JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF MECHANICAL ENGINEERING
SUSTAINABLE ENERGY ENGINEERING STREAM

DESIGN AND OPTIMIZATION OF HYBRID SOLAR PV, MICRO HYDRO AND BIO-MASS POWER GENERATION: THE CASE OF KEDEMESA KEBELE, AGARO WOREDA, JIMMA ZONE.

BY

FIKADU KIFLE FANTAYE

A thesis Proposal submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the requirements for the Degree of Masters of Science in Sustainable Energy Engineering.

December, 2016

Jimma, Ethiopia.

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DECLARATION

I, the under signed, declare that this thesis entitled “Design and Optimization of Hybrid Solar PV, Micro Hydro and Bio-Mass Power Generation: the Case of Kedemesa Kebele, Agaro Woreda Jimma Zone.” is my original work, and has not been presented by any other person for an award of a degree in this or any other university.

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JIMMA, ETHIOPIA

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ABBREVIATIONS

HRES	Hybrid renewable energy systems
MHP	Micro Hydro power
EEPCO	Ethiopia Electric Power Corporation
GIS	Geographical Information System
GPS	Global Positioning System
HOMER	Hybrid Optimization Modeling for Electrical Renewable
MOWE	Ministry of Water and Energy
NASA	National Aeronautics and Space Administration
NMA	National Meteorological Agency
JNMA	Jimma National Meteorological Agency
NGO	Nongovernmental Organization
HPGS	Hybrid Power Generation System
GIZ	German Agency for International Cooperation
SWERA	Solar and Wind Energy Resource Assessment
BIOMES	Bio-mass energy system
GIZ	German Agency for International Cooperation

ABSTRACT

Ethiopia is one of the developing countries in the horn of Africa with a total population of over 80 million in 2007. Population where is living in rural areas, mostly access to modern electricity is difficult. Kedemesa kebele is found around 82 km away from Jimma town at 1675.2m above sea level having latitude of 7.51^0N and longitude 36.35^0 E for the specific study site is found. And has no electricity access from grid connection. Objective of the thesis would focus on Design and Optimization of Hybrid Solar PV, Micro Hydro and Bio-Mass Power Generation in the selected site .The study area has an average 6.6325 sunshine hrs per day. The incoming average solar energy has been converted in to 5.16 $kWh/m^2/d$using Angestron model. The flow rate of Naso River was found $1.22m^3/s$ from the flow rate of Gigel Gibe I through empirical area ratio method. Monthly average biogas feedstock (i.e. cow dung), the kebele is 1.35 $tonnes/day$. To produce18 KW from Solar PV system 416 modules, having $83m^2$ area and Solar insolation at the site during the worst month at July is $3.86kWh/m^2/d$was used. For the Micro-hydro to produce 63KW, $1.22m^3/s$ flow rate, 8.1m head, 65% efficiency and 0.36m weir length, 2.13 m^2canal area and 100 m penstock length was found. To produce 20 KW from Bio-mass system through the processes of anaerobic digestion mechanism, I have to found that daily an average of 70.6 m^3/day biogas production could be found. The homer software has been design and cost estimation of each components of the hybrid system (i.e. Solar PV-Bio-mass-Micro-hydro power generation) has been modeled. Hence the designed peak power demand at installed capacity after 10 year is around 122.24 KW. The output power generation was seen that from homer software is 209 kW to satisfy power demand from customer side at specific area of site was got saved. Since EEPCO can sells for urban is $0.025\$/kWh$ and for the rural is double price that is $0.05\$/kWh$ because of by considering transmission line cost, maintenance cost and transportation cost. The hybrid system is cost would found around $0.031\$/kWh$. So that from Economic Point of View the hybrid system is feasible.

Key-Words: Solar PV, Bio-mass/biogas, an aerobic processes, Micro-Hydro, digestion, hybrid, .homer software.

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Ethiopia is one of the developing countries in the horn of Africa with a total population of over 80 million in 2007[1]. Population where is living in rural areas, mostly access to modern electricity is difficult. Kedemesa is not rich in fossil fuel resources but it has plenty of renewable energy resources, in particular water that is running down. The sun's freely available solar energy can also be converted into electricity. The kebele is presently facing an energy crisis of unprecedented proportions. In this context renewable energy development continues to be a high priority program of government as it provides a least cost solution to remote, sparsely populated areas unviable considered for the hybrid system. Rural people's day to day energy need is satisfied based on using traditional fuels mostly firewood and biomass (i.e. Dry dung). Unfortunately the use of such traditional fuels has negative impacts such as: deforestation, soil erosion, emission of greenhouse gasses.

The main task is to find a suitable design and optimization from hybrid of energy system which the results lead, to overcome the problem around the site. The compulsion to access electricity via national grid at higher cost due to geographical structure would be eliminated or reduced by the establishment of hybrid systems where people of such region can experience a reliable, affordable and continual supply of power by exploiting the locally available renewable resources. EEPCO is only the organization responsible for the generation, transmission and distribution of electrical power to this kebele. The major of population in site are deprived of electricity only due to their geographical locations where the extension of national grid line is economically not feasible, thus dependence upon traditional sources of energy has been a compulsion to fulfill energy needs. The current energy crisis clearly indicates that the future energy- demand cannot be met by traditional energy-sources. In coming time it would like solve the scarcity of electricity around the site, using of conventional renewable energy resources to fulfill the energy demand.

In this thesis, I will have to assess Solar, Biomass & Micro Hydropower (MHP) potential for kedemesa kebele. The power supply based on single resource (either Solar /Micro-Hydro/Biomass), thus hybrid energy system is brilliant solution for electrification of remote rural areas where the grid extension is difficult. Such system incorporates a combination of renewable energy sources such as micro-hydro, solar and biomass energy and may be conventional battery for backup. In this thesis I design each component Solar PV, Micro Hydro and Biomass for specific hybrid system.

The purpose of this thesis is to explore the possibility of hybridizing with renewable energy sources through design and optimization of solar/Hydro/biomass Hybrid system using a computer based design (HOMER software) optimization.

This thesis would cover solutions that can reduce dependency on fossil fuel and reduces the amount of greenhouse gas emission entering into the environment.

Hydro turbine-Solar-biomass-battery bank-converter have been simulated and optimized for the rural community of Kedemesa kebele in the regional state oromiya Jimma. Zone, Ethiopia. The hybrid power generation system is a system aimed at the production and utilization of electrical energy coming from more than one renewable energy source.

1.2 Problem Statement

Kedemesa kebele is found around 82 km away from Jimma town at 1675.2m above sea level having latitude of 7.51^0N and longitude 36.35^0E. It has no electricity access from grid. Electrifying this remote area by extending a grid system is very difficult and challenging because these are, costive, Power from EEPCO is not sufficient to supply both rural and urban, The Use traditional fuel (i.e. Kerosene) used for lighting. Fire wood and dry dungs for cooking purposes Emission will cause the environment and human pollution effect.

Sustainable Development without power electrification is not possible. When people get electricity, the way of life becomes change. The study area would have rich in renewable energy, so it is possible to satisfy the demand for the selected sites. The over increasing load demand of the kebele will stress on the power generation and gradually decrease the extending of the research because of sufficient problem. Based on design optimization of Hybrid power generation system can used to solve the scarcity of electricity and Emission controlling around the site.

1.3 Motivation of the Study

Most Ethiopian rural country (i.e. kedemesa kebele) living by traditional and cultural way. That is why these are still in this way keep going, because people are using energy sources such as traditional Biomass (i.e. dry animal dung)for cooking purposes, kerosene gas for their day to day activities and for light, the emission gas is polluting the environment as well as the people. My motivation is addressing lack of electricity for the specific site of the people in the living in the kebele and controlling the pollution of the environment from the kerosene gas emission.

1.4 Objectives of the Study

1.4.1 General Objective

Design and optimization of hybrid Solar PV, Micro-Hydro and Biomass power generation: the case of Kedemesa kebele, Agaro woreda, Jimma Zone.

1.4.2 Specific Objectives

- To assess solar, micro-hydro and biomass energy potential and get the secondary data for hybrid power generation around the sites.
- To assess and estimate the electrical consumption for the community around the sites.
- Design parts of hybrid system.(i.e. solar PV ,micro-hydro and biomass)
- To design the optimization result.
- To design the feasible solar PV, micro hydro and biomass hybrid power system that will meet the required demand.
- Battery and convertor sizing and selection.

1.5. Scope of the Study

The aim of this research is to estimate the solar, biomass and micro hydro potential for the selected site in Kedemesa kebele. Depending on the finding of the potential designing of a hybrid system at the selected place would be done and simulation of a cost effective hybrid system. Immediate load (consumer electricity) was estimated as well as the optimization and feasibility the hybrid system could also determine.

1.6. Significance of the Study

The main significance of the study is to pass basement design and optimization of hybrid system of solar PV, micro hydro and biomass system on the remote areas that have these renewable resources. The cost of solar PV, micro hydro and biomass power generation lays in the form of up front capital expenditures where by the operation and maintenance cost is low.

Therefore, the generating cost via solar PV, micro hydro and biomass system are marginally more than a conventional system with respect to the additional generating capacity, nevertheless promises customer satisfaction of a continuous electricity supply, reduced emission and noise pollution. Hybrid system promotes efficient use of power since renewable energy system could be configured with base load.

On the other side, there are Non-Governmental Organizations in Ethiopia that work on renewable energy systems. If those organizations want to work through this study area, this study can give direction to facilitate their work.

Generally, this thesis will give direction and guidance to any volunteer, NGO & EEPCO those work their project around kedemesa kebele.

1.7. Limitation of the Study

There are expected limitations that would be faced in this study.

- ✓ The site has not a good access of transportation which is available at all seasons, and also there is no transport line from Agaro to this site.

1.8. Description of Study Area

Kedemesa kebele is located in Jimma zone around 37 km away from Agaro town that is 82 km from Jimma town having latitude of 7.51^0N and longitude of 36.35^0E with 1675.2m above sea level in Oromia Region Ethiopia [2]. The residents who are 100% farmers use Naso River for irrigation. The village does not have access to electricity supply from the main grid and supply of electricity from distributed sources to solve energy related problems of the inhabitants of the village is very important.

