increase parallel with increasing irradiance the maximum output power point also increased.

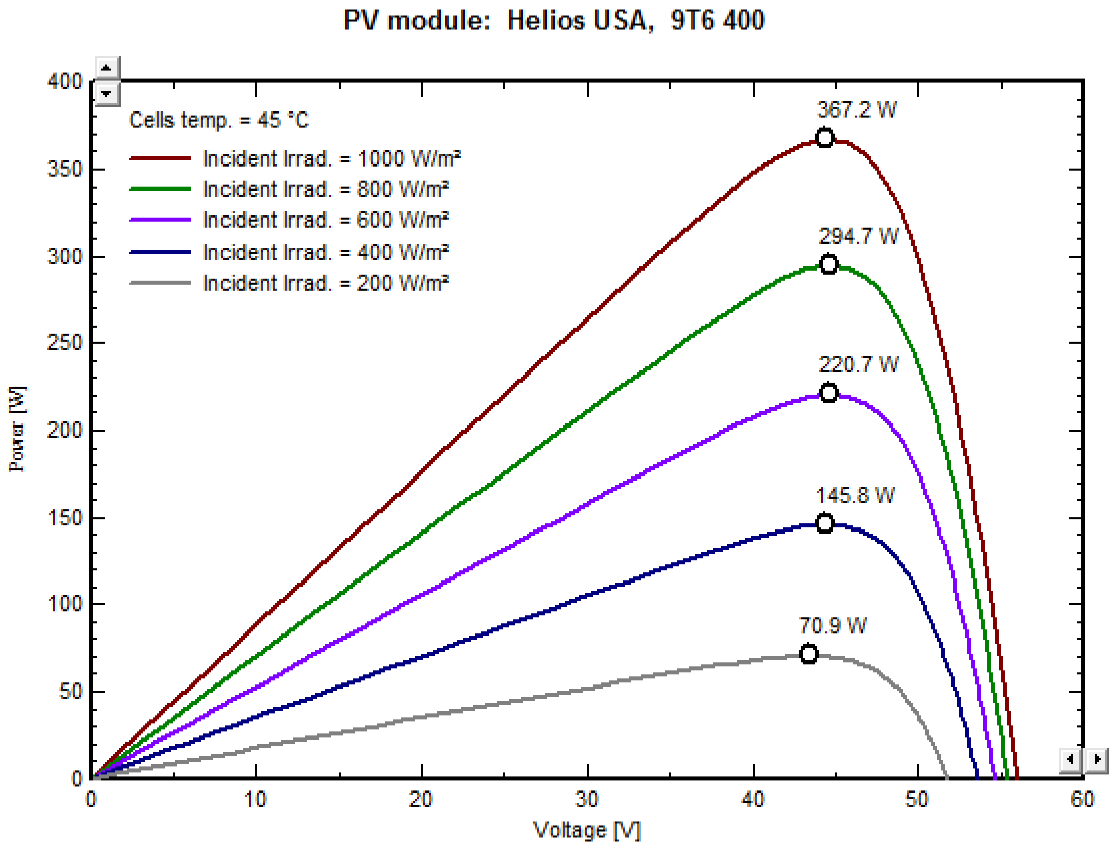


Figure 4-10: Effect of irradiation on power output.

As illustrated in Fig. shows that At constant temperature the change in irradiation has a clear effect on the PV output maximum power. Its clearly to understand that as the irradiation level increases the PV power output and voltage increases with it. But at change in cell temperature lead to increase or decrease PV power out and Vis versa.

In general, the increase in the irradiation level leads to a theoretical increase in the maximum power voltage when there is no change in the cell temperature.

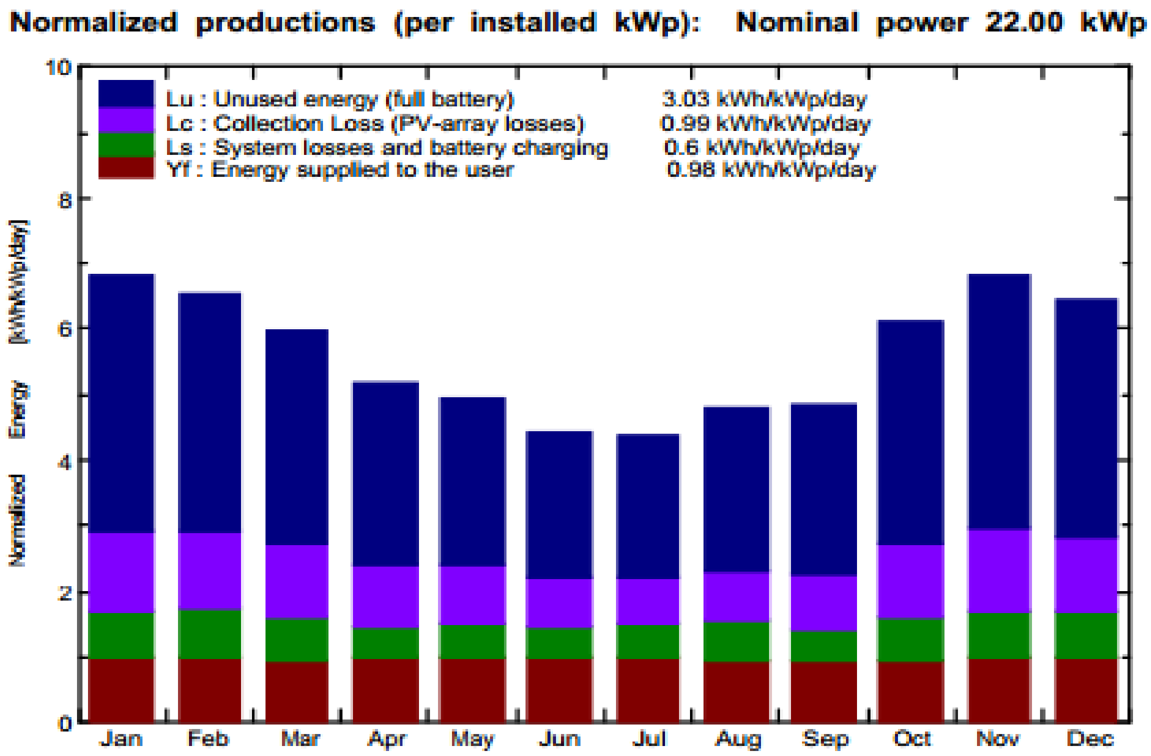


Figure 4-11: Normalized production

From figure show that the energy supplied to user is 0.98kWh per kW_p per day nominal power 22kWp with PV-array loss and system loss and battery charging then net energy produced that delivered to pump is 21.56kw

4.6. RETScreen Simulation Result

Table 4-10: Weather data of NASA from 2003-2012 year at study area

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature
	°C	%	mm	MJ/m²/d	kPa	m/s	°C
January	17.6	0.5%	18.73	20.21	85.9	1.8	24.7
February	19.0	0.5%	28.28	20.91	85.9	2.0	27.1
March	20.4	0.5%	92.33	21.26	85.8	1.9	29.4
April	21.2	0.6%	278.45	20.36	85.7	2.2	29.6
May	22.1	0.6%	157.42	21.38	85.7	2.5	30.3
June	22.4	0.6%	93.05	19.71	85.7	3.1	26.0
July	20.8	0.7%	216.31	19.03	85.7	3.3	22.3
August	20.6	0.7%	267.11	19.61	85.7	3.0	21.9
September	20.9	0.7%	238.57	18.06	85.7	2.3	24.3
October	18.9	0.5%	79.84	20.58	85.8	2.0	25.9
November	17.2	0.5%	30.98	20.83	85.9	1.9	24.8
December	16.2	0.5%	29.84	18.75	86.0	1.9	24.0
Annual	**19.8**	**0.6%**	**1,530.91**	**20.05**	**85.8**	**2.3**	**25.8**
Source	User-defined	User-defined	User-defined	User-defined	NASA	User-defined	NASA
Measured at					m	10	0

Figure 4-12: daily solar radiation horizontal Vs Precipitation

This graph is show that high solar radiation during month of October to march this time the site can get slightly rare precipitation from June to September the site has enough precipitation during this time no need of irrigation the power goes to appliance.

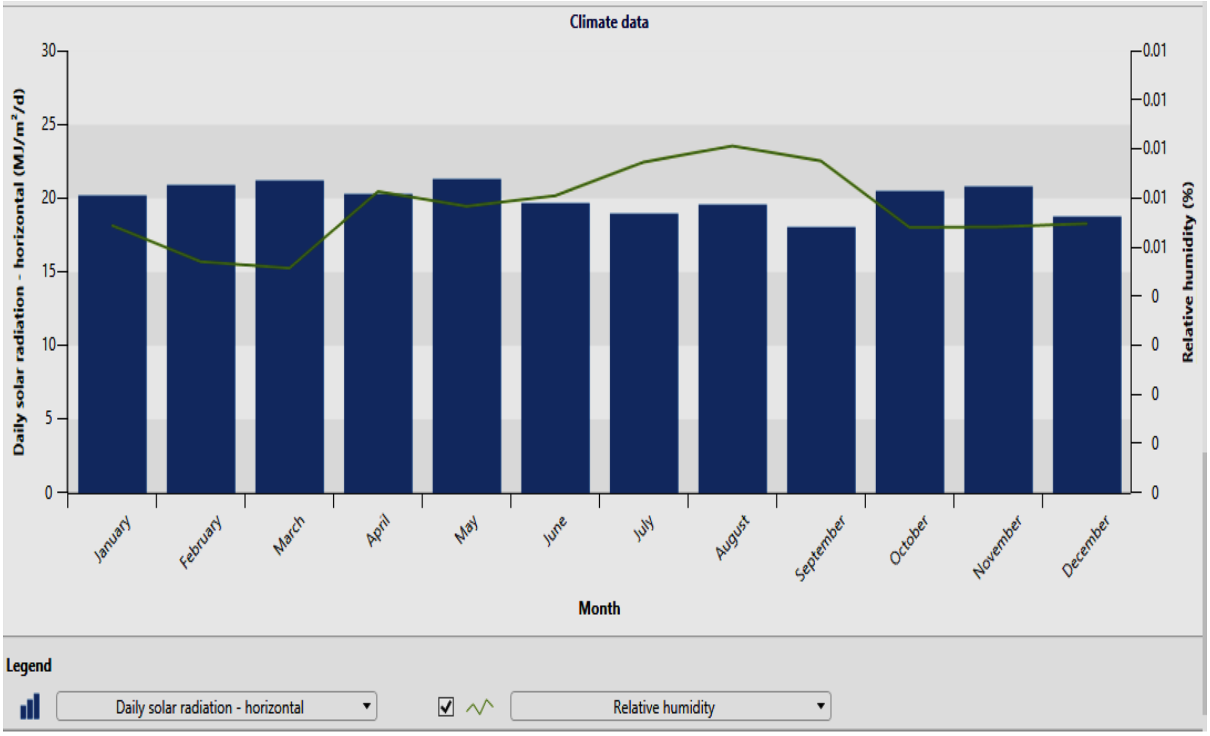


Figure 4-13: daily solar radiation horizontal Vs Relative humidity

The maximum relative humidity indicate slightly low amount of solar radiation at site and decreasing relative humidity result provided increasing irradiance during month of winter season.

Figure 4-14: The effect Earth temperature on daily solar radiation horizontal

As earth temperature increase the irradiance required at winter season is increased but due to lower the earth temperature in summer season can direct effect on daily solar radiation its result of lower produced power output.

Figure 4-15: daily solar radiation horizontal Vs Air temperature

this graph shows that the air temperature clearly decrease in winter contrary it increase during summer season.