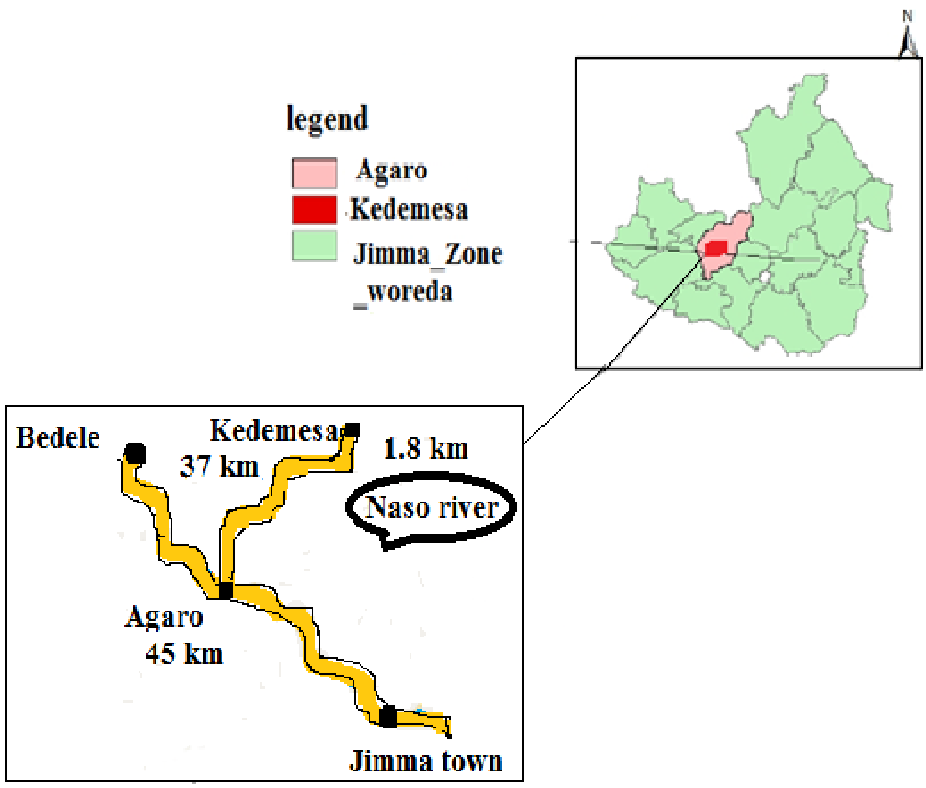


Figure 1 Map of study area

CHAPTER TWO

2. LITERATURE REVIEW AND RENEWABLE ENERGY

2.1. Literature Review

Arnau González, et al **.[3]**"Optimal Sizing of a Hybrid Grid-Connected Photovoltaic–Wind–Biomass Power System." This work presents an optimization methodology for minimum life cycle cost of Hybrid renewable energy system. based on solar photovoltaic, wind and biomass. Biomass power seeks to take advantage of locally available forest wood biomass in the form of wood chips to provide energy .in periods when the PV and wind power generated are not enough to match the existing demand. Such a system would have benefits in terms of energy autonomy and environment quality Improvement. He has not considering of optimization design and modeling through HOMER softer. There is also feasibility, sensitivity analysis not considered. For my thesis I would have to consider three renewable energy resources then checking the overall design and optimization by homer software.

Mahmud Abdul, Matin Bhuiyan, et al. **[4]**,"optimum use of renewable energy resources to generate electricity via hybrid system." The necessity of hybrid energy system is gaining more importance day by day as it incorporates two or more than two renewable energy resources that when integrated overcome limitations inherent in either. Hybrid energy system has been seen as an excellent solution for electrification of rural place where the grid extension is difficult and economically not feasible. Such system may consist of several renewable resources such as solar PV, wind, biomass, micro-hydro, geothermal and other conventional generator for back-up where the deficiency of one system can be compensated by others. This thesis depicts the different system components and their optimal combination for the efficient generation of electrical energy exploiting locally available resources. The optimized hybrid system shows a unit cost of $0.088/KWh which is obtained after the simulation considering contribution of individual renewable resources participating in the system.

Siddhartha Gobina, 2012**[5],** designs stand-alone solar, wind and Biomass hybrid power system to meet the load demand of the village at Sagar Island by using genetic algorism. The decision variables he considered for this optimization processes are numbers of PV -panels, numbers of wind turbines and capacity of biomass generator. The monthly average solar radiation and wind speed of the study area are converted in to hourly solar irradiance and hub height speed; here minimum values are considered for optimization process. This writer also tries to compares per unit energy cost and co2 emission of Biomass generator and diesel generator. Finally research results indicates hybrid power system considering Biomass has minimum per unit energy cost and less co2 emission as compared to diesel generator consisting hybrid power system. Biomass is economically feasible.

SmrutiRanjan Pradhan et al.[**6**].Hybrid of standalone PV- Biomass power generationsystems in in remote areas, India. The use of renewable energy sources is becoming very necessary due to the limited reserves of fossil fuels and global environmental concerns for the production of electrical power generation and utilization. In remote areas, villages, it is easy to get more amountof biomass. Hence by the use of hybrid systems consisting of Biomass and PV for production of electrical energy in these remote areas can be more economical. If the development of a computer-based approach for evaluating, the general performance of standalone hybrid PV- Biomass generating systems are analyzed ,then these results are useful for developing and installing hybrid systems in remote areas. This paper focuses the economical consideration of standalone hybrid systems having PV and Biomass for electrical production in remote areas. Also in this paper a simulation approach has been suggested for designing stand-alone grid for remote areas. The average solar radiation and quantity of biomass required data are to predict the general performance of the generating system. The batteries can also be used in this system to store the extra energy which can further be used for backup. Also the extra power is used to supply to the grid. Here the simulation is carried out using HOMER software. The results and analysis can used to improve the development of the proposed model.

Albert H.P.N. Munthe, 2009 [**7**], hybrid of PV and Biomass power generating for Ikem village, Nigeria. He has proposed hybrid renewable energy system for Ikem (Nigeria) consists of PV array, biomass combustion Stirling engines and batteries. As he wrote on his research after he proposed hybrid PV and Biomass generating unit for Ikem. He looked at steady state and dynamic characteristics of designed system to see coordination of the generators due to the control system and situation when load fluctuates respectively using Matlab software. According to his discussion the continuity supply of renewable energy resources is sufficient and the performance of the whole hybrid renewable energy system is good. However the result, cost is high because of the battery and there is deforestation because of the Biomass.

Rajiis kamm, 2014 **[8],**Hybrid of PV, wind, micro-hydro and diesel generator district of Orissa state, India. Two simulations have been carried out in this case study, one with a combination of wind, solar PV and diesel generator and the second was a combination of wind, PV, small hydro and diesel generator. The authors also suggested that the wind power fluctuation and household demand variation are the only constraints influencing the system.

Rahul Mishra, et al **[9],**Hybrid of optimization of solar and biomass power generation, India. Increasing electricity demand, hike in fuel prices, environmental concerns are the main factors which motivates the use of renewable energy sources in India. In past few year India has shown a significantly growth in utilization of renewable energy sources. Today the share of renewable energy sources is almost 12% in total electricity generation. According to Ministry of Power in India so far 1.15 thousands of villages still un electrified. In this paper the potential of renewable energy sources (solar + biomass) is estimated in a village in Punjab, India. Based on a survey conducted in an Indian village named “Kaidupur” situated in district Patiala in Punjab, the available resources like biomass and solar are identified. This paper provides a complete solution to meet energy demand of a village by renewable energy sources. The optimization (biomass + solar) is done by Hybrid optimization Model for Electric Renewable (HOMER). Hybrid energy system is becoming popular in area where grid extension is considered uneconomical or not feasible. This paper provides a better understanding of utilization of renewable resources in an isolated /off grid locations.

Bimrew Tamrat, 2007 **[10],** comparative analysis of feasibility of solar pv, wind and micro hydro power generation for rural electrification in the selected sites of Ethiopia. But, he didn’t consider the possibility of combining the resources into hybrid system and the analysis is done manually without any computer tool.

Sisay Fitwi, August 2014 **[11]** Feasibility Study of Standalone PV/Wind/Biogas Hybrid System for Rural Electrification: A Case Study of Midrwa community in AdigratDistrict. Ethiopian electric power corporation utility company uses extension of grids and installation of diesel generators as an option for the electrification of rural villages. Grid expansion to such areas is either financially not viable or practically not feasible as these locations are geographically isolated, sparsely populated and have a very low power demand. The use of diesel generators has also harmful effect on the environment in addition to their higher cost of fuel, maintenance and operation. Consequently, rural areas are dependent on local solutions for electricity supply. These areas have been using Kerosene for lighting, diesel for milling and pumping, traditional biomass as source of energy for cooking and dry cells for radio and tape recorders. However, the current increase in oil price and the negative effects of fossil fuels on the environment motivates to search for other alternative (preferably renewable) sources of energy.

In this work, feasibility of PV-Wind-Biogas hybrid system with battery storage as a backup is studied to electrify the village in Adigrat district. It also compares the cost of the hybrid system against the cost required to electrify the village by extending the grid. The feasibility of this paper is analyzed using HOMER (Hybrid Optimization Model for Electrical Renewable) software. The data needed for calculating the cost of extending the grid is taken from Ethiopian Electric Power Corporation.

2.2. The Idea of Renewable Energy

2.2.1 Solar Photovoltaic System and Operation

To understand the operation of a PV cell, both the nature of the material and the nature of sunlight need to be considered. Solar cells consist of two types of material. p-type and n-type Silicon. Light of certain wave length is able to ionize the atoms in the silicon and the internal field produces by the junction separate some of the positive charge (“hole”) from the negative charge (electron) within the photovoltaic device. The holes are swept into the negative or n-layer. Although these opposite charge are attracted to each other, most of them can only recombined by passing through an external circuit outside the material because of the internal potential energy barrier. Therefore, if a circuit is made as is shown in the figure 2 below. Power can be produce from the cell under illumination, since the free electrons have to pass through the load to recombine with the positive holes.

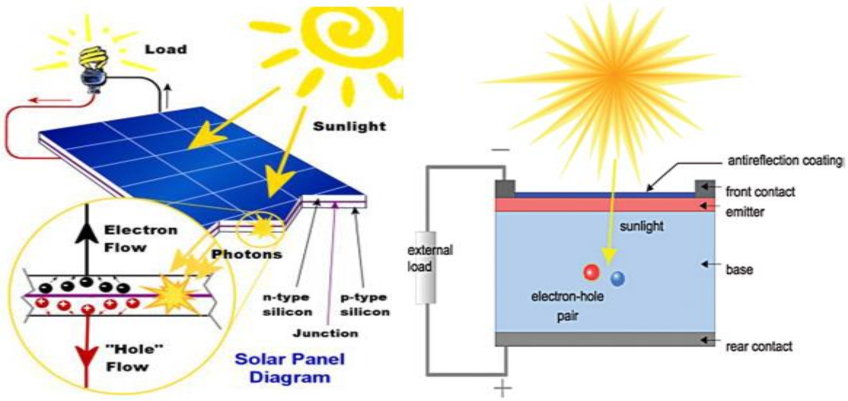


Figure 2 the configuration of a basic solar cell [**12**]

An electrical field is created near the top surface of the cell where these two materials are in contact (the P-N junction). When the sunlight hits the semiconductor surface, an electron springs up and is attracted towards the N-type semiconductor material. This will cause more negatives in the n-type and more positives in the P-type semiconductors, generating a higher flow of electricity. This is known as Photovoltaic effect.

Advantage and Disadvantage of Photovoltaic Power Generation

Advantage

- PV system is lasting longing sources of energy which can be used almost anywhere. They are particularly useful where there is no national grid.
- PV systems can also be installed in a distributed fashion, i.e. they don't need large scale installations it can be installed on roofs.
- PV systems have no moving parts and no noise or pollution is created from their operation that makes them the safest method of power generation.
- The environmental impact of a photovoltaic system is minimal.

Disadvantages

- Most types of PV power generation system require large areas of land to achieve average efficiency.
- PV system can only ever generate during the daytime due to the intermittent and variable manner in which the solar energy arrives at the earth's surface.
- At present, the high cost of PV modules and equipment is the primary limiting factor for the technology.