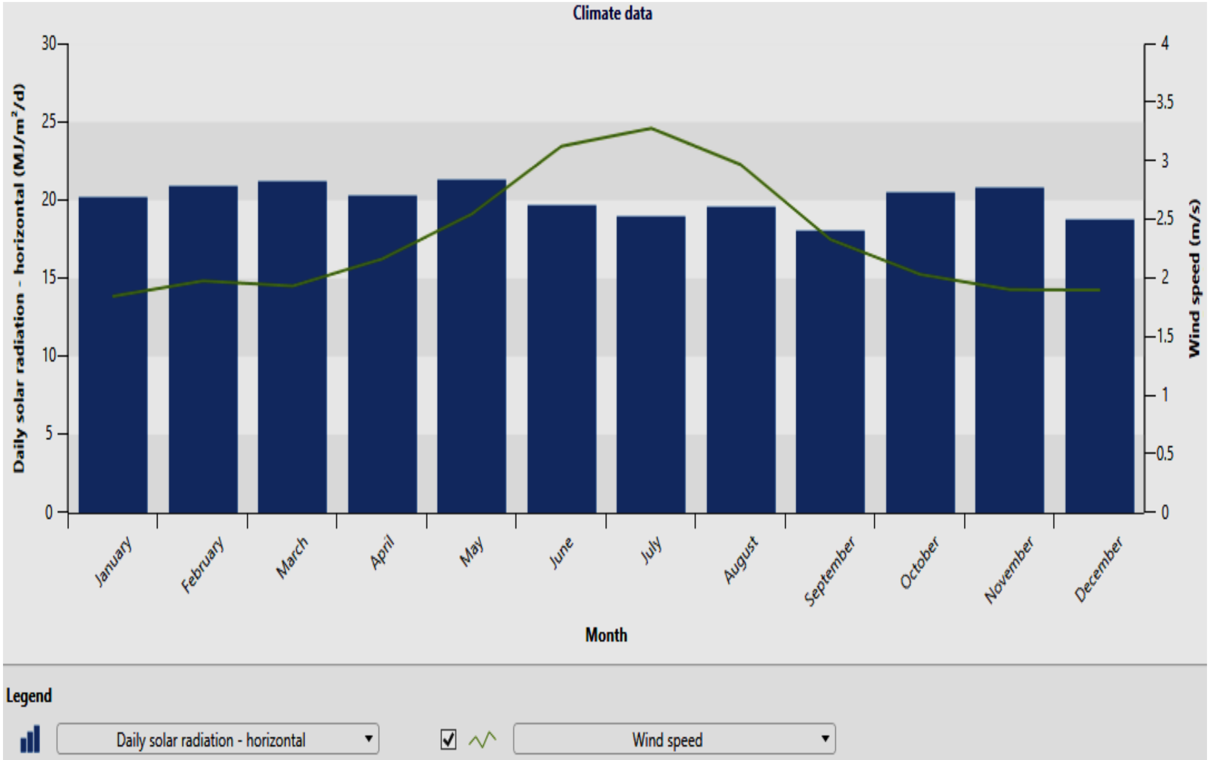


Figure 4-16: the influence of Wind speed on daily solar radiation

What was observed from the above graph the highly increased wind speed during summer season lower produced of daily solar radiation its can lead low power output.

By inputting peak sun hour and energy required to get output daily electricity required for the proposed system (PV system).

Table 4-11: Load characteristics

Load characteristics

○ Method 1
⊙ Method 2

Description	AC/DC	Intermittent resource-load correlation	Base case load kW	Hours of use per day h/d	Days of use per week d/w	Proposed case load reduction %	Proposed case usage time reduction %
pump	AC	Positive	20.00	6.27	7		

	Unit	Base case	Proposed case
Electricity - daily - DC	kWh	0.00	0.00
Electricity - daily - AC	kWh	125.40	125.40

Energy produced

The solar PV panel output of DC electricity is delivered to motor pump from solar irradiance data which is taken from **table 4-12** inputted to RETScreen software can give electricity delivered to pump power.

By inputting average monthly horizontal solar insolation to software that can give output electricity delivered to the system so that it's to more satisfy energy requirement at site.

Table 4-12: Daily solar radiations on horizontal and tilted surface

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity delivered to load MWh
January	5.61	7.51	4.57
February	5.81	7.43	4.07
March	5.91	6.77	4.14
April	5.66	5.86	3.51
May	5.94	5.81	3.60
June	5.48	5.25	3.18
July	5.29	5.12	3.22
August	5.45	5.50	3.72
September	5.02	5.43	3.26
October	5.72	7.19	4.37
November	5.79	7.61	4.53
December	5.21	7.18	4.38
Annual	**5.57**	**6.38**	**46.54**

The above output power obtained from the software is to satisfied the power required for pump at the winter season basically this energy is needed for two season first season for four month (October ,November ,December and January) second season also for month (February ,March ,April and May)

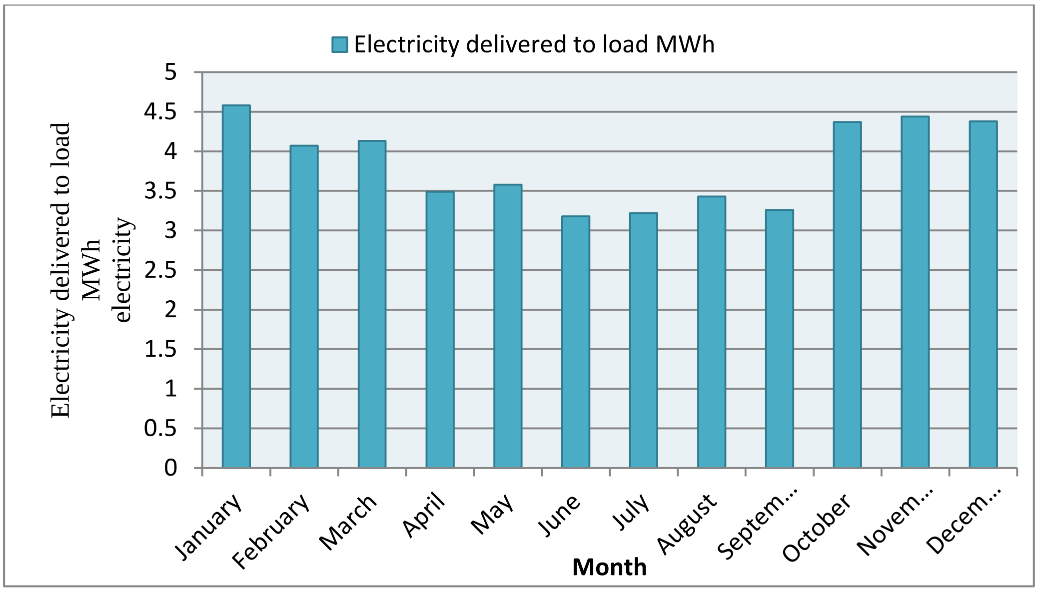
Winter energy available

In the winter 240 day /year are available the summation of monthly electricity delivered to the load is: 4.57+4.07+4.14+3.51+3.60+4.37+4.53+4.38=33,170 kWh Table 4-12

Total summation of daily energy obtained is 33,170 kWh

Energy required for pump in those months =33,170 kwh/240day=138.21 kWh=22.04kw*0.93(system loss)=20.5kw

This energy produced from system is enough for pump power of 20 kW



No-tracking mode

Winter: to produce high electricity delivered to the load the slope or inclination angle should be increased within the fixed mode conversely in **summer** mode the slope will be decreased to generate the maximum electricity delivered to the load the slope also indicate that the daily solar radiation tilted at summer and winter might be varies

In order to optimize electricity delivered to target used which is based on different slope angle that found in two season winter and summer

In case at slope of winter

In winter season at study area indicated that high slope angle resulted high electricity outcome

In case at slope of summer

Summer mode of fixed solar mode decreasing angle of inclination or slope angle by the solar panel can be resulted to increased energy output.

4.7. Working principle

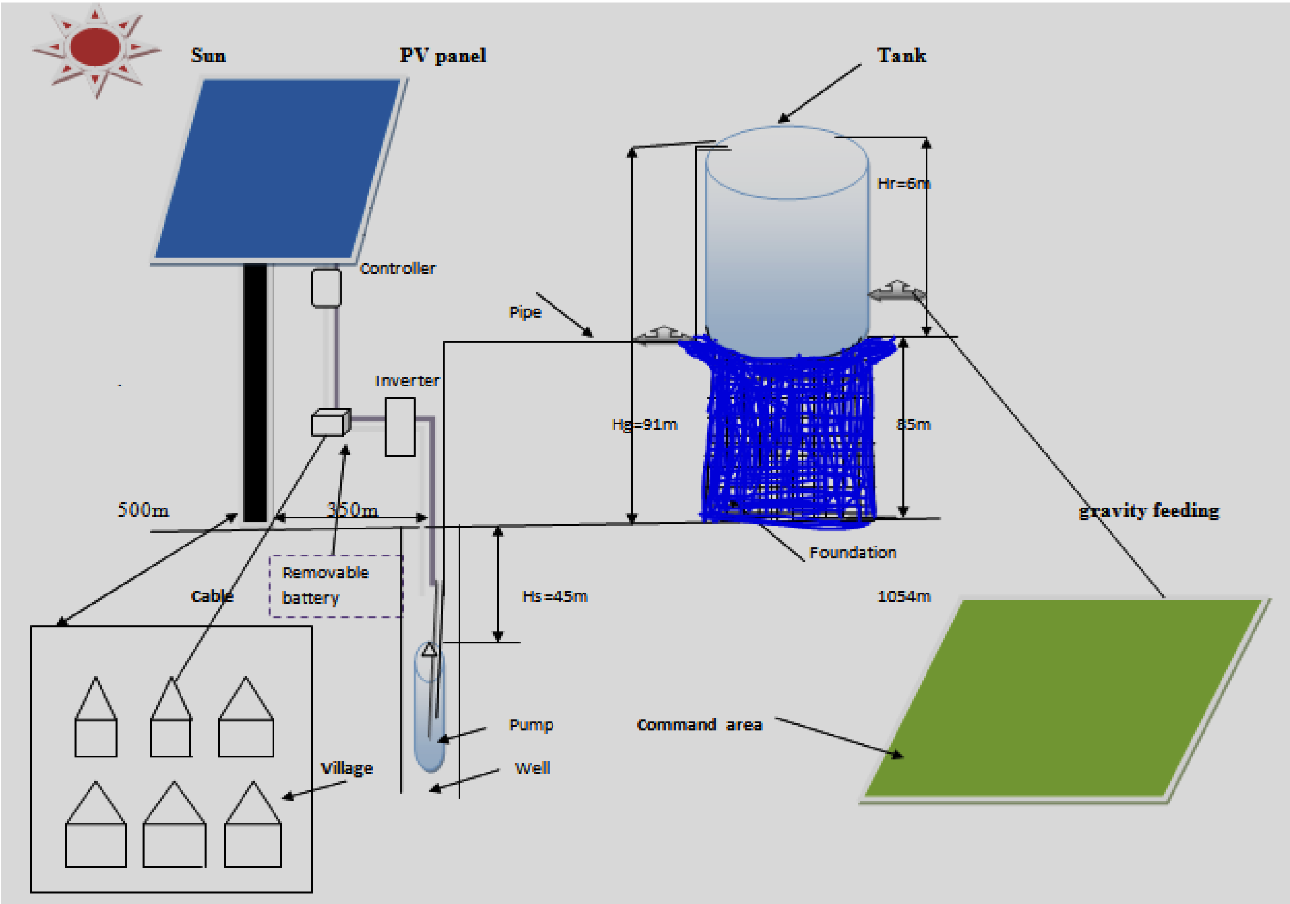


Figure 4-17: Schematic diagram for solar PV water pumping system.

The system is working directly coupled in order to supply maximum amount of power during peak sun hours of pumping at the time of winter season; however, when no need of irrigation solar removable battery can be attached to the system in summer season consequently, the power attained from PV panel used for other purpose.

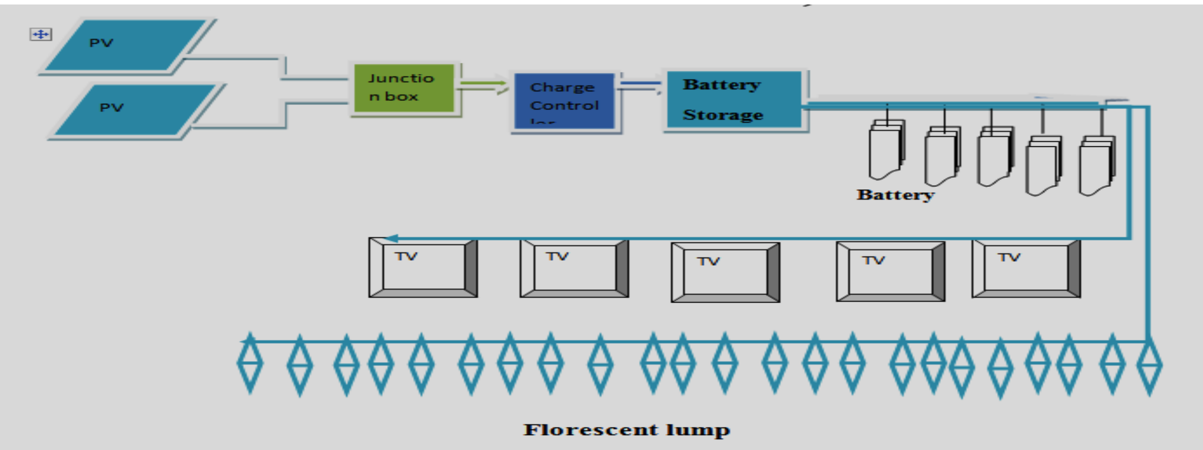


Figure 4-18: summer season flow diagram

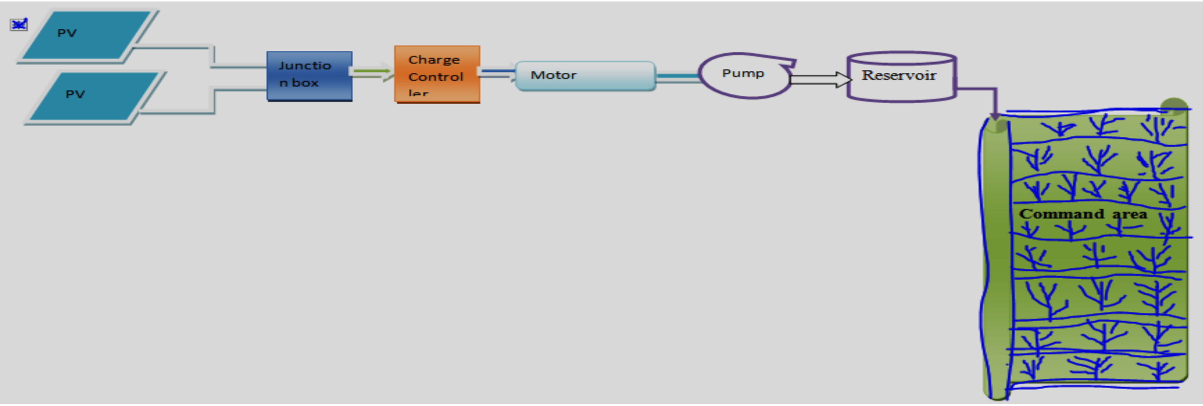
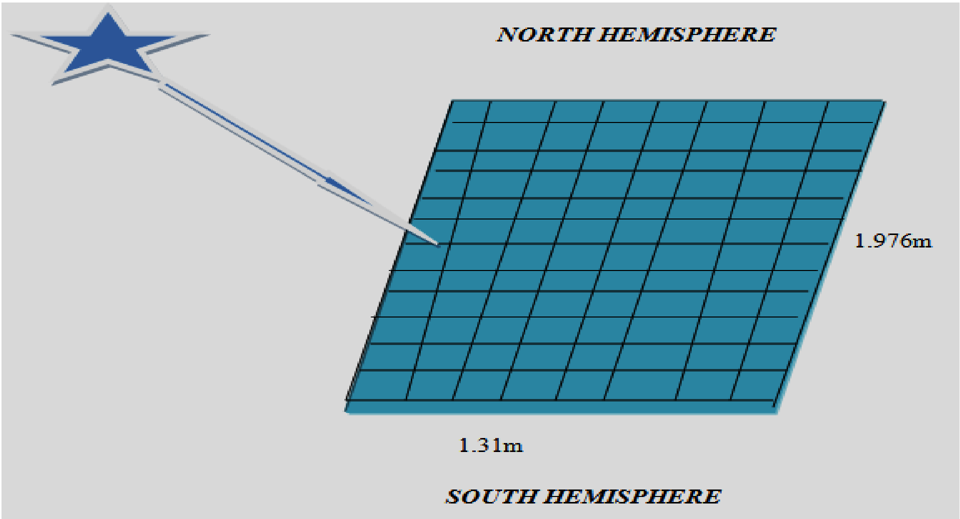


Figure 4-19: direct coupled winter season flow diagram



CHAPTER FIVE

5. Economic Analysis

5.1. Financial Comparison of solar photovoltaic and Diesel water Pumping System

The methods to be calculate the financial costs of both systems is first The cost of fuel for the diesel pumps in Ethiopia must be known based on the year price. The most common techniques in economic analysis the LCC and the payback period, the LCC method is the most complete approach and is widely used.

The aim of this study is to choose from both that has minimum total cost during the proposed life cycle and after life cycle of each alternative and has less cost per unit water pumped. Even though there is a high capital investment required for this system to be implemented, the overall benefit are high and in long run this system is economical *(Harishankar et al., 2014).* Life cycle cost analysis has been performed. In addition unit cost has been computed per KWh hydraulic energy and per m^3 of water output by determining the annual equivalent worth of the system.The life-cycle cost of both alternatives mentioned in this research could be calculated using the formula:

$$LCC = CC + MC + EC + RC - SC \quad (5.1)$$

Capital Cost (CC) of diesel generator =**12,769.2USD 347,833.008ETB**

Capital cost of PV water pumping=92,426.125**USD 2,517,687.645ETB**

The Capital Cost (CC) of a project includes the initial capital expense for equipment, the system design, engineering, and installation. The Maintenance Cost (MC) is the sum of all yearly operation and maintenance (O&M) costs discounted to present. Maintenance cost through life cycle is calculate using the following equation:

$$MC = A*\left[\frac{(i+1)^N - 1}{i*(i+1)^N}\right] \quad (5.2)$$

MC_{DG}=21,210.65USDand MC_{PV}=16,386.63USD

Where, A is the annual worth i interest rate N life cycle time (year)

The Energy Cost (EC) of a system is the sum of the yearly fuel cost.

$$EPC = A\left[\left(\frac{1+FE}{i-FE}\right) * \left[1-\left(\frac{1+FE}{1+i}\right)^{N}\right]\right] \quad \textbf{(5.3)}$$

EC_{DG}=33,708.29USD and $EC_{(PV)}$ = 26,042.15USD

Where, FE is the fuel escalation rate

This equation belongs only to diesel engine life cycle cost of fuel. Because there is no energy cost considered in case of PV system. The Replacement Cost (RC) is the sum of all equipment that will need to be replaced through the life of the system.

Pump for the PV water pumping system assumed to be replaced after 10 years and all components of the diesel pumping system also have to be replaced after 10 years. The total replacement cost through the life time is calculated using this equation:

$$RC = F*\left[\frac{1}{(i+1)^{N}}\right] \quad (5.4)$$

$RC_{(DG)}$ =60,092.76USD and $RC_{(PV)}$ =16,443.37USD

The Salvage Value (SC) of a system is its- net worth in the final year of the life-cycle period. The salvage value through the life time is calculated using the following equation:

$$S_{PC} = F\left[\frac{1}{(i+1)^{N}}\right] \quad (5.5)$$

$SC_{(DG)}$ =21,301.94USD and $SC_{(PV)}$ =46,412.75USD

Where, F is the future worth of money

LCC_{DG} = CC +MC+EC+RC-SC

LCC_{DG} =**12,769.2+21,210.65+33,708.29+60,092.7-21,301.94=106,478.9USD**

LCC_{PV} = CC +MC+EC+RC-SC

LCC_{PV} =**57,938.6+16,386.63+26,042.15+16,443.37-46,412.75=70,398 USD**

$$AW_{(DG)} = PW_{(DG)} * \left[\frac{i(1+i)^n}{(1+i)^{n-1}}\right] \quad (5.6)$$

$$AW_{(PV)} = PW\ (PV) * \left[\frac{i(1+i)^n}{(1+i)^{n-1}}\right] \quad (5.7)$$

5.2. Financial Parameters

Table 5-1: financial parameter for LCC analysis

Parameter	Unit	Value
Inflation rate	%	9
Discount rate		11
Fuel escalation rate		6
Project life		20

Table 5-2: Cost estimation of PV pumping system

Component description	[$]	Total cost[$]
PV module	1.235/W	27,160.025
Battery	940/kwh	16,920
Operation &maintenance	496/year	9,920
Pump motor	1900/kw	38,000
Inverter	1250/kw	17,600

Source:[Appendix-G]

total initial cost taken in average 92426.125 because some the above price estimated based on minimum before 8 year price but now a day the price might be decreased due to this reason we used the above initial value.

Table 5-3: Capital cost of PV and DG water pumping

system description	Capital investment cost [$]
PV system	92,426.125
DG system	12,769.2

For PV system Initial cost = (PV module+ inverter +battery +pump-motor) cost

5.3. Cost Breakdown

Under normal operating conditions the life of the Diesel generator is assumed to be 16,019.85 hours and to satisfy the daily water requirement it has to operate for 6 hours every day. Based on this the generator must be replaced after 7 years of operation

Table 5-4: PV cost breakdown

Sno	Cost description	cost[$]
1	Initial cost	92,426.125
2	Annual O&M cost	496
3	Battery Replacement cost	15,187.5

Table 5-5: Diesel generator cost breakdown

Sno	Cost description	cost[$]
1	Initial cost	12,769.2
2	Annual O&M	37,917
3	Replacement cost	12,769.2
4	Salvage value	1,915.35

Present worth of diesel generator

$$PW_{(DG)} = Ic + A\,(P/A, 11, 20) + R_C\,(P/F, 11, 6) - SV\,(P/F, 11, 6) + R_C\,(P/F, 11, 12) - SV\,(P/F, 10.5, 12) - SV\,(P/F, 11, 20) \quad (5.8)$$

Where, PW (DG) - Present worth of DG

IC - Initial cost =12,769.2

A - Annual M&O cost=37,917

SV - Salvage value =1,915.35

n - Economic Life of Project (years)=20

i - Discount rate =11

Rc- Replacement cost=12,769.2

The factors:

- (P/A , i, n) is $\left[\frac{(1+i)^n-1}{i(1+i)^n}\right]$, n is economic life of the project
- (P/F, i, n) is $[(1+i)^n]$, n is the year at which the future value is considered

PW $_{(DG)}$ = 12,769.2+ 37,917 (7.96) + 12,769.2 (1.87) - 1,915.35 (1.87) + 12,769.2 (3.5) - 1,915.35 (3.5) - 1,915.35 (8.06)

PW $_{(DG)}$ = 338,466.724-3,581.7045+44,692.2-6,703.725-15,437.721

=357,435.7735USD

PW $_{(PV)}$ = 92,426.125+ 496 (P/F 11, 10) +1875(P/A, 11, 20)