2.2.2 Biogas Energy System and Its Operation

The ever growing demand for energy world-wide can only be met by considering the possible range of energy solutions, and the development of technologies that produce emerging sources of energy, reduce our dependence on conventional, non- renewable fossil fuel including oil and coal. Renewable energy such as solar, wind, geothermal, biomass and alternative fuels are promising clean energy resources of the future, which are environmentally friendly and which sources replenish itself or cannot be exhausted. The focus of this thesis is on biomass energy and the design and implementation of small-scale anaerobic digester to produce biogas. Earlier results of this research was published in. [**13**]

Biomass energy is derived from waste of various human and natural activities, including, municipal solid waste, manufacturing waste, wetlands, agricultural crops waste, woodchips, dead trees, leaves, livestock manure etc., which are abundant anywhere and everywhere, at any time. Any of these sources can be used to fuel biomass energy production with the design of an efficient digester or processing plant to harness the energy from the biological mass.

Biogas is more convenient to use than traditional fuels, such as fire wood, dried dung and even kerosene. It gives a hot, clean flame that does not dirty pots or irritates the eyes, as does the smoke from other fuels. The composite from the plant can be used for fertilizer. Biogas can also be used in engine to drive machinery and water pumps. The concept of replacing wood fuel and petroleum oils by alternative fuels, such as biogas has encouraged governments in various countries to set up biogas programs.

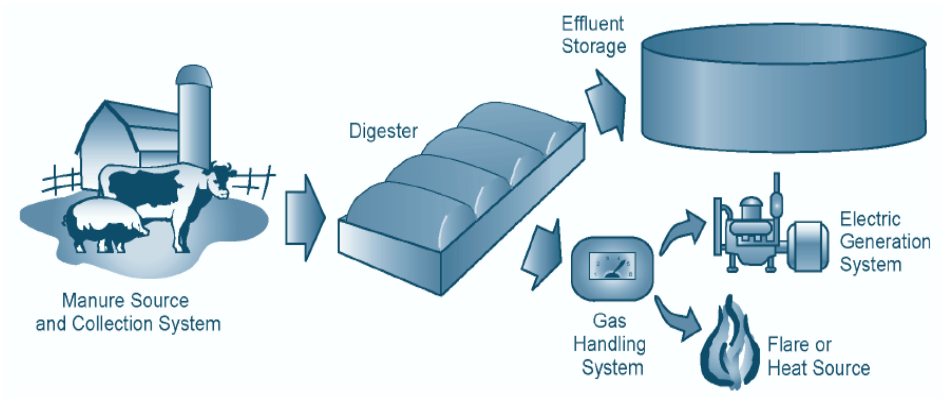


Figure 3 processes of biogas system **[14]**

Biogas Production Process

Biogas microbes consist of a large group of complex and differently acting microbe species, notable the methane producing bacteria. Biogas production process (Anaerobic digestion) is a multiple-stage process in which some main stages are in the figure 4 below.

- Hydrolysis
- Acidification
- Methane formation

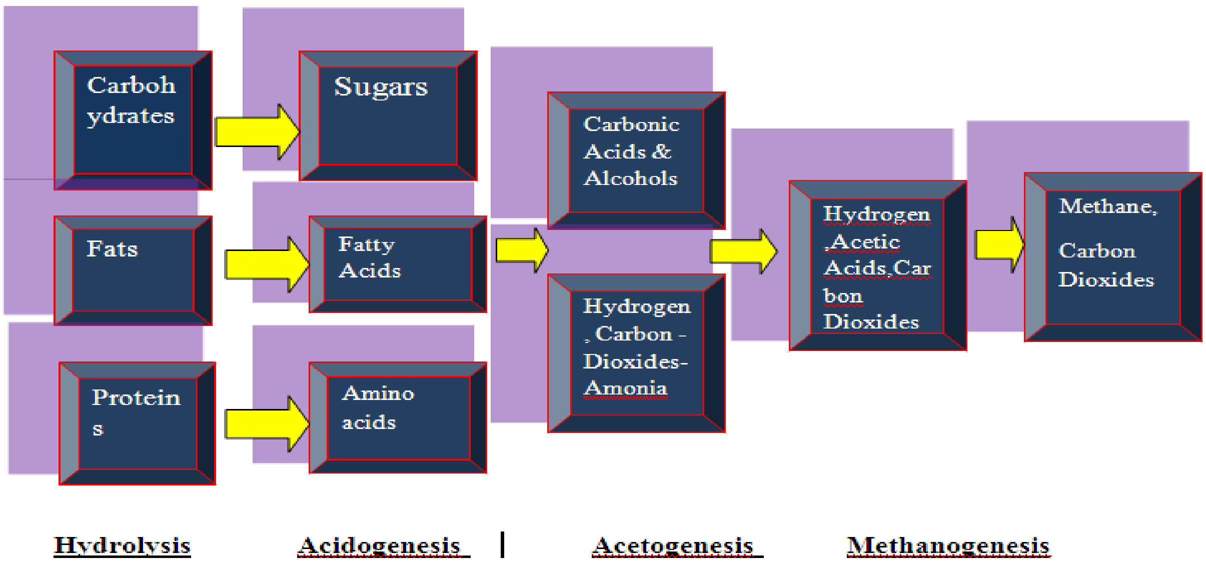


Figure 4 Production Process and steps of biogas

Step1: **Hydrolysis**

In the first step (hydrolysis), the organic matter is enzymolyzed externally by extracellular enzymes (cellulose, amylase, protease and lipase) of microorganisms. Bacteria decompose the long chains of the complex carbohydrates, proteins and lipids into shorter parts. For example, polysaccharides are converted into monosaccharide. Proteins are split into peptides and amino acids.

Step2: **Acidification**

Acid producing bacteria, involved in the second step, convert the intermediates of fermenting bacteria into acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide (CO_2). These bacteria are facultative anaerobic and can grow under acid conditions. To produce acetic acid, they need Oxygen and Carbon. For this, they use the Oxygen solved in the solution or bounded oxygen. Hereby, the acid producing bacteria create an anaerobic condition which is essential for the methane producing microorganisms. Moreover, they reduce the compounds with a low molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane. From a chemical standpoint, this process is partially endergonic (i.e. only possible with energy input), since bacteria alone are not capable of sustaining that type of reaction.

Step3: **Methane formation**

Methanogenes are involved in the third step; decompose compounds to low molecular weight. For example, they utilize hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide. Under natural conditions, methane producing microorganisms occur to the extent that anaerobic conditions are provided, e.g. under water (for example in marine sediments), in ruminant stomachs and in marshes. They are obligatory anaerobic and very sensitive to environmental changes. In contrast to the acidogenic and acetogenic bacteria, the methanogenic bacteria belong to the archaebacter genus, i.e. to a group of bacteria with a very heterogeneous morphology and a number of common biochemical and molecular-biological properties that distinguish them from all other bacterial general. The main difference lies in the makeup of the bacteria’s cell walls.

Composition of Biogas

Biogas is clean environment friendly fuel that can be obtained by anaerobic digestion of animal residues and domestic and farm wastes, abundantly available in the countryside. Biogas is an important renewable energy resource for rural areas in Ethiopia. Biogas generally comprise of 55-65% methane, 35-45%, carbon dioxide, 0.5-1.0% hydrogen sulfide and traces of water vapor. Average calorific value of biogas is 20MJ/m^3 (4713kcal/m^3) in Table 1.

Biogas like Liquefied Petroleum Gas (LPG) cannot be liquefied under normal temperature and pressure.

Critical temperature required for liquefy action of methane is 82.1℃ at 4.71MPa pressure;

Table 1 Composition of Biogas [**15**]

Substance	**Symbol**	**Percentage (%)**
Methane	CH_4	50-70
Carbon Dioxide	CO_2	30-40
Hydrogen	H_2	5.0-10
Nitrogen	N_2	1.0-2.0
Water Vapor	H_2O	0.3
Hydrogen Sulphide	H_2S	Traces

Methane and carbon dioxide are odorless and colorless gases. Hydrogen sulfide is colorless but it has an odor of rotten eggs in addition to its toxicity .Carbon dioxide, hydrogen sulfide, ammonia and water vapor considered corrosive substances .In general; biogas with all its components is colorless, odorless and lighter than air. [**16**]

Factors Affecting Anaerobic Process

a) Microbes Balance

Methanogenes convert simple acids and hydrogen that produced by fermentative bacteria species into methane gas and carbon dioxide; this means there should be stable ratios between the different types of anaerobic bacteria population. For example; if the acidogenic bacteria population increases more than the appropriate ratio then there will be an excess accumulation of acids inside the digester which will increase acidity (pH fall down) causing deactivation or stop acting of methanogenes and so the digestion process. In contrast; if the population of acidogenic bacteria decreases significantly, there will be no enough acids for methanogenic bacteria which will decrease biogas production. [**17**]

b) Substrate type

Anaerobic bacteria can digest all organic materials but they differ in the time interval required for complete digestion. That is, some are easily digested and in short time (from few to many days) while others are hardly digested and in long time (months or years) and this is according to the compounds from which the organic matter is composed.

c) Carbon to Nitrogen ratio (C/N ratio)

C/N ratio means the ratio of carbon element amount in organic matter to its content of nitrogen element amount. The best C/N ratio is 20-30 atoms of carbon for each atom of nitrogen (20-30carbon atoms: 1 nitrogen atom) [**16**]. High or low C/N ratio will effect negatively on the digestion of the substrate. Substrates with a too low C/N ratio lead to increased ammonia production, results in toxic effects, and inhibition of methane production. A too high C/N ratio means lack of nitrogen, from which negative consequences for protein formation and thus the energy and structural material metabolism of the microorganism result. A high carbon nitrogen ratio is likely to acidify and bring about the failure of fermentation.

d) Temperature

Methanogenes can act on the substrate in wide range of the temperature from below freezing to above 57.2℃. There are three ranges of temperature at which digestion process can be occurred and these ranges are

- ✓ Low temperature range (Psycrophilic bacteria range): less than 35℃
- ✓ Medium temperature range (Mesophilic bacteria range): ranged between 29℃ and 40℃
- ✓ High temperature range (Thermophilic bacteria range): from 50℃ to55℃.

e) PH value

PH value is an important parameter affecting the growth of microbes during anaerobic digestion. PH value of the digester should be kept within the desired range of 6.8-7.2 by feeding it at optimum loading rate. Acetate and fatty acids produced during digestion tend to lower pH of the digester liquor. However, the ion bicarbonate equilibrium of carbon dioxide in the digester exerts substantial resistance to PH change. This resistance to the change in pH is known as buffer capacity, is quantified by amount of strong acid or alkali added to the solution in order to bring about change in PH. Thus the presence of bicarbonate helps to prevent adverse effect on the microorganisms which result from low PH caused by excess production of fatty acids during digestion. Proteins and other organic compounds, as well as bicarbonate, take part in the buffering capacity and the resistance to the changes in PH.

f) Stirring

Optimum stirring substantially reduces the retention time. Stirring is very important for completing digestion process and enhancing biogas production. Since stirring break down the scum formed on the surface of digester contents and prevent the bacteria from stagnating in their own waste products. Stirring is more important for large scale biogas plants. Stirring for digester contents of small plants could be done manually by steel rods from substrate introducing pipe, or by paddles while large scale plants require more sophisticated stirring system as gas recirculation and mechanical stirrer. Good mixing of organic wastes with water before introducing the slurry into the digester enhances the digestion process.