PW $_{(PV)}$ =92,426.125+ 496(2.83) +22500(7.96) = **214,722.305USD**

Then the equivalent annual worth is given by equation 5.9

AW = PW (A / P i, n)

$$AW = PW\left[\frac{i(1+i)^n}{(1+i)^n-1}\right] \dots . \qquad (5.9)$$

n=20

Equivalent annual worth for both systems is calculated below as shown in equation 5.9

$$AW_{(DG)} = PW_{(DG)} * \left[\frac{i(1+i)^n}{(1+i)^n-1}\right]$$

=**357,435.7735** *(0.125) = **44,679.4716875USD**

$$AW_{(PV)} = PW_{(PV)} * \left[\frac{i(1+i)^n}{(1+i)^n-1}\right]$$

=**214,722.305***(0.125) = **26,840.288USD**

AW is annual worth and **PW** is present worth (value)

5.4. Unit Water Cost

The unit water cost (UWC) reflects the cost of water and therefore provides a measure for the cost at which water at a particular installation needs to be sold at in order to recover the all inclusive costs for providing the water supply service. To determine the unit water cost, the LCC should be converted into the annual equivalent life cycle cost. In other words, the LCC will be distributed equally over the system's economic life. Then the ALCC (AW) is divided by the annual water production (AWP) (requirement) to determine the unit water cost as shown in equation 5.10

$$UWC = \frac{AW}{AWP} \qquad (5.10)$$

Annual water production(AWP)= 194m^3/d*365d/y=70,810 m^3/annual

UWC $_{(DG)}$ =$\frac{\mathbf{44{,}679.472}}{70{,}810}$=0.63 \$/m^3

UWC $_{(PV)}$ =$\frac{\mathbf{26{,}805.285}}{70{,}810}$=0.42 \$/m^3

4.1.1. Diesel driven Generator

Currently, the cost of diesel fuel price in Ethiopia in 2017 is 1liters of diesel =0.96USdolar 26.688birr /liter

Annual Fuel Cost = Specific fuel consumption× Fuel Rate× total no of operating hours in a year = 0.8lit/hr × 8hr/day×240day/year×0.96USD/lit=1475 $/year

= 1475/-Energy/ fuel cost of diesel engine for 20 years= 20× 1475= 864,000 $/annual

From this due to replace the PV water pumping system in terms of diesel driven generator it can save 29,491.2 USD per annually. Currently, the price of one liters of diesel is 27birr =0.97$

The price of 1m^3 for that of diesel generator is **0.62**$ **/** m^3

CHAPTER SIX

6. RESULT AND DISCUSSION

The system has been done when irrigation demand is critically needed that is almost used the power at winter season during no rain fall .However, when no need of irrigation (summer season) the energy produced can be used alternatively for multi-purpose particularly grain milling mobile charging etc.the summer season the power produced is low. The system has been used to almost energy obtained from the system for pumping water to irrigation purpose.

6.2. Analysis of Data at Study Area

Data Analysis of Site

The specified data of selected site is one of central feature of every research and solar radiation data is very critical important for my work. This radiation data is different in one location to another location from year to year. Site location of this work is Madhicho kebele at Chiro District and solar radiation data used for design and analysis of solar PV water pumping power for irrigation. A data that collected from different source was compared the average solar radiation that collected calculating. Two Source of data collected one From **NASA** which describe in **table 3 and** other from **recorded data** at near site station (MI’ESO) which describe in **table 3** then take the minimum solar radiation as shown **below figure**

6.3. Comparison of solar radiation data of Recorded and NASA.

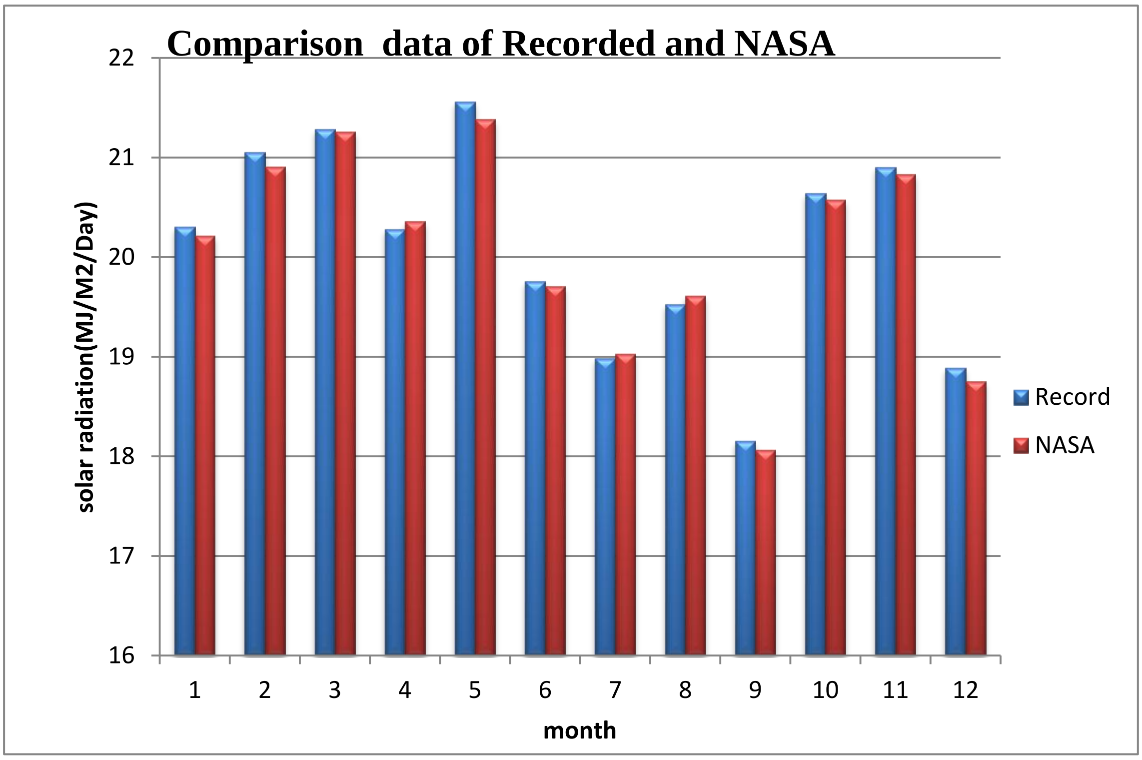


Figure 6-1: Comparison data of Recorded and NASA

From the figure 6-1 there are two source of data Recorded and NASA at Madhicho site near Mi'eso station could be compared based on minimum value of solar radiation. The minimum horizontal solar radiation can be provided in winter season on the month of December it was observed thereby data of NASA.

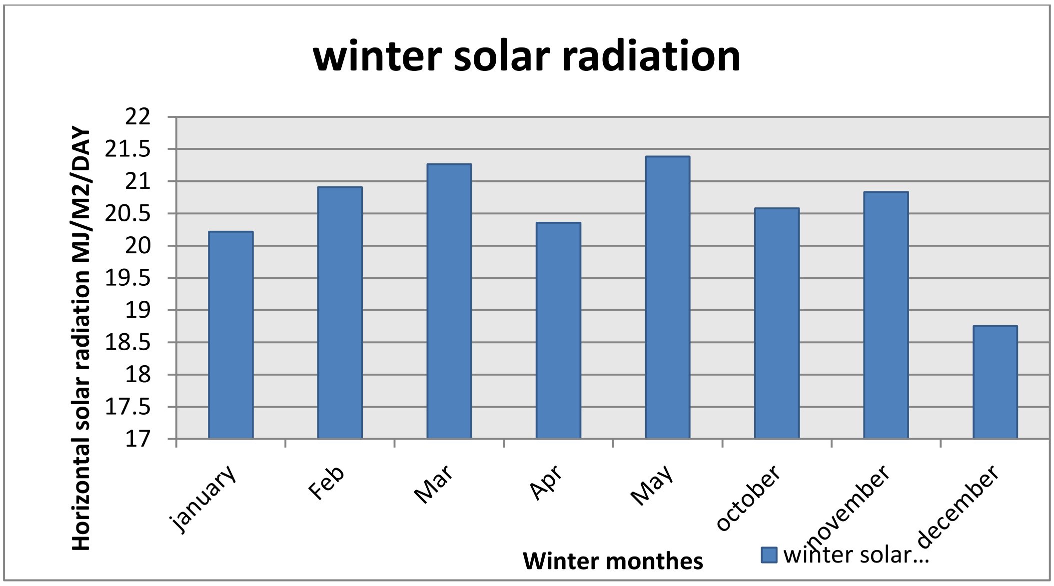


Figure 6-2: shows only winter horizontal solar radiation

This graph indicate that the maximum solar radiation was in May and minimum solar radiation in December

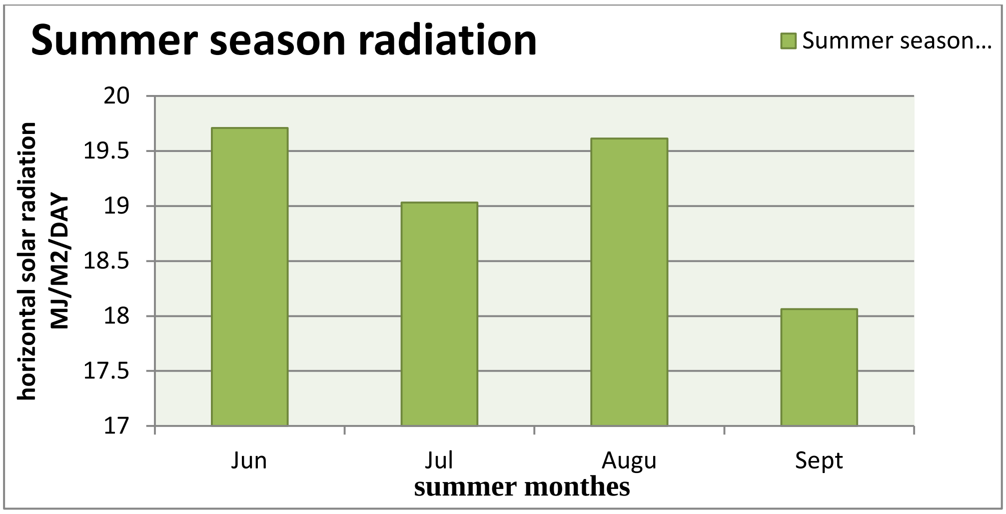


Figure 6-3: shows only summer horizontal solar radiation.

From this fig. the maximum and minimum solar radiation is in month of June and September respectively.

6.4. Water pumped and water consumption

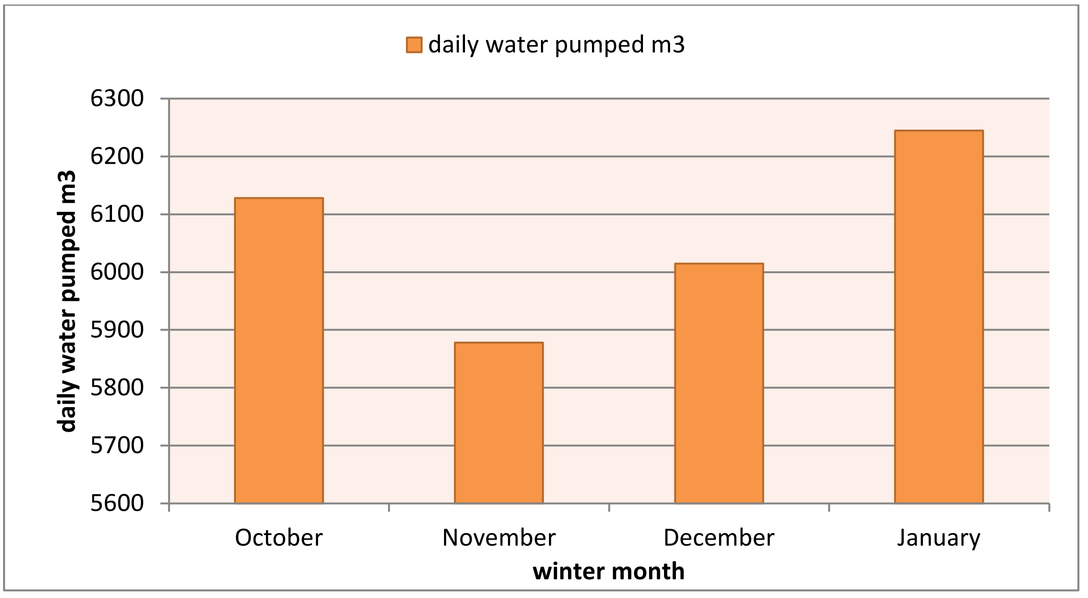


Figure 6-4: first season Daily water pumped during winter

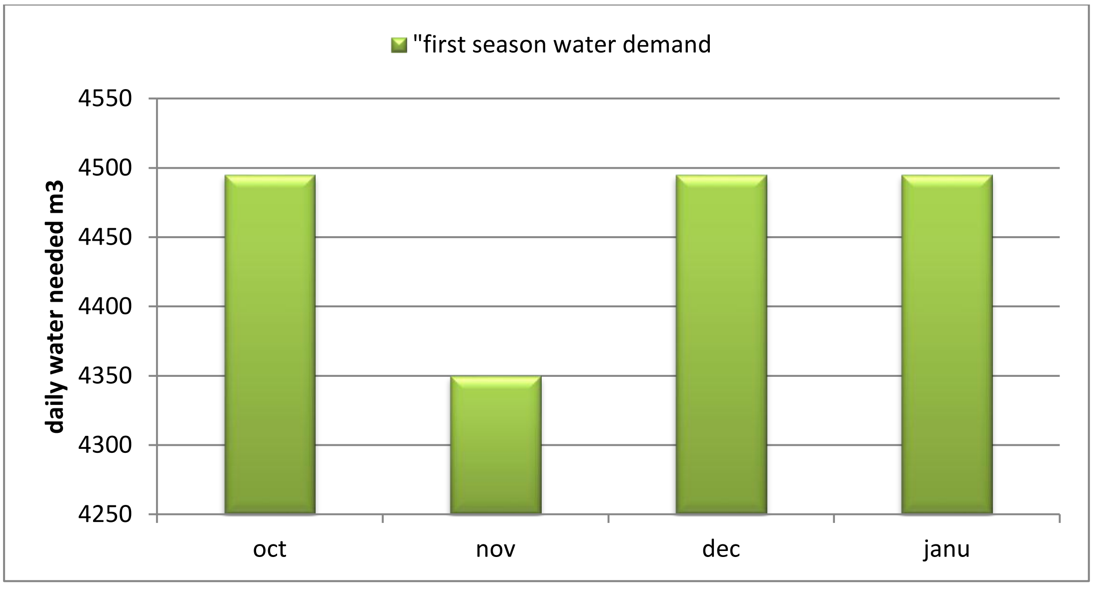


Figure 6-5: First season daily water demand during winter

From the graph November month show that minimum water consumption. Therefore,

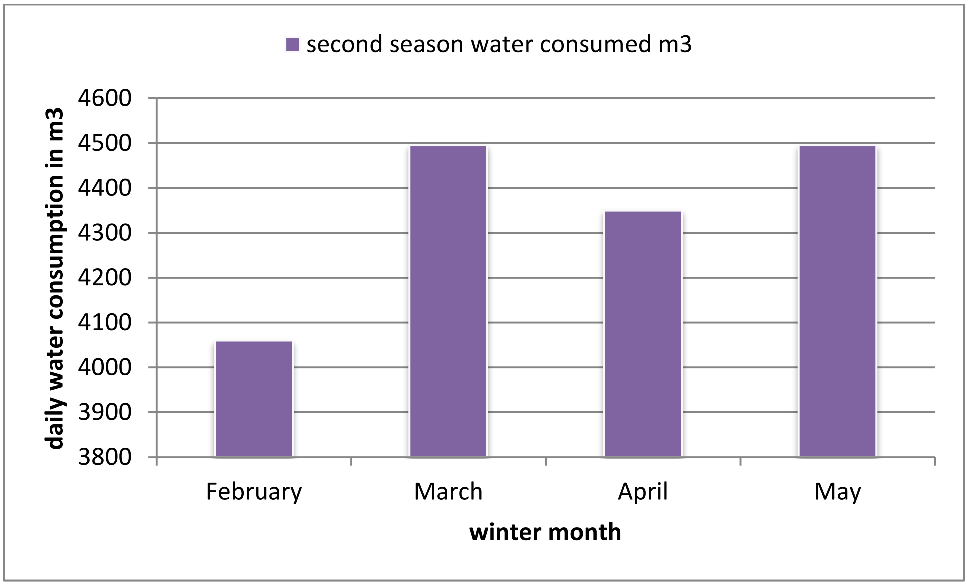


Figure 6-6: second season daily water demand during winter.

What was observed from this graph the month of maximum water consumption indicated in March and may while the same to that the minimum water consumption in February