g) Total Solids

Total solids mean the amount of solid particles in the unit volume of the slurry and they usually expressed in the percentage form pointed that the percentage of total solid should be between 5% and 12% while other source reported that the best biogas production occur when total solid is ranged from 7% to 10% because of avoiding solids settling down or impeding the flow of gas formed at the lower part of digester .Therefore; dilution of organic substrate or wastes with water to achieve the desirable total solids percentage is required.

h) Hydraulic retention time (HRT)

Most anaerobic systems are designed to retain the waste for a fixed number of days. The number of days the materials stays in the tank is called the hydraulic retention time. The required time for complete digestion of the substrate inside the digester depends on the type of the substrate,

substrate particles size, stirring and mainly on the temperature of the digester. In general the highest digester temperature and the finest substrate particles size the shorter retention time. According to the most reports about anaerobic digestion process the retention time of 40 to 60 days is satisfied for digesters work at temperature range between 20℃ and35℃.

i) Inhibitors and Activators

Presence of some substances in the contents of the digester below certain concentrations may activate the digestion process and so increasing the biogas production, but at higher concentrations it may become inhibitors. For example, presence of NH4 from 50 to 200 mg/l stimulates the growth of microbes, where as its concentration above 1500mg/l produces toxicity .Results of other study pointed that adding small amount of nickel metal. The presences of some substances can kill anaerobic bacteria as antibiotics, drugs and other medical wastes.

j) Digester Loading Rate

The digester loading indicates how much organic material per day has to be supplied to the digester or has to be digested. The digester loading is calculated in kilograms of organic dry matter per cubic meter of digester volume per day. Long retention times result in low digester loading. If the digester loading is too high, the pH falls. The plant then remains in the acid phase because there is more feed material than methane bacteria.

Fixed-Dome Plants

The fixed-dome plant consists of a digester with a fixed, non-movable gas holder, which sits on top of the digester. When gas production starts, the slurry is displaced into the compensation tank. Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank.

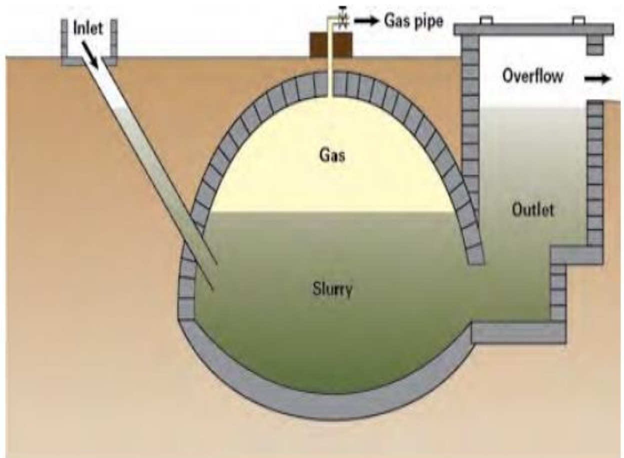


Figure 5 Fixed-dome plants [**18**]

Advantage of Fixed-dome plants

- Relative low construction costs
- Long life span if well-constructed
- Absence of moving parts or corroding metal parts
- Underground construction saves space and protects the digester from temperature fluctuations
- Local construction provides opportunities for skilled local employment

Disadvantage of Fixed-dome plants

- Certain specific technical skills are required to ensure a gas-tight construction
- Fluctuating gas pressure depending on volume of stored gas
- Special sealant is required for the inside plastering of the gasholder (e.g. bee wax – engine oil mixture, acrylic emulsion)
- Gas leaks may occur when not constructed by experienced masons
- Difficult to construct in bedrock
- Difficult to repair once constructed as the reactor is located under soil

2.2.3 Micro-Hydro Energy System

Hydropower engineering refers to the technology involved in converting the pressure energy and kinetic energy of water into more easily used electrical energy. The prime mover in the case of hydropower is a water wheel or hydraulic turbine which transforms the energy of the water into mechanical energy. Mechanical energy will be converted to electrical energy by using electrical generator [**19**].These prime movers convert the power available in the water to rotational/mechanical energy of the shaft of the generator. Then the generator acting as an energy converting unit converts the rotational/mechanical energy to electrical energy. This is the principle of hydropower engineering, the technology involved in converting the pressure energy and kinetic energy of water into electrical energy.

Types of Hydro Power

There are four basic types of hydro power generation Impoundment [Hydropower Basics, [**20**] [**21**].An impoundment facility, typically in a large hydropower system, uses a dam to store river water in a reservoir. The water may be released either to meet changing electricity needs or to maintain a constant reservoir level.

i) Run-of-river type

A dam with a short penstock (supply pipe) directs the water to the turbines, using the natural flow of the river with very little alteration to the terrain stream channel at the site and little impoundment of the water.

ii) Diversion and Canal type

The water is diverted from the natural channel into a canal or a long penstock, thus hanging the flow of the water in the stream for a considerable distance.

iii) Pumped Storage Type

When the demand for electricity is low, pumped storage facility stores energy by pumping water from a lower reservoir to an upper reservoir. During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity.

iv). Impoundment type

In large hydropower systems the construction of large dams is necessary to store water and to provide sufficient head for the turbine. Sufficient head for the turbine, the dam/reservoir has the advantage that the stored water is used during dry seasons. And also these water storage schemes enable the power station to generate at times of peak power demand, and then allow the water level to rise again during off peak time. Schemes with large dams are better suited to larger, gently graded rivers in the given Table 5below.

Components of the Micro-Hydro Power System (MHP)

The components for a MHP system can be grouped in to civil work components and electromechanical components. These components are presented in detail in the following subsections. Depending on the site, the following may be needed to develop a micro-hydropower system.

Civil Works Components Micro-Hydro Power System

Weir and intake: In the run-of-the river schemes a low diversion structure is built on the streambed prior to the intake to divert/channel the required amount of flow to the intake for power generation whilst the rest of the excess water continues to overflow it.

Canals and channels: These are components of a hydropower scheme used to convey water relatively larger distance from the stream to the inlet of the penstock, with minimum of head loss and cost.

Settling basin: Depending on soil type and geographical feature of the area, a flowing river can usually carry a suspension of small particles.

Forebay tank: The forebay is a basin located just before the entrance to the penstock and which forms the connection between the channel and the penstock. This structure can serve as a final settling basin to allow the last particles, water borne debris which either passed through the intake or were added in the canal, to settle down before entering to the penstock and to the turbine.

Penstock: The penstock is the pipe between the forebay and the turbine which conveys water under pressure to the turbine depending on factors such as the nature of the ground, the penstock material, the ambient temperatures and the environmental requirements; they can be installed over or under the ground.

Electro mechanical components:-The principal electro mechanical components of micro hydro plants are the turbine and generator.

Hydro turbines A hydro turbine is a rotating machine that converts the potential energy of the water to mechanical energy. Hydro turbines can be of either impulse or reaction types.

Drive systems The drive system transmits power from the turbine shaft to the generator shaft or the shaft powering another device through a coupling device. It also serves the function of changing the rotational speed from the one shaft to the other when the turbine speed is different to the required speed of the alternator or device.

Types of Generator used in Micro Hydro Power Generation

AC generators: There are two types of generators suitable for use in a micro hydroelectricity supply scheme. These are synchronous generators (or 'alternators') and induction generators (in which induction motors used as a generator) this machine is simpler or more reliable machine than the synchronous generator. It contains fewer parts, is less expensive, and is more easily available from electrical suppliers. It can withstand 200% runway speeds without harm, and has no brush or other parts which require maintenance. These factors all make induction generator an attractive choice for micro hydro power generation than that of synchronous can generates. The first problem that arise from power plant is the determination of the generator to be used, generator simultaneously (synchronous generator) or no simultaneous generator (asynchronous generator), both for the rotor cage and the rotor turns. The generator with permanent magnet is also being developed as a solution to power generation turbines at low rotation without having to use the gear box [**22**].

The use of synchronous generator at the same time we made it easy to adjust the output voltage and frequency generator by regulating the field current of generators. Unfortunately, the use of synchronous generator at the same time rarely applied due to the expensive cost requires current amplifiers and requires complex control systems. Asynchronous generator is often used for wind turbine system and micro hydro systems, both for fixed speed system and variable speed systems. The advantage of fixed speed system using asynchronous generators is cheap, simple and robust system. This system operates at a constant speed, so that the turbine only obtains at maximum power. This system suitable for application in micro hydro that water flow rate can be regulated mechanically. The weakness of this system is the generator requires reactive to generate electricity so that the capacitor banks should be installed. The systems are vulnerable to the pulsating power and are prone to mechanical changes [**23**].

Electrical Generator

There are two types of AC generators suitable for use in a micro hydro electricity supply scheme. These are synchronous generators (or ‟alternators‟) and induction generators (in which induction motors (IMs) used as a generator). These generators are constructed in the same fashion as a motor having the stationary stator which contains coils that produce the magnetic field. These motors have their stator windings, which are the source of voltage, connected to the electrical system that receives the power and their rotor short circuited. The machine can't function as a generator until a revolving magnetic field has been produced in the machine, and the current that produces the rotating magnetic field must therefore be supplied to the stator winding from an external source. For this reason an IG of this type must be operated in parallel with an existing power system. However in the absence of grid connection it is possible to operate IGs using capacitors designed for that particular generator. The best choice is induction generators (in which induction motors (IMs) used as a generator).

Advantages of Micro-Hydro Power System

- **Clean energy source**: Hydropower does not produce greenhouse gas emissions, which are the major cause of the international concerns about environmental problems: Hydroelectricity does not involve a process of combustion, therefore it avoids polluting emissions like carbon dioxide (responsible for global warming) that otherwise would be produced by conventional energy when burning fossil fuels. MHP is a clean energy source (it does not produce waste in the rivers, or air pollution) and renewable (the fuel for hydropower is water, which is not consumed in the electricity generation process).

- **Efficient energy source:** It only takes a small amount of flow (as little as two gallons per minute) or a drop as low as two feet to generate electricity with micro hydro. Since MHP is a de-centralized energy source located close to the consumers, transmission losses can be reduced.

- **Reliable electricity source:** Hydro produces a continuous supply of electrical energy in comparison to other small-scale renewable technologies. The peak energy season is during the winter months when large quantities of electricity are required. Power is usually continuously available on demand and the energy available is predictable.

- **No reservoir required:** Micro-hydro is considered to function as a 'run-of-river' system, meaning that the water passing through the generator is directed back into the stream with relatively minimal or no impact on the surrounding ecology.

- **Power for developing countries:** Because of the low-cost versatility and longevity of micro hydro, developing countries can manufacture and implement the technology to help supply much needed electricity to small communities and remote villages. No fuel and limited maintenance are required, so running costs are low (compared with diesel power). Localized power can be utilized for the benefit of the local economy.

Disadvantages of Micro-Hydro Power System

In order to take full advantage of the electrical potential of small streams, a suitable site is needed. Factors to consider are: distance from the power source to the location where energy is required, stream size (including flow rate, output and drop), and a balance of system components.