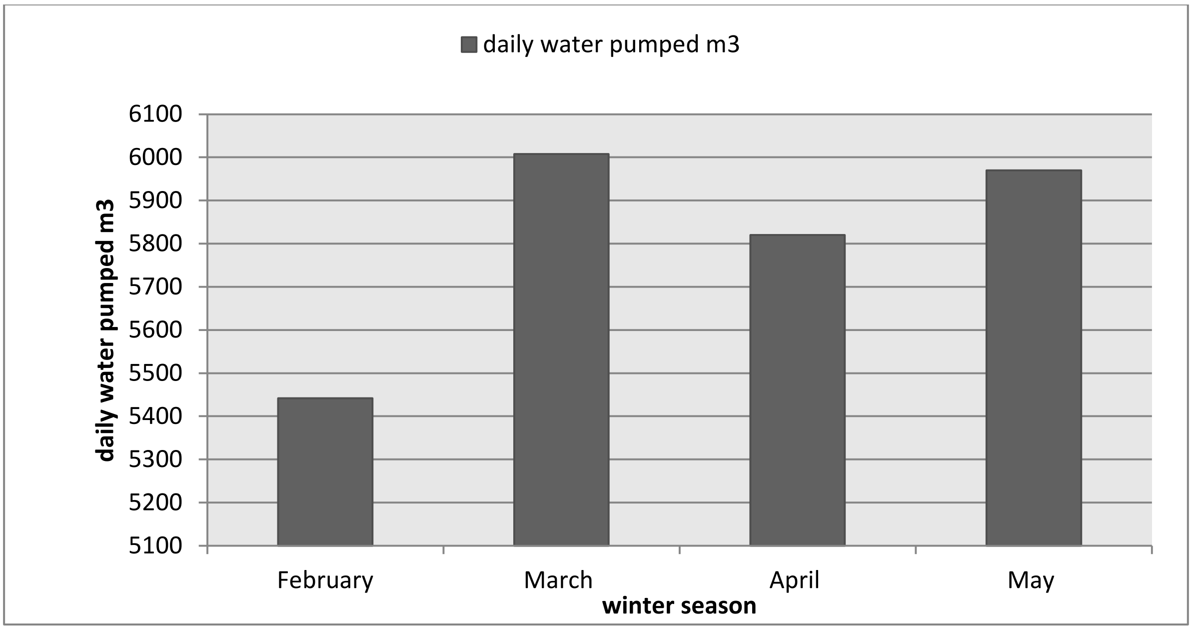


Figure 6-7: second season Daily water pumped during winter

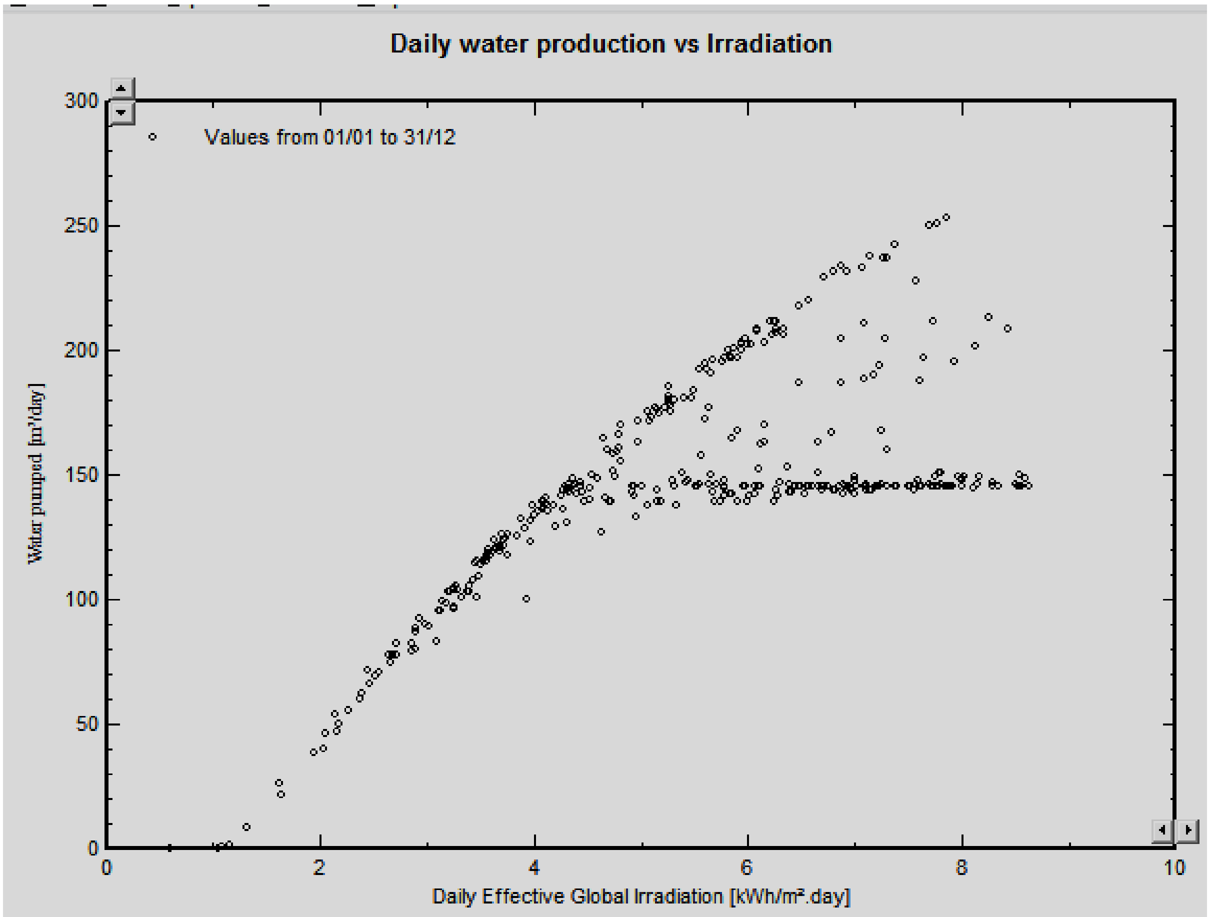


Figure 6-8: Daily water production vs. Irradiance

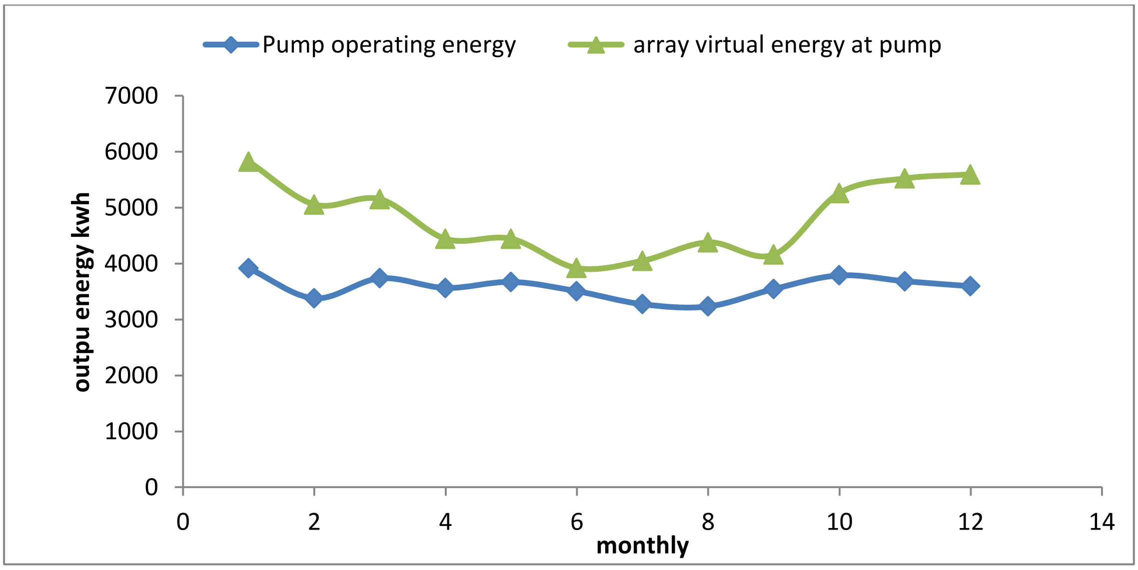


Figure 6-9: daily energy output from array and for pump operation

What is observed from the graph the array virtual energy is greater than pump operating energy however, in this research main objective is to find out energy requirement that has capacity to pump water from the well to reservoir then use by gravity feeding. During winter season the energy operating pump that has for irrigation demand is increased pump capacity to discharge water from borehole is 20kw so that from the graph we have enough energy to satisfy pump capacity.

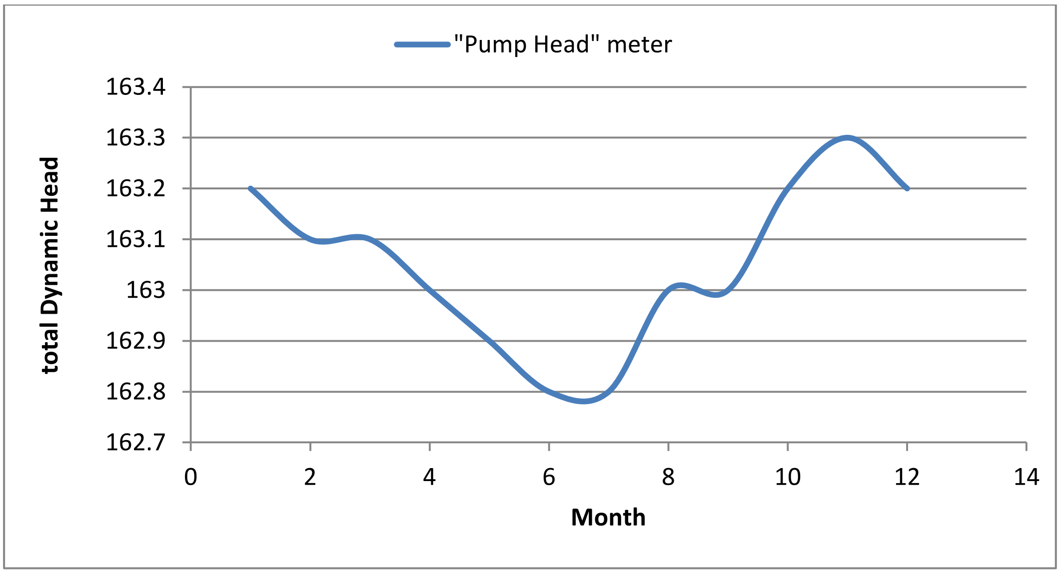


Figure 6-10: monthly total dynamic.

Water head increases and also naturally water requirement of vegetable increases.

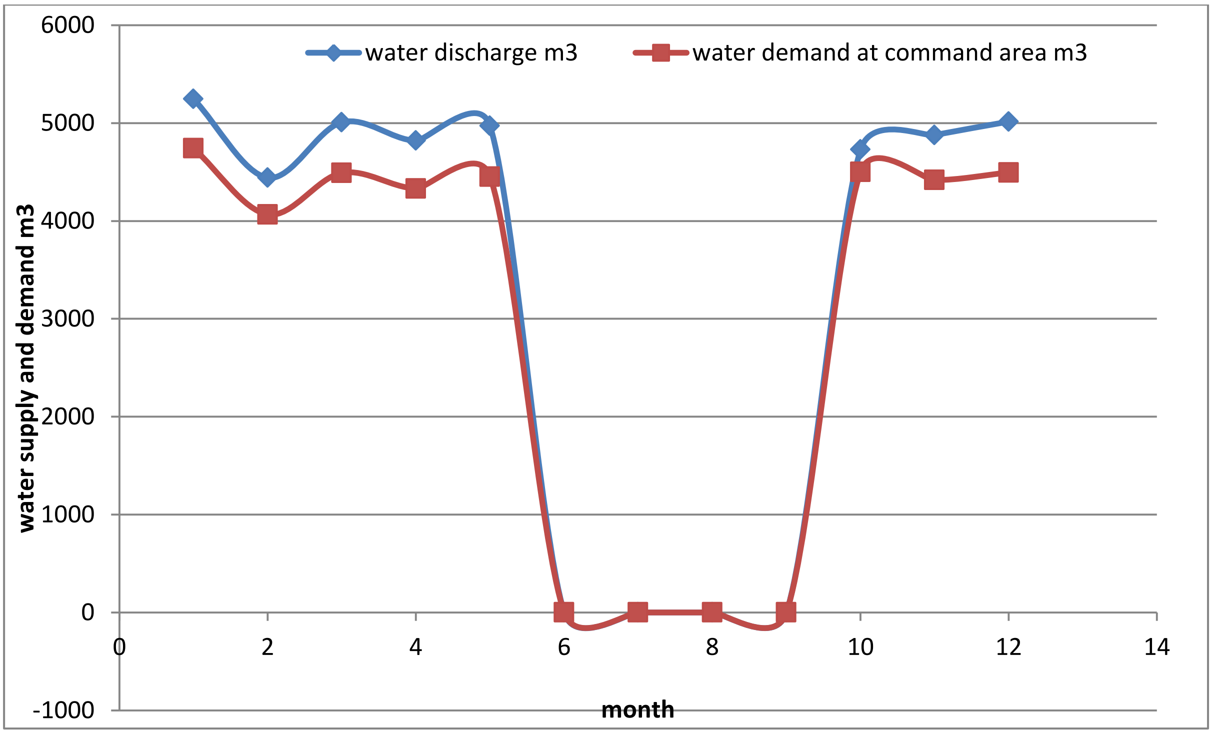


Figure 6-11: monthly water discharge and water demand at command area

This graph shows that the amount of water discharge is greater than the amount of water required for irrigation it's to more than enough to satisfy water demand.

6.5. Pay Back Cost

The purpose of this solar PV power pumping is water pumping for small scale irrigation proposed on 4hector land from now **1.5** hector of land approximately produce the tomato crop about **10 woodboxes per day in such a way that one box can hold 50kg which are 4ha * 500kg =2000kg/day.** During no rainfall a demand of community live in rural and urban area are highly increase their demand having for tomato crop its very expensive in everywhere in Ethiopia for exchanging due by adding minimum3 up to 5 birr per price of one kg. Therefore to estimate the profit price of tomato crop two seasons for four month of expensive tomato crop in a year would be calculated as follow:

When adding 3 birr per price of one kg Pc =3birr/kg*2000kg/day*240day = 1,440,000birr/year

When adding 4 birr per price of one kg Pc =4 birr/kg*2000kg/day *240day =1,920,000birr/year

When adding 5 birr per price of one kg Pc =5 birr/kg*2000kg/day *240day =2,400,000birr/year

Table 1-5: add value of money in a year

Add. Value in year	payback cost
3	1,440,000
4	1,920,000
5	2,400,000

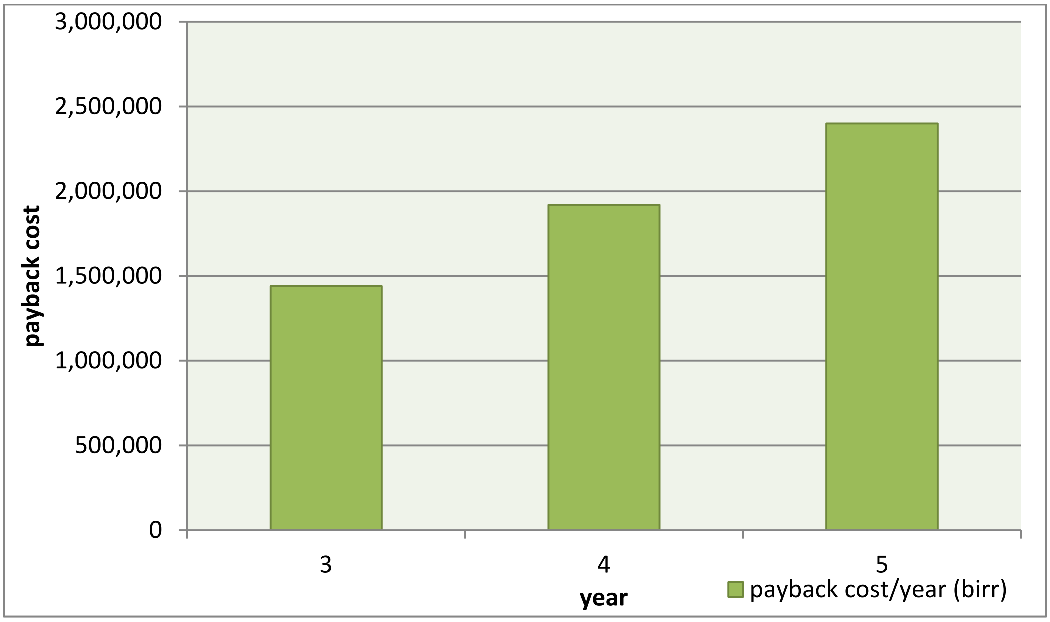


Figure 6-12: Pay back cost/year versus by adding price/kg

The initial cost of solar pump is 92,426.125USD (2,311,501.69 ETB) Therefore as shown under pay back cost, the initial cost of the system would be obtained after three to five year from the tomato crop.

Table 6-1 Pay back Cost up to Ten Years

Year value	add.3	add.4	add.5
1	1,440,000	1,920,000	2,400,000
2	2880000	3840000	4800000
3	4320000	5760000	7200000
4	5760000	7680000	9600000
5	7200000	9600000	12000000
6	8640000	11520000	14400000
7	10080000	13440000	16800000
8	11520000	15360000	19200000
9	12960000	17280000	21600000
10	14400000	19200000	24000000

6.6. Pay back Cost up to Ten Years

Product cost in year for seven month during tomato crop is required by people if adding 3, 4 and 5 birr per price of one kg is shown in below figure.