- **Energy expansion not possible:** There is always a maximum useful power output (size and flow from small streams for example) available from a given hydropower site, which limits the increase in power generation and the level of expansion of activities which can make use of the power.

- **Seasonal variations:** In many locations the flow in a stream fluctuates seasonally and this can limit the firm power output to quite a small fraction of the possible peak output. During winter months there is likely to be less flow and therefore less power output. Advanced planning and investigations are needed to ensure adequate energy generation and power demands are met

Charge Controller

Charge controllers are used in these power plant systems to protect the batteries from overcharge, prevent backflow of current which can cause damage to a photocell and excessive discharge. Most controllers function by sensing battery voltage and then take action based on voltage levels. Other controllers have temperature compensation circuits to account for the effect of temperature on battery voltage and state-of-charge.

Battery

The electrical energy is stored to the batteries in order to be provided in intervals with minimum solar irradiance (during nights, cloudy days). Solar energy systems for this thesis use a lead-acid deep cycle battery. This type of battery is different from a conventional car battery, as it is designed to be more tolerant of the kind of Ongoing charging and discharging would expect when variable sunshine from one day to the next. Lead-acid deep cycle batteries last longer but it also cost more than a conventional battery. The plate is made of a sponge-like material [**22**].

Convertor

Convertor are the device usually solid state, which change the array DC to AC or AC to DC of suitable voltage, frequency, and phase to lead power generated in to the Power local load and battery as the per the requirement.

2.2.4. Proposed Hybrid Renewable Energy System

The hybrid system consists of a PV- solar, micro-hydro and renewable combination with a bio-mass power generator which acts as the other energy sources. The supply of the electric power hybrid systems is to fill- full the power demand on the selected area.

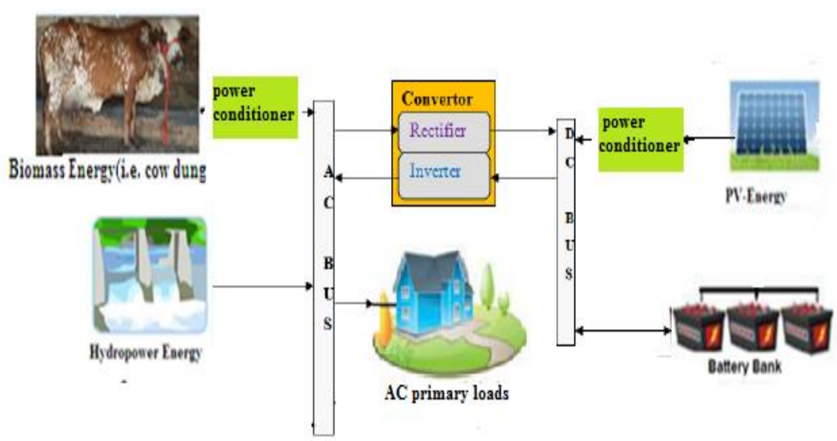


Figure 6 Model of Standalone Hybrid Power System with AC & DC buses coupled

From Figure 6 configuration, all electricity-generating components which supply AC (biomass and micro hydro generator) are connected to AC bus and DC components (PV panel and storage batteries) are connected to a DC bus. There is a need of convertor between AC and DC buses and they depend on the design and system requirements. The convertor includes both an AC/DC rectifier and DC/AC inverter. When there is excess biomass and micro hydro power, the rectifier converts the AC to DC and store energy in the battery through DC bus. The operation ways are going to find that, the energy balance between the total power generation and the total consumption or demand the site.

CHAPTER THREE

3. ENERGY DEMAND AND RESOURCE ASSESSMENT OF THE STUDY AREA

3.1 Energy Demand/Load Profile

3.1.1. Assessment and Design of Load Analysis for the Study Area

The data collection, used data collection techniques such as interviewing concerned peoples and statistical method in obtaining the required data. The load data is collected from the woreda administration office of Agaro, load data that was collected is tabulated below in the table 2.

Table 2 Types of loads and their specifications for the base year (2016)

Appliance	Power rating per unit(w)	Daily hours(hr.)	Daily energy demand(WH)
For House hold			
Lamp(salon)	11x1	4	44
Lamp(bed room)	11x1	2	22
Socket outlet(CD players & cell phone)	60x1	8	480
TV (not used by all peoples)	80x1	8	640
Toilet	11x1	1	11
Refrigerator(not used by all peoples)	100x1	24	2400
Kitchen	11x1	2	22
For Schools			
Lamps(class)	60x4x2	3	1440
Toilet(lamp)	11x1	1	11
Verandah(lamp)	60x1	12	720
For Healthy Center			
Toilet	11	1	11
Class (reception room)	11	3	33
Class (laboratory)	11	8	88

Class (bed room)	11	2	22
Verandah	60	12	720
Socket out let	60 x 2	10	1200

3.2. Resource Assessment of the Study Area

3.2.1. Solar Energy Resource Assessment

The most common solar energy resource data collected in many of the meteorological stations (NMSA) throughout the country is the average daily sunshine hours. The available sunshine hour data from the National Meteorological Agency of Ethiopia (Jimma, and Agaro branch) was used to estimate the solar-radiation energy of the site.

Table 3 the average value of Sun shines hour data of the year

Years	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2009	7.73	7.53	8.19	7.13	6.70	4.89	3.88	3.66	4.49	8.15	8.38	9.06
2010	7.73	7.53	8.19	7.13	6.70	4.89	3.88	3.66	4.49	8.15	8.38	9.06
2011	7.73	7.67	8.05	7.54	7.56	6.28	3.96	4.44	5.23	6.29	7.05	8.04
2012	6.44	7.48	7.37	7.23	7.56	7.69	4.66	4.64	5.02	6.28	8.75	5.67
Avg. Ssh.Hrs	**7.41**	**7.58**	**7.95**	**7.26**	**7.13**	**5.94**	**4.09**	**4.10**	**4.81**	**7.22**	**8.14**	**7.96**

Source: [NMSA, Jimma branch]

As it is seen in Table 3 the maximum average sunshine hour occurs during November, December, January, February, March and the minimum average sunshine hour occurs during June, July, August and September.

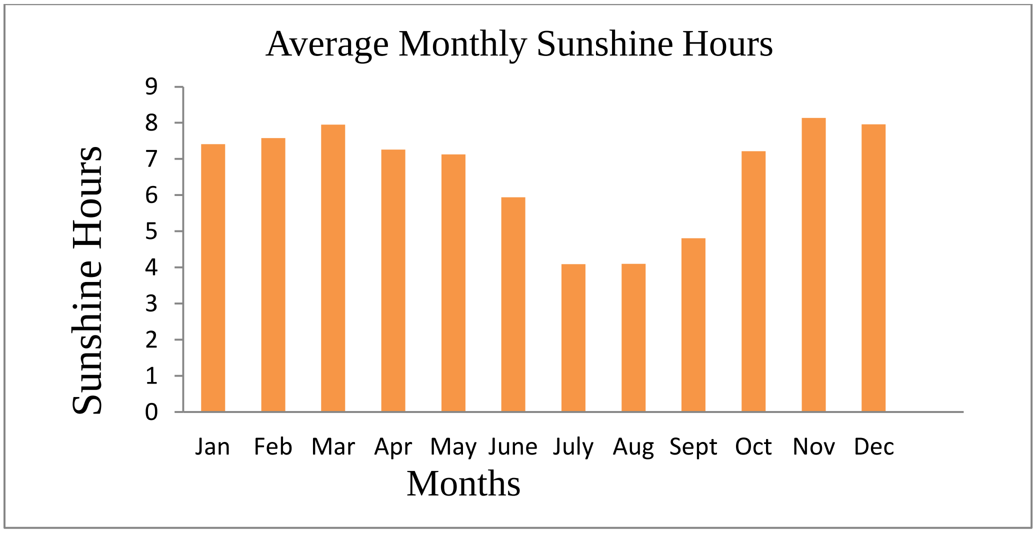


Figure 7 Average monthly sunshine hours

3.2.2. Biomass Energy Resource Assessment

About 85% of the Ethiopian populations depend on re-production of animal farm, processing and marketing. Kedemesa kebele has around 1350 cattle's as the summarized below.

a) The total number of cow available is 1350 at the study area "Kedemesa"

b) I have select Number of cows for my hybrid design is in average is 135 for hybrid system

(It has to be enough for my hybrid system expectance i.e. take sampling technique)

c) The average cow dung discharge is = 8- 10 kg / cow /day (i.e. practically taken)

Table 4 Monthly average cattle's manure (tonnes/day) at the site

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cattle manure (tonnes/day)	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35
Average = 1.35												

Source: [from the site gathered]

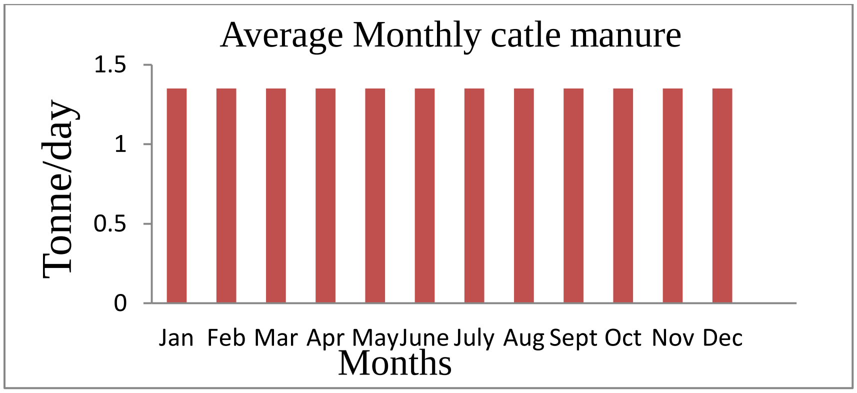


Figure 8 Monthly average biogas feedstock's (i.e. cow dung)

3.2.3. Micro-Hydro Energy Resource Assessment

Flow Rate of Naso River

Naso River is one of the larger feeding sites at Gilgel Gibe-1 gauging station catchments area of 2966 km^2. For the case of Kedemesa there is gauging station. Thus to estimate the stream flow of un-gauged sites empirical area ratio method of estimation is used rather than statistical model and rainfall-run off model for this study. Stream flow estimation for un-gauged catchments by transposing gauged stream flow data from an analogue catchment is a widely use technique requiring the rescaling of the flow regime to the un-gauged target catchment. [**24].**

- The area of Naso River is 20% the area of Gilgel Gibe River I that is, the area ratio method was employed for calculation of area of Naos River **[24].**
- Since the area of at Gilgel Gibe I River is $2966 km^2$**[25]**

Table 5 the Average value of mean monthly flow at Gilgel Gibe I River (m^3/s)

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	17.4	7.76	6.43	44.26	70.07	181.61	187	279.18	185.68	122.77	324.73	143.09
1998	76.12	38.96	43.58	30.32	55.16	78.13	226.85	458.64	257.03	226.38	88.51	39.91
1999	26.97	14.21	19.56	15.68	44.39	92.15	213.17	291.11	154.38	194.37	67.40	29.49
Avg. flow rate	**40.16**	**20.31**	**23.25**	**30.08**	**56.54**	**117.29**	**209.00**	**342.97**	**199.13**	**181.17**	**160.21**	**70.83**

Source: [JMAS, Jimma branch]

The information was gathered from the office of rural development and environmental protection of Agaro Woreda. Naso River can generate electrical power at the sites of the study area. In this thesis the Naso River was considered as the source of water for the Micro-hydro power generating system. From table 5 the minimum average flow rate is 20.31 m^3/s (February) and maximum average flow rate is 342.97m^3/s(August).

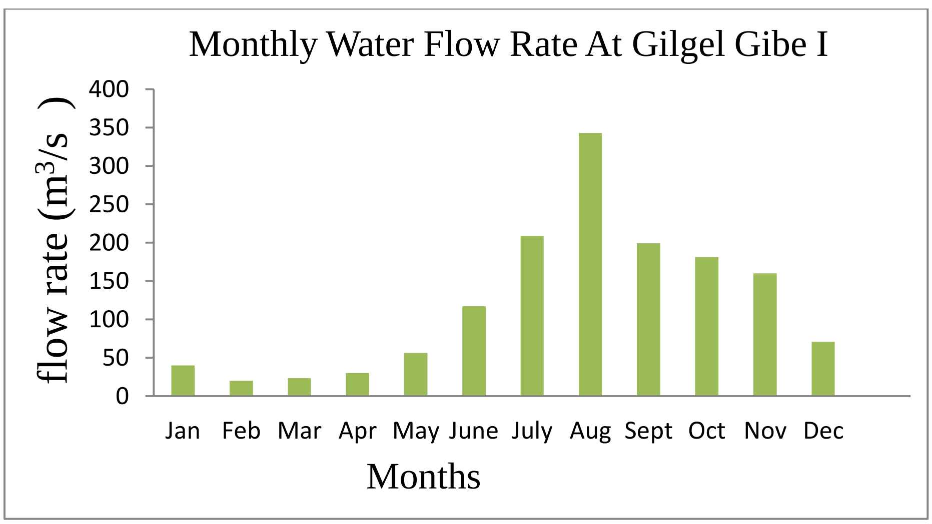


Figure 9 Average monthly flow rate of Gilgel Gibe I river

From Figure 9 the average flow rate of Gilgel Gibe-I River from December-April is less than $50m^3/s$, whereas the average flow of this river from June-November is greater than $100m^3/s$.

CHAPTER FOUR

4. METHODOLOGY USED IN THE HYBRID OF RENEWABLE ENERGY

It is shows that methodologies and kindly used for primary and secondary data collection of PV-solar system, Micro-hydro and Bio-mass digester system. the primary data took from the sited and secondary data obtained from NMSA (Jimma and Agaro) as well as information gathered during field survey from interviewing the higher officials of the Agaro Woreda were used for this thesis work.

4.1. Modeling Daily Solar Radiation

The four year average sunshine hour data available has been converted to monthly average daily global solar radiation. The Angstrom estimation, model was used to find the monthly average daily global solar radiation by using input data such as latitude, altitude, the average day in the month, the declination angle for the day and the sunshine hour data. A worksheet was created with all the input data for each month and employing Eq.(4.1).The parameters N, a, n, b, H_o and finally H were calculated. [**26**] [**27**].

$$H = H_o\left(a + b\frac{n}{N}\right) \qquad \text{eq. (4.1)}$$

Where

H = is monthly average daily global solar radiation

H_o = is monthly average daily extraterrestrial solar radiation

a and b= is Angstrom's correlation parameter

n = is monthly average daily hours of sunshine from sunshine recorder

N= is monthly average of the maximum possible hours of sunshine

$$H_O = \frac{24}{\pi} \times 3600G_{SC}[1 + 0.033\cos(\frac{360\times N}{365})] \times [\cos(L)\cos(\delta)\sin\Omega_{ss} + \frac{2\times\pi\times\Omega_{ss}}{360} \times \sin(L)\sin(\delta)] \qquad \text{eq. (4.2)}$$

Where

N= Day number starting from January $1st$

G_{SC}= solar constant= 1367w/m^2

Φ= Latitude of the location

δ = Declination angle (°) and

Ω_{ss}= Sunset hour angle (^{0})

The day length is twice the sunset hour, since the solar noon is at the middle of the sunrise and sunset hours. Therefore, the length of the day in hours is

$N= \frac{2}{15}\cos^{-1}(-\tan L \tan \delta)$……………………………………………………….eq. (4.3)

$\delta = 23.45 \sin(360/365(284 + N)$…………………………………………………eq. (4.4)

Where

L= latitude angle north i.e. L=7.51^{0}N

$\cos \Omega_{ss} = \; -\tan(L)\tan(\delta)$…………………………………………………………..eq. (4.5)

Where

Ω_{ss} = The sunset hour angle

$\Omega_{ss}= \cos^{-1}(-\tan(L)\tan(\delta))$

The mean daily radiation on the horizontal surface outside the earth's surface (H_o) will be.The accuracy of the estimated values of the regression coefficients "a" and "b" are expected to improve by adding the effect of elevation, sunshine duration, and latitude together. Thus the regression coefficients "a" and "b" in terms of the latitude, elevation and percentage of possible sunshine for any location around the World (for 5° ≤54°) are correlated by Gopinathan with equation below. [**28**]

a = −0.309+0.539 cos L −0.0693 h +0.290($\frac{n}{N}$)……………………………………….eq. (4.6)

b = 1.527−1.027 cos L +0.0926 h −0.359 ($\frac{n}{N}$)…………………………………………eq. (4.7)

Where

h = (is Altitude of a site = 5496ft = 1.6752 km for the specific study site) with an elevation of at sea level. h= 1875.2 m

δ = is declination angle for the average day in the month

L= is Latitude of the site (7.51^{0}N and 36.35^0 E for the specific study site)

Table 6 Day Number and Recommended Average Day for Each Month. [**28**]

Month	n_d for i^{th} day of the month	For the average day of the month		
		Date	Day of year (n_d)	declination (δ)
January	i	17	17	-20.9
February	31+i	16	47	-13.0
March	59+i	16	75	-2.4
April	90+i	15	105	9.4
May	120+i	15	135	18.8
June	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	-23.0

$$H_O = \frac{24}{\pi} \times 3600G_{SC}[1 + 0.033\cos(\frac{360\times n}{365})] \times \left(\cos(L)\cos(\Delta)\sin\Omega_{ss} + \frac{2\times\pi\times\Omega_{ss}}{360} \times \sin(L)\sin(\Delta)\right)$$

<u>The calculation part for January month would be as follow</u>

N= 17,

δ (^{0}) = -20.9^0

L= latitude angle south i.e. L=7.51^{0}N,

h = (is Altitude of a site = 5496ft = 1.6752 km n=7.41hrs/day

$\Omega_{ss} = \cos^{-1}(-\tan(L)\tan(\delta))$

$\Omega_{ss} = \cos^{-1}(-\tan(7.51)\tan(-20.9))$

$\Omega_{ss} = 87.114^0$

N= $\frac{2}{15}\cos^{-1}(-\tan L \tan\delta) = \frac{2}{15}\cos^{-1}(-\tan(7.51)\tan(-20.9)$= 11.62hrs

The overall average clear index will be

$\frac{n}{N} = \frac{7.41\text{hrs}}{11.62\text{ hrs}} = 0.64$

To obtained the values of the regression coefficients a and b can be calculated as follow

a = $-0.309+0.539\cos(7.51) - 0.0693\times 1.6752 + 0.290\times(0.64) = 0.29$

b = $1.527 - 1.027\cos(7.51) + 0.0926\times(1.6752) - 0.359\times(0.64) = 0.43$

$1\text{kWh/m}^2\text{/d} = 3.6\text{ MJ/m}^2\text{/d}$
$1\text{MJ/m}^2\text{/d} = 0.278\text{ kWh/m}^2\text{/d}$

$$H_O = \frac{24}{\pi}\times 36001367[1+0.033\cos(\frac{360\times17}{365})]\times\left(\cos(7.51)\cos(-20.9)\sin(87.114) + \frac{2\times\pi\times87.114}{360}\times\sin(7.51)\sin(-20.9)\right)$$

$H_O = 9.21\text{kWh/m}^2\text{/d}$

H= $9.21\text{kWh/m}^2\text{/d}\times(0.29+0.43\times0.64) = 5.2\text{kWh/m}^2\text{/d}$

- It will do the rests (i.e. from February to December) by the calculation step as summarized by table below by all the above steps.

Table 7 Average solar radiations in $kWh/m^2/d$ of Kedemesa kebele

Month	N	$\delta(^0)$	Ω_{ss} $(^0)$	N (hours)	n(hours)	$\frac{n}{N}$	a	b	H_O (kwh/ m²/d)	H (kWh/ m²/d)
January	17	-20.9	87.114	11.62	7.41	0.64	0.29	0.43	9.21	5.2
February	47	-13.0	88.26	11.77	7.58	0.64	0.29	0.43	9.84	5.56
March	75	-2.4	89.68	11.96	7.95	0.66	0.30	0.43	10.36	6.05
April	105	9.4	91.25	12.17	7.26	0.60	0.28	0.45	10.49	5.77
May	135	18.8	92.57	12.35	7.13	0.58	0.28	0.46	10.27	5.62
June	162	23.1	93.22	12.44	5.94	0.48	0.25	0.49	10.07	4.89
July	198	21.2	92.93	12.4	4.09	0.33	0.20	0.55	10.12	3.86
August	228	13.5	91.81	12.25	4.10	0.33	0.20	0.55	10.33	3.94
September	258	2.2	90.29	12.04	4.81	0.40	0.23	0.52	10.34	4.53
October	288	-9.6	88.72	11.84	7.22	0.61	0.29	0.44	9.94	5.55
November	318	-18.9	87.41	11.66	8.14	0.69	0.31	0.42	9.33	5.59
December	344	-23.0	86.79	11.58	7.96	0.69	0.31	0.42	8.99	5.39
Annual Average										5.16

The average daily global solar radiation varies from around 3.86 $kWh/m^2/d$ in rainy month of July to just 6.05$kWh/m^2/d$ in the dry months.

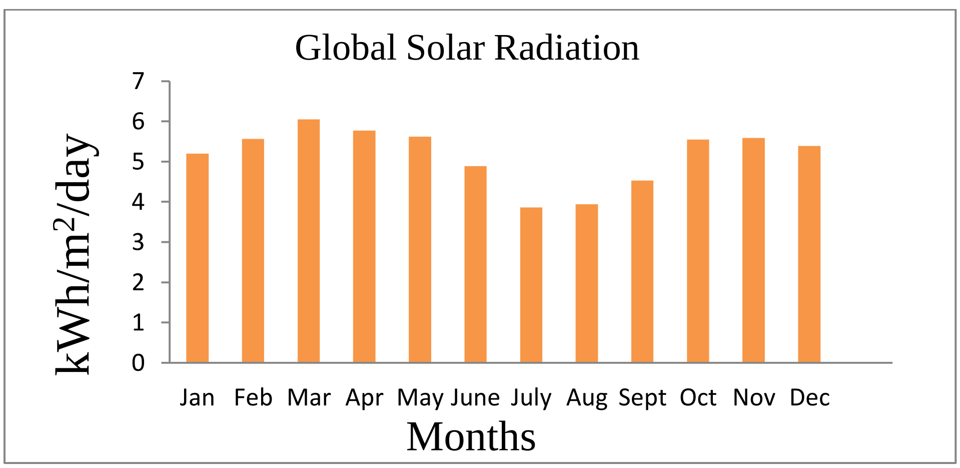


Figure 10 Average global solar radiations

4.1.1. Data Comparison of Global Solar Radiation NMSA and NASA

Table 8 compares the post processed data taken from the JNMSA and NASA.