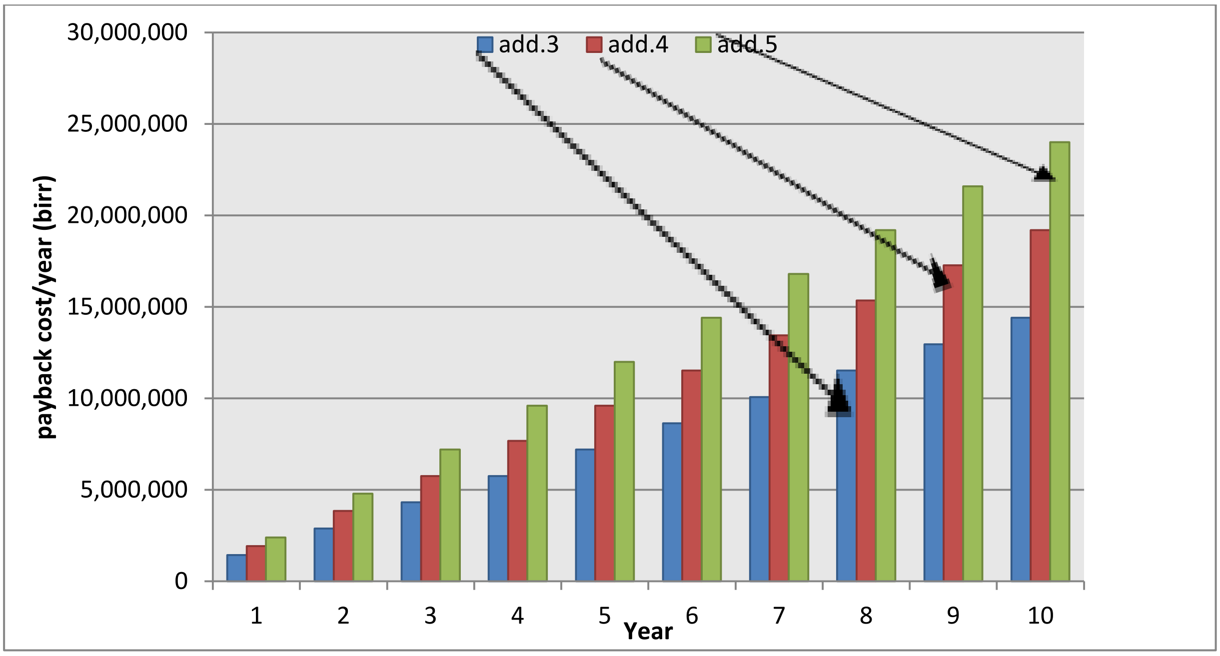


Figure 6-13: Pay back cost up to ten years

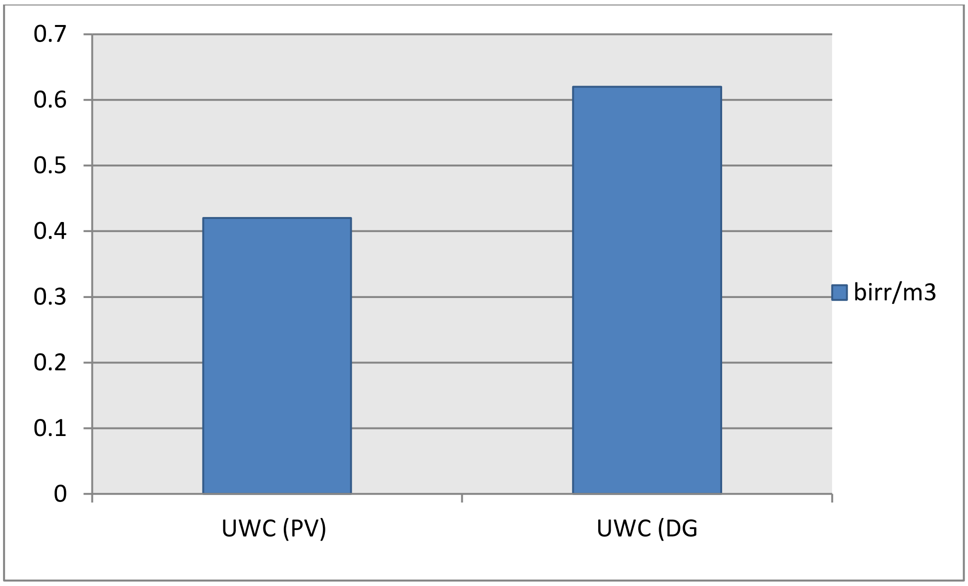


Figure 6-14: UWC comparisons of PV system and Diesel for a well

Figure 6-14 shows that the cost of a cubic meter of water produced by DG system is high percent of a cubic meter of water produced by PV for a well under the study.

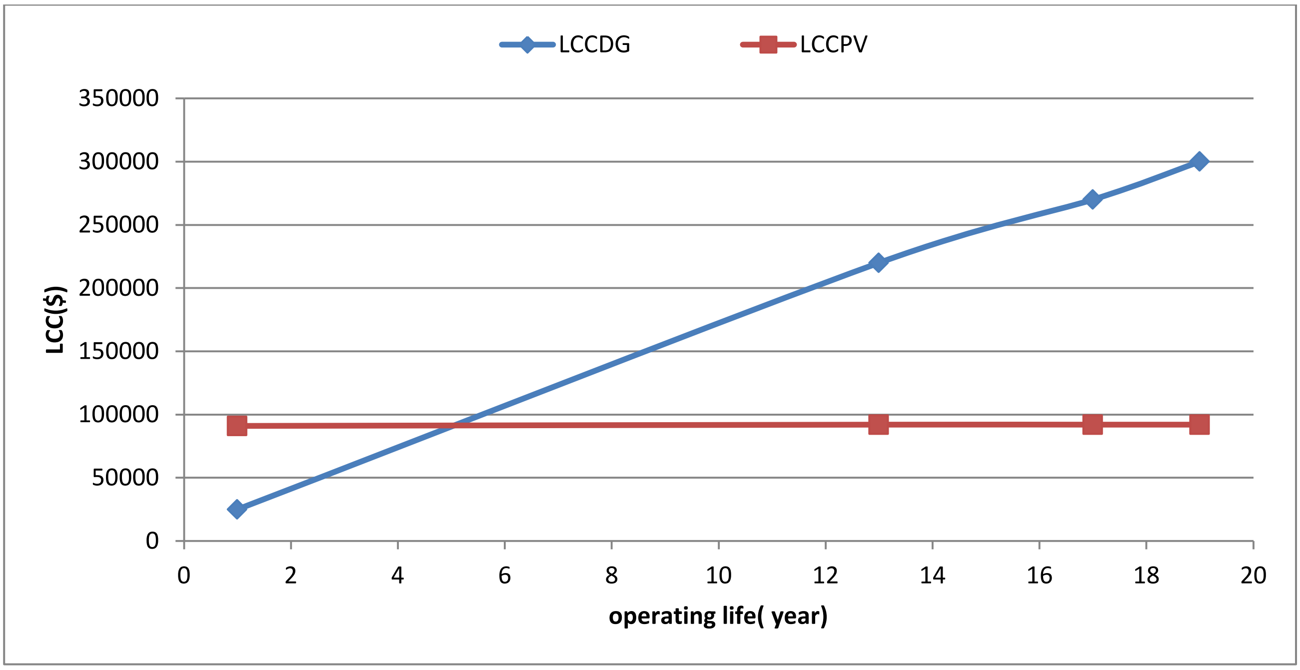


Figure 6-15: Life cycle cost of years to breakeven point for PV vs. Diesel generator water Pumping system

The breakeven point between PV water pumping system and diesel pumping system is found or occurs after five years that of using life cycle cost comparison. The cost of solar PV has come down and cost of diesel has been regularly increasing.

What is concluded from the above graph is the most interesting beteween DG and PV generator application that must depending on comparative life cycle cost that has lower cost over throught project life which mean that the one reach speedly to shorter year to breakeven point is more interested and became the solution of renewable energy attach environment .the cumulative life cycle cost of PV generatore is indecate to shorter year to breakeven pont so that it has higher cost saving over project life. The decision rule for life cycle cost analysis is to choose the alternative with the lowest life cycle cost. Since PV has the lowest LCC it should be chosen.

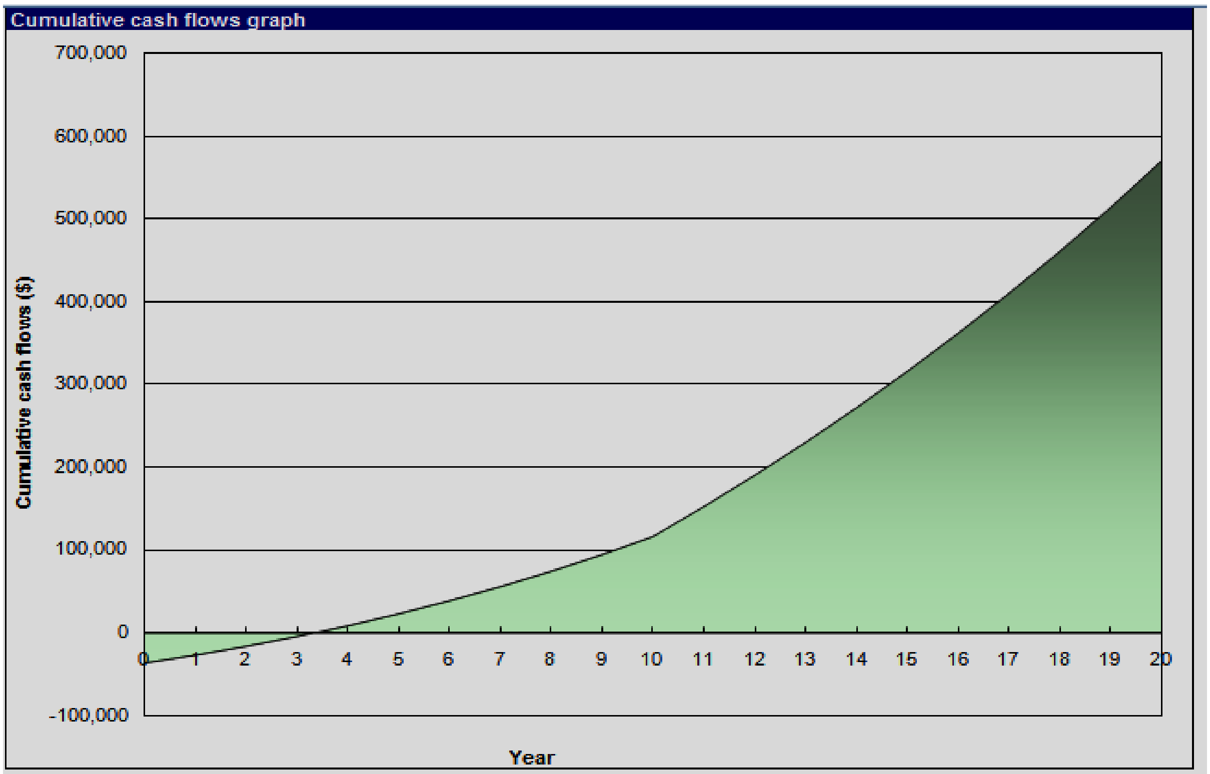


Figure 6-16: Cumulative Cash Flow diagram

The project's initial investment will be fully recovered within **5.7** years. Equity pay-back period is **3.3** years.

CHAPTER SEVEN

7. CONCLUSION AND RECOMONDATION

7.1. Conclusion

Generally Ethiopia has huge potential for solar energy because it is located near the equator with an average daily solar radiation of 5.25 kWh/m^2. The Site location of this work is Madhicho kebele at Chiro District and solar radiation data used for design and analysis of solar PV water pumping power for irrigation. A data that collected from different source was compared the average solar radiation calculating. Two Sources of data collected one From **NASA and** other from **recorded data** at near site station (MI'ESO). In this work Madhicho is study area of this thesis and it located at 9.14° latitude and 40.75° Longitude elevation 1332 m

In this paper study alternatively use solar energy and solve some energy problem in rural area at non-irrigating season using battery for store energy.

In this paper analysis of PV water pump by using PVsyst, Ret screen software and also compare solar PV with diesel powered pumping system by making economic to show system feasibility.

Many researches are done on Photovoltaic water pumping technology which used for irrigation. But in Ethiopia irrigation water is not required during the whole season. In Ethiopia irrigation season is starting from November up to April use solar energy during non-irrigation season.