Site of KedemesaKebele													
Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Avg.
NMSA	5.2	5.56	6.05	5.77	5.62	4.89	3.86	3.94	4.53	5.55	5.59	5.39	**5.16**
NASA	5.43	5.82	5.87	5.64	5.39	4.87	4.41	4.64	5.21	5.39	5.40	5.41	**5.29**

From above Table 8 the average global solar radiation of NMSA Jimma branch was 5.16kWh/m^2/d, average global solar radiation of NASA was 5.29KWh/m^2/d.

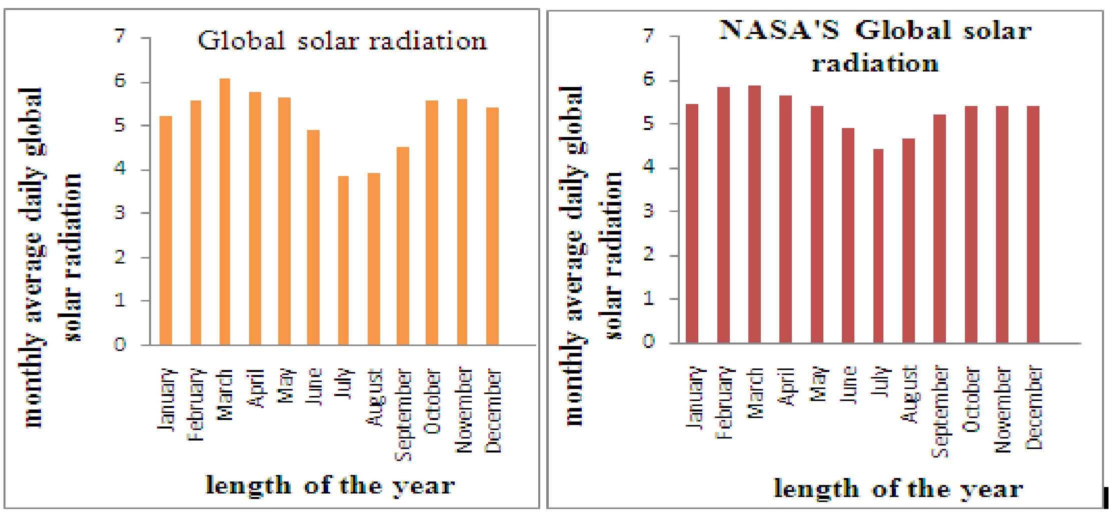


Figure 11 Data comparison of global solar radiation of NMSA and NASA

From the above table 8 and Figure 11 it is possible to understand the data taken from NMSA was almost the same/valid and there was enough solar radiation to electrify the Kedemesa Kebele from Solar system.

4.2 Biomass Energy and Power

a) The total number of cow available is 1350 at the study area “Kedemesa”

b) For my design Number of cows in the village the average is =135 have been selected.

c) The average cow dung discharge is = 8- 10 kg / cow-dung/day

Take average cow dung discharge = 10 kg / cow-dung/day

Total discharge for the village is determined

TS_d= 135 × 10 =1350 kg / cow-day

Therefore, the daily biomass input is = 1350 kg.

. Total solid content of night soil is, TS = 0.16

Volatile solid content of night soil is, VS = 0.13

The amount of biogas generated each day is calculated on the basis of the specific gas yield of the substrate and the daily substrate input. The estimation can be based on [**16**]

The volatile solids content VS

$$G_d = VS \times G_y \text{ (solids)} \left[{m^3}/{day} = kg \times {m^3}/{(day \times kg)} \right] \text{..............................eq. (4.8)}$$

The weight of the moist mass

$$G_d = W_{biomass} \times G_y \text{ (moist)} \left[{m^3}/{day} = kg \times {m^3}/{(day \times kg)} \right] \text{..........................eq. (4.9)}$$

Standard gas-yield values per livestock unit LSU

$$G_d = n_{LSU} \times G_y \text{ (species)} \left[{m^3}/{day} = number \times {m^3}/{(day \times number)} \right] \text{............eq. (4.10)}$$

Where,

G_d = Daily biogas generated=

G_y = Specific biogas yield

n_{LSU} = Number of Livestock Unit

4.3. Micro-Hydropower Energy and Power System

For the case of Kedemesa there is gauging station. Especially for the design of all the components of MHP (Micro-hydro power) it must have a water flow rate data. There is one river flow gauging station at Gilgel Gibe I River having a catchments area of 2966km^2[**4**]. Naso River it have smallest catchments of 593 km^2 feeding site at Gilgel Gibe I gauging station

Thus to estimate the stream flow of un-gauged sites by empirical method of estimation is used rather than statistical model and rainfall-run off model for this study. Stream flow estimation for un-gauged catchments by transposing gauged stream flow data from an analogue catchment is a widely use technique requiring the rescaling of the flow region to the un-gauged target catchment. These techniques all take by the following formula. [**29]**

$$QX_T = K\left(\frac{A_T}{A_A}\right)QX_A \quad \text{eq. (4.11)}$$

Where

QX_T = the flow in the target un-guaged catchment T

QX_A= the corresponding flow in the analogue guaged catchment A

A_T = the catchment area for the unguaged catchment T

A_A= the catchment area for the analogue gauged catchment A

k = a scaling constant or function

Table 9 The Values of k as a function of land use, topography and soil type

Land use and topography	**Soil Types**		
	Sandy loam	**Clay and silt loam**	**Tight clay**
Cultivated land	0.30	0.50	0.60
i) Flat	0.4	0.60	0.70
ii) Rolling	0.52	0.70	0.82
iii) Hilling			
Pasture land	0.10	0.30	0.40
i) Flat	0.16	0.36	0.55
ii) Rollin	0.22	0.42	0.60
iii) Hilling			
Forest land	0.10	0.30	0.40
i) Flat	0.30	0.50	0.60
ii) Hilling			
Populated land	0.40	0.55	0.65
i) Flat	0.50	0.65	0.80
ii) Rolling			

Kedemesa site is where the land use, topography and soil type composed of flat Pasture land Surfaces that is the land cover Clay and silt loam soils type with high clay content. During excavation the water came out easily based of this topography settlement, so that the type of soil at site is found Clay and silt loam.

Table 10 the Average value of mean monthly flow at Gilgel Gibe I River

Years	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1997	17.4	7.76	6.43	44.26	70.07	181.61	187	279.18	185.68	122.77	324.73	143.09
1998	76.12	38.96	43.58	30.32	55.16	78.13	226.85	458.64	257.03	226.38	88.51	39.91
1999	26.97	14.21	19.56	15.68	44.39	92.15	213.17	291.11	154.38	194.37	67.40	29.49
Avg. flow rate	**40.16**	**20.31**	**23.25**	**30.08**	**56.54**	**117.29**	**209.00**	**342.97**	**199.13**	**181.17**	**160.21**	**70.83**

The area ratio method was employed for this area where A_{site} is 20% of the A_{gauge} or the ratio $\frac{A_{site}}{A_{gauge}}$= 0.2 so that

Using the equation of the empirical method area ratio above I calculate the Naso river flow rate from gauged Gilgel Gibe I river as follow.

$\frac{A_T}{A_A}$= 0.2

$$A_T = 0.2 \times A_A$$

$$= 0.2 \times 2966 km^2 = 593.2 = 593\ km^2$$

$$QX_T = K\left(\frac{A_T}{A_A}\right) QX_A$$

But I have select K= 0.3. For January Average value of monthly flow at Gilgel Gibe I River is $Q_{gauge} = 40.16\, m^3/s$

$$Q_{un,guage} = 0.3\left(\frac{593}{2966}\right) 40.16\ m^3/s = 2.41\ m^3/s$$

Table 11Average monthly water flow rate of Gilgel Gibe I and Naso River

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. GGR-I (m^3/s)	40.16	20.31	23.25	30.08	56.54	117.29	209.00	342.97	199.13	181.17	160.21	70.83
Avg. Naso River (m^3/s)	2.41	1.22	1.39	1.39	3.39	7.04	12.54	20.57	11.94	10.87	9.61	4.25
Avg. Naso River (L/s)	2410	1220	1390	1800	3390	7040	12540	20570	11940	10870	9610	4250

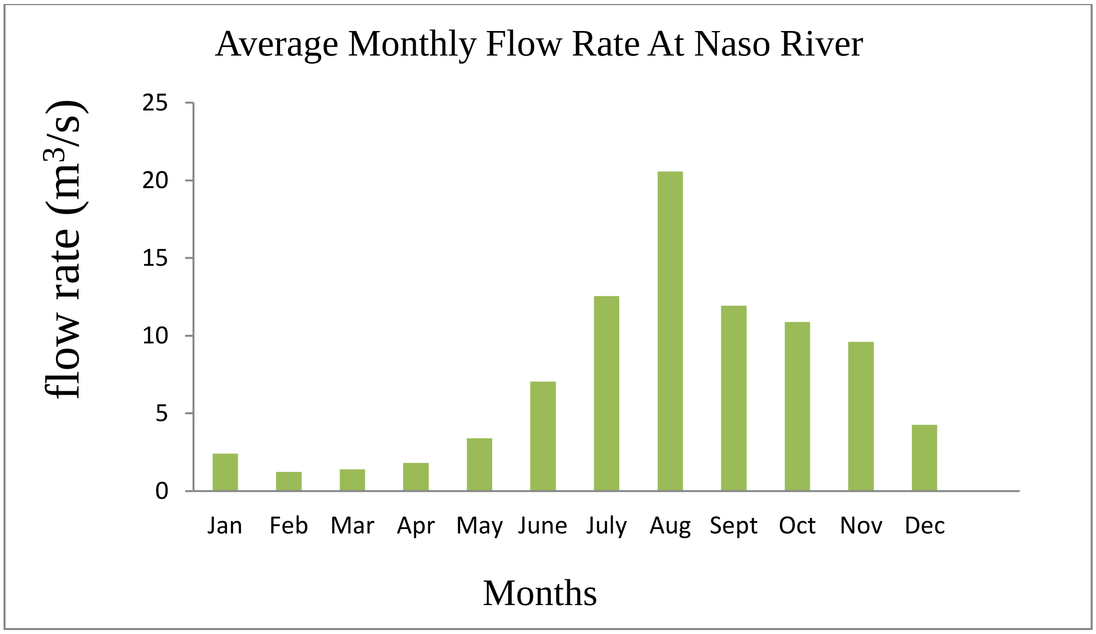


Figure 12 Average monthly water flow rate at Naso River

From the Figure 12 it has shown that for Naso River, The maximum flow rate is 20.57m^3/s and the minimum flow rate is 1.22 m^3/s

CHAPTER FIVE

5. DESIGNING AND MODELLING OF THE HYBRID SYSTEM

5.1. Load Calculation and Analysis for the Study Area

For 2016 (530 households)

Total energy of **households e**xcept TV and refrigerator

= (44+22+480+11+22) x 530 =306.87 KWh/day

Annual energy consumption = 306.87 KWh/dayx 365day/year=112007.55kWh=112.008 MWh/year