The main point that must be focused in this research is to find expected energy required from solar the PV panel which can able to satisfy pump power during winter season and another aspect when the amount of power output is low PV panel power used for multipurpose (Appliance) period of summer season. The required power of the solar panel depends on the amount of energy demand to operate pumping. The Power requirement to operate Pump has power capacity around 27.5 kWp and power requirement for other purpose 132262Wh per day. It is used as supplementary power for other purpose has to be considered. The minimum solar radiation of site is 5.21kwh/m^2.

For the selection of source & designing of the delivery of water supply project, it is necessary to determine the total quantity of water required for various proposes by the beneficiaries.

Actually, the determination of the quantity of water depends up on the size of the command irrigable area and the purpose for which it is needed.

On the study area three wells were available to operated with a diesel generator having capacity about 30 kW. The investigation carryout on one wells with submersible AC pumps having 20 kW power capacity which can able to discharge of $0.009m^3/s$, with total dynamic head of 162.3 m to meet water required at command area.

The initial cost of solar pump is 92,426.125USD (2,311,501.69 ETB) Therefore as shown under pay back cost, the initial cost of the system would be obtained after three to five year from the tomato crop.

The most interesting beteween DG and PV generator application that must depending on comparative life cycle cost that has lower cost over throught project life,the cumulative life cycle cost of PV generatore is indecate to shorter year to breakeven pont so that it has higher cost saving over project life.

7.2. Recommendation and future work

- Proper adjusting of the solar panel and using the sensor between PV panel to pump to reservoir to obtain perfect energy demand for equipment
- The system required high initial cost to install PV pumping system so that its need aid from different aspect like government .non government and mobilize people living around project
- Distribute weather station data at near the project site such as recorded data in some area of country for benefit to compare NASA and Recorded data from both then to select the better option.
- As using PV technology and adaptation of it to provide good awareness for community beneficiary as they change face to this renewable technology and due to weather condition change from time to time so that in our country deep research studies must be needed to conducted in the future

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APPENDEX A-1

Typical Roughness Values for Pressure Pipes

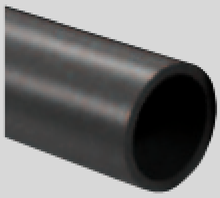
Typical pipe roughness values are shown below. These values may vary depending on the manufacture

Table B-4: Comparative Pipe Roughness Values

Material	Manning's Coefficient n	Hazen-Williams C	Darcy-Weisbach Roughness Height	
			k (mm)	k (0.001 ft.)
Asbestos cement	0.011	140	0.0015	0.005
Brass	0.011	135	0.0015	0.005
Brick	0.015	100	0.6	2
Cast-iron, new	0.012	130	0.26	0.85
Concrete:				
Steel forms	0.011	140	0.18	0.6
Wooden forms	0.015	120	0.6	2
Centrifugally spun	0.013	135	0.36	1.2
Copper	0.011	135	0.0015	0.005
Corrugated metal	0.022	—	45	150
Galvanized iron	0.016	120	0.15	0.5
Glass	0.011	140	0.0015	0.005
Lead	0.011	135	0.0015	0.005
Plastic	0.009	150	0.0015	0.005
Steel				
Coal-tar enamel	0.010	148	0.0048	0.016
New unlined	0.011	145	0.045	0.15
Riveted	0.019	110	0.9	3
Wood stave	0.012	120	0.18	0.6

Table A-1-1: PIPE PVC-U PRESSURE PIPE CLASS E

PIPE PVC-U PRESSURE PIPE Class E PRE



SIZE	CODE PVC-U	PER LENGTH £	PER M £
1/2"	R PRE.0200	9.66	1.61
3/4"	R PRE.0250	13.75	2.29
1"	R PRE.0320	19.15	3.19
1 1/4"	R PRE.0400	29.38	4.90
1 1/2"	R PRE.0500	38.28	6.38
2"	R PRE.0630	59.41	9.90
3"	R PRE.0900	127.05	21.18
4"	R PRE.1100	209.00	34.83
6"	R PRE.1600	452.20	75.37

Price per metre - 6 metre lengths

Source: www.astore.uk.com

The price of pipe 59.4eu/6meter which is total the pipe length has 1000m =12,090.5USD

Table A-1-2: Recommended Average Days for Months and values of N by Months (Duffie and Beckman, 1991)

Month	N for i^{th} Day of month	For the average day of the month		
		Date	Day of year N	Declination δ
January	I	17	17	-20.9
February	31 + i	16	47	-13
March	59 + i	16	75	-2.4
April	90 + i	15	105	9.4
May	120 + i	15	135	18.8
Jun	151 + i	11	162	23.1
July	181 + i	17	198	21.2
August	212 + i	16	228	13.5
September	243 + i	15	258	2.2
October	273 + i	15	288	-9.6
November	304 + i	14	318	-18.9
December	334 + i	10	344	-23

Appendix B: Submersible Motor Specification

Submersible Motor

Product details

Brand name xingkang
Model number YQS200-22
Type Asynchronous
Frequency 50Hz
Output power 22kw
Product feature waterproof
Phase three phase
Certification CCC
Ac voltage 380v/480v/660v
Place of origin Hebei, china (main land)
Efficiency IE2
Payment &shipping
FOB price: **Get Latest Price**
Minimum order quantity 10unit/units
Port Tianjin
Packaging detail **:** plastic bag first then wounded by rope and packing by flywood at last
Delivery time 10days
Payment terms L/C,T/T
Supply ability 20000unit/units per month

Detailed product Description:

Submersible motor
i 380V/50HZ
ii proction stage IP68
iii power 22Kw
iv material stainless steel and cast iron
This submersible motor is AC submersible motor, suit to working in deep well
Power factor (cosp) =0.84
Rate current: 48A
Rated voltage: 380 V
Rated power: 22Kw
Suitable diameter of bore holds 8’’
Eff.82.5

APPEDIX-C-1

Table C-1-2 Climate data input

Location | Climate data

Location

	Unit	Climate data location	Facility location
Name		Ethiopia - Mi'eso Madhicho kebele (west Hararghe)	Ethiopia
Latitude	˚N	9.1	9.1
Longitude	˚E	40.8	40.8
Climate zone		2A - Hot - Humid	2A - Hot - Humid
Elevation	m	1332	1000

Table C-1-3: Project information

Project information	*See project database*
Project name	22kW - Off-grid
Project location	West Harerghe Zone, Madhicho kebele, Ethiopia
Prepared for	Irrigation (agriculture)
Prepared by	Mohammed Aliyi
Project type	Power
Technology	Photovoltaic
Grid type	Off-grid
Analysis type	Method 2
Heating value reference	Lower heating value (LHV)

Table C-1-4: Financial analysis

Yearly cash flows			
Year #	Pre-tax $	After-tax $	Cumulative $
0	-36,165	-36,165	-36,165
1	9,543	9,543	-26,622
2	10,653	10,653	-15,970
3	11,817	11,817	-4,152
4	13,040	13,040	8,887
5	14,440	14,440	23,328
6	15,670	15,670	38,997
7	17,083	17,083	56,080
8	18,567	18,567	74,647
9	20,123	20,123	94,770
10	21,930	21,930	116,700
11	36,047	36,047	152,747
12	37,846	37,846	190,593
13	39,733	39,733	230,326
14	41,713	41,713	272,040
15	44,044	44,044	316,084
16	45,970	45,970	362,054
17	48,256	48,256	410,310
18	50,654	50,654	460,964
19	53,169	53,169	514,132
20	56,086	56,086	570,218

Pre-tax IRR - equity	%	37.1%
Pre-tax IRR - assets	%	15.2%
After-tax IRR - equity	%	37.1%
After-tax IRR - assets	%	15.2%
Simple payback	yr	5.7
Equity payback	yr	3.3
Net Present Value (NPV)	$	137,359
Annual life cycle savings	$/yr	17,249
Benefit-Cost (B-C) ratio		4.80
Debt service coverage		1.76
GHG reduction cost	$/tCO2	(435)

APPENDEX –D: BATTERY SELECTION

1875ah Best Batteries For Solar Off Grid / Deep Cycle Gel Battery, Black

Brand Name: Champion

Certification: CE ; UL

Model Number: GFM1875

Minimum Order Quantity: 50 pcs

Delivery Time: 25 days

Payment Terms: 30%advance, T/T

Appendix-E Duty of tomato crop water requirement

4. TOMATO	138.6	87.1	0	0	0	0	0	0	0	22.3	55.8	143.1
Net scheme irr.req.												
in mm/day	120	110	20	10	60	80	30	50	40	60	130	120
in mm/month	120	110	20	10	60	80	30	50	40	60	130	120
in l/s/h	120	110	20	10	60	80	30	50	40	60	130	120
Irrigated area(% of total area)	120	110	20	10	60	80	30	50	40	60	130	120
Irr.req. for actual area(l/s/h)	1.68	0.84	0.18	0	0.18	0.48	0	0.06	0.06	0.72	1.08	1.92

Source: Woreda agricultural office and PA

Appendix-F Type of inverter selected

Inverter type: MNE-SP11KV3…MNE-SP30KV3	
Input	Output
(310 -450) DC volt	380 AC volt, 3 phase, 50 HZ
Rated power: 22kw	

Appendix-G: Approximation based and exact price

Pipe: Typically the price of PVC Pipe 59.4Eu/6meter which is total the pipe length of 1000m about =12,090.5$

Cost of Solar: The cost of solar PV that produces 400W power in off-grid is calculated as follow:

Sale Price: $494.40

PV module panel cost =494*55=$ 27,170

=400Wp*1.235($)/WP*55 number of panel arranged

Capital costs of the composition of solar panels ($) ($C_{PV}$) =27,170

source:https://www.gogreensolar.com/pages/solar-financing-options
Inverter type: MNE-SP11KV3…MNE-SP30KV3 having 22kw capacity. For off-grid systems, the cost of inverters typically ranges from $1,000/kW AC to $2,000/kW AC

Source:CHM::/TrainingMaterial/FiguresAndGraphs/FigureTypicalCostsInverters.htm

Battery types: 1875a-h 12V Best Batteries for Solar off Grid / Deep Cycle Gel Battery

Cost of solar battery $640/kwh

Source: https://www.solarchoice.net.au/blog/wp-content/uploads/Solar-battery-storage-prices-out-of-pocket-Jan-2018.png

https://www.solarchoice.net.au/blog/news/

Pump: The price of submersible pump is USD 1500-3000 in average USD1900 Initial cost =USD495=20*1900=38,000 $

Local cost of Tomato crop

1.5 hector of land can produced approximately 105 pack box

4hector give = 4*105=420 pack box.

One box holds 40kg
=420*40=16,800kg
At One month tomato box
In a day among four hector of land can be provided 93kg/day
In a winter the price of tomato is very expensive it's twice as price of summer
The Cost of One box in average is 1200 birr but summer season its very cheap in average 350birr

Tomato crops has three harvesting season's yield

Gathering period of Tomato is three time

1. Low gathering it is the first time to start to supply for market it's to give 70 woodboxes in a day from four hector 9 pack per day can gathered
   1pack hold 40-55kg, 9pack per day*45kg= 405kg/day

One kg of tomato in the winter minimum about 15birr

=15birr*405kg/day*30day=182,250 birr

2. Medium gathering it's the second times that prepared for market to give 130 woodboxes in a day from four hector 17 pack per day can gathered

1pack hold 40-55kg , 17pack per day*45kg= 765kg/day

=15birr *765kg/day*30day=344,250birr

3. High gathering to give 135 woodboxes in a day from four hector18 pack per day can gathered

1pack hold 40-55kg , 18pack per day*45kg= 810kg/day

=15birr *810kg/day*30day=364,500 birr

The total tomato number of backed box gathering as harvested are prepared and provided to market become 267 box. 44 pack per day obtained =1,980 kg/day

One pack holds 40-55kg

In two season the total value 1,782,000 birr