Average load demand per hours = $\frac{112007.55\text{kWh}}{8760\ hr/yrs}$ = 12.79 kW

Peak load (PL) = average load demand ÷ load factor

Assuming load factor = 0.57=57%, PL = 12.79 kW÷ 0.57 = 22.43kW

Installed capacity (IC) = peak load + loss, Loss = 0.1 x 22.43 kW = 2.243kW

IC = 22.43 kW + 2.243kW

Therefore, Electrical Energy demand of the site for the year 2016 is 24.67 KW

Per households consumption (U) = annual energy consumption ÷ numbers of households

= 112.008 MWh/year ÷ 530 = 211.336 kWh

Forecasting of the load demand for 10 years of Households

$\log G = 1.28 + C_1 + C_2 + C_3 \ldots\ldots - K_1 X K_2 \ldots K_N \log U$……………….. [**ref. 30**]……eq. (5.1)

Where

G= annual percentage growth in per household consumption

U= annual kWh usage per household

C_1, C_2, and C_3 are constant for households growth, growth of agricultural pump sets, growth of industrial loads

K_1 , K_2 , ... K_N are constant assumed unity

$C_1 = 0.05$ x (percentage rate of growth of households)

C_2 = 0.01 x (percentage rate of growth of agriculture)

For 2017

$\log G = 1.28 + C_1 - 0.15 \log U$

C_1 = 0.05 x PR

PR = constant Growth rate = 2.6 [**30**]

$C_1 = 0.05 \times 2.6 = 0.13$

From above results U = 211.336 kWh

$\log G = 1.28 + 0.13 - 0.15 \log 211.336 \rightarrow \log G = 1.061 \rightarrow G = 10^{1.061} = 11.51$

Annual kWh usage per households in the year 2017

$U_{2017} = U_{2016} \times \left(1 + \frac{G}{100}\right) \div \left(1 + \frac{PR}{100}\right)$ .... [**ref.30**]……………………………….eq. (5.2)

$= 211.336 \times \left(1 + \frac{11.51}{100}\right) \div \left(1 + \frac{2.6}{100}\right) = 229.661\text{KWh}$

Number of house hold (HS) for 2017

Number of house hold (HS) $= HS_{2016} \times \left(1 + \frac{PR}{100}\right) = 530 \times \left(1 + \frac{2.6}{100}\right) = 544$

Energy for 2017

E= 229.661KWh x 544 = 124.95 MWh

Load factor (LF) for 2017

LF = 65 – Y (65 - Z)………………………………………………………………eq. (5.3)

Where

Y = from table 1 below

Assumed Z= 57%

Table 12 Load factor starting from the base year [**31**]

Year from start	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Values of Y	1	0.96	0.92	0.88	0.84	0.8	0.77	0.74	0.71	0.68	0.65	0.62	0.6	0.59	0.58	0.57	0.5

Assume at year 1, Y= 0.96 and Z= 57%

LF = 65 – 0.96 (65 –57) = 57.32 %, Peak load = $\frac{124.95\text{MWh}}{365 \text{ x } 24 \text{ x } 0.5732}$ = 24.88 kW

The forecasted load for 2026 will be (after 10 year)

Annual kWh usage per households

$$U_{2026} = U_{2016} \times (1 + \frac{G}{100})^{10} \div (1 + \frac{PR}{100})^{10}$$

$$= 211.336 \times (1 + \frac{11.51}{100})^{10} \div (1 + \frac{2.6}{100})^{10} = 485.561\text{kwh}$$

Households for 2026

Number of house hold (HS) =HS_{2016}x $(1+\frac{PR}{100})^{10}$= $530\times(1+\frac{2.6}{100})^{10}$= 685

Energy for 2026

U_{2026} x Number of house hold $(HS)_{in,2026}$= 485.561 kWh x 685= 332.65 MWh

Load factor for 2026

At years = 10, Y= 0.65 and Z=57%

Load factor = 65 – Y (65 – Z) = 65 – 0.65 (65 - 57) = 59.8%

Peak load = $\frac{332.65\ \text{MWh}}{365\ \text{x}\ 24\ \text{x}\ 0.598}$ = 63.5kw

For TV of household equipment's

If from 10 households only 4 households has TV in the forecasted year

For 2026, in this thesis out of 685 household only 274 households uses TV.

Total energy = 80 W x 8 hr/day= 640W hr/day

Households has TV in the forecasted year energy consumption

E = 274 x 640W hr/day = 175.36 kW hr/day

Annual energy consumption

= 274 x 640W hr/dayx 365 = 64 MWh

Average load demand = $\frac{\text{Annual energy consumption}}{\text{total times of the year}}$ = $\frac{64\text{MWh}}{365\ \text{day x}\ 24\ \text{hr /day}}$ = 7.3 kW

Peak load = $\frac{7.3\ \text{kW}}{0.598}$ = 12.22 kW

For Refrigerators uses

Refrigerators(R) with rating of 100W (If 30% of households will use refrigerators)

Total number of house hold = 685

30% of this house hold will be = 206 house holds

Total energy = 100w x 24hr/day = 2400 Whr/day

Households will use refrigerators energy consumption

E= 206 x 2400Whr/day = 494.4 k Whr/day

Annual energy consumption = 206 x 2400Whr/day x 365 day = 180.5 MWh

Average load demand $= \frac{\text{Annual energy consumption}}{\text{total times of the year}} = \frac{180.5\ \text{MWh}}{365\text{day x } 24\ \text{hr/day}}$ = 21 kW

Peak load = $\frac{21\ \text{kw}}{0.598}$ = 35 kW

For schools uses in the base year (2016)

Annual energy consumption = (1440 +11 +720)× 365 = 2.2 Whr

In 2026

For class lamps (energy consumption) = 6 x 2 x 60 w x 3hr

Where

number of class = 6, in one class = 2 lamps (fluorescent)

For class lamps (energy consumption) = 6 x 2 x 60 w x 3hr = 2160 Wh

Toilet

Energy consumption = 11W x 1hr = 11Whr

Verandah

Energy consumption = 60W x 2 x 12hr = 1440

Where, Number of lamps = 2

Total energy consumption = 2160wh + 11wh + 1440wh = 3611 Wh = 3.611 kWh

Average load demand = $\frac{3.611\text{kwh}}{24\text{ hr}}$ = 0.15 kW, Peak load = $\frac{0.15\text{ kw}}{0.598}$ = 0.252 kw

For health center (2026)

The total load energy for health center is $\sum = \mathbf{2074wh}$

Average load demand = $\frac{2074\text{wh}}{24\text{ hr}}$ = 86.42 W = 0.086 kW, Peak load = $\frac{0.086\text{kw}}{0.598}$ = 0.1445 kWh

Summation of peak loads will be

$\sum 63.5\text{kw} + 12.22\text{kw} + 0.252\text{kw} + 0.1445\text{kw} + 35\text{KW}$ = 111.12 kW

Installed capacity(IC) = peak load + loss, Assuming loss = 10%

Loss = 0.1 x 111.12 kW=11.12 kW

The total install capacity after ten year will be IC = 111.12 KW + 11.12 kW= 122.24 kW

The peak load and energy consumption up to 2026 as shown in table 13 below

Table 13 summarized Total Average Energy Consumption including the forecasting

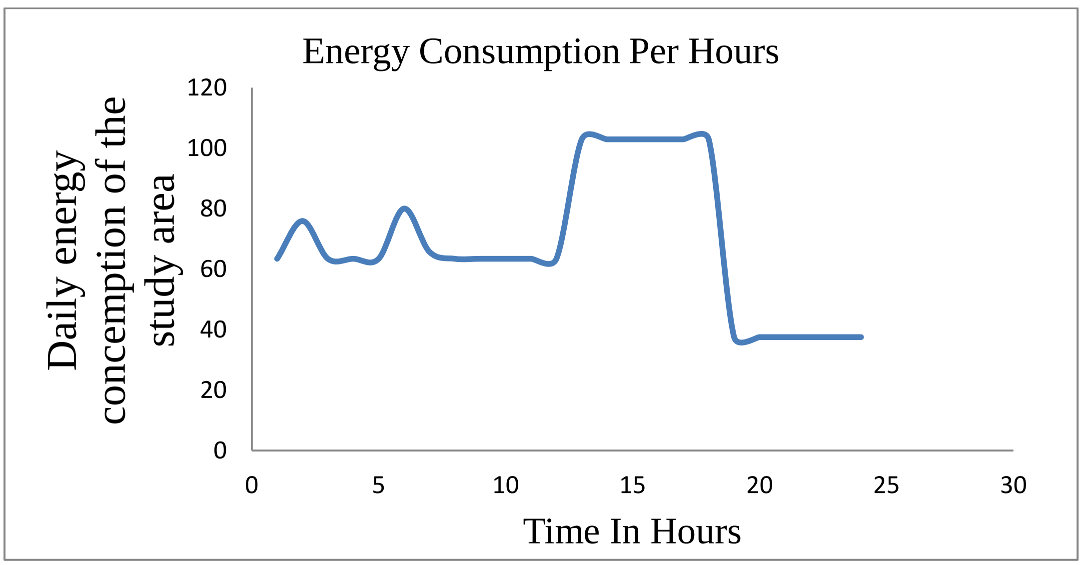
Total Average Energy Consumption					
Appliance	Quantity	Rated Power (W)	Energy (Kw)	House use per day	Energy W h/day
Light	530	40	21.2	6	127,200
Street light	240	25	6	12	72,000
Television	159	150	23.8	5	119,000
Mobile charger	420	5	2.1	3	6300
Radio	150	20	3	6	18,000
Stove	75	500	37.5	5	187500
DVD player	100	40	4	4	16000
Refrigerator	127	200	25.4	24	609600
Hair and beard machine	1	3kw	3	8	24,000
Flour mill	1	12kw	12	8	96,000
Total Energy consumption			**123**		1,275,600

Daily consumption of energy with time variation is given in table 14 below. To simulate the system, the approximate energy consumption for each hour is required. The table shows the energy in kW for each appliance, all total hours is 24.

Table14 Daily demands at kedemesa kebele

Morning		Afternoon		Evening		After midnight	
Daily Hour	Energy(KW)	Daily Hour	Energy(KW)	Daily Hour	Energy(KW)	Daily Hour	Energy(KW)
00:00-1:00	65.900	6:00-7:00	65.700	12:00-13:00	108.00	19:00-20:00	37.500
1:00-2:00	73.900	7:00-8:00	65.900	13:00-14:00	108.00	20:00-21:00	37.500
2:00-3:00	65.900	8:00-9:00	65.900	14:00-15:00	108.00	21:00-22:00	37.500
3:00-4:00	65.900	9:00-10:00	65.900	15:00-16:00	108.00	22:00-23:00	37.500
4:00-5:00	65.900	10:00-11:00	65.900	16:00-17:00	108.00	23:00-00:00	37.500
5:00-6:00	96.000	11:00-12:00	65.900	17:00-18:00	108.00	19:00-20:00	37.500

(Source: From table 13)



Figures 13 Load curve of kedemesa kebele

5.2. System Designing For Hybrid Components

5.2.1 Design of Solar Photovoltaic System

From HOMER software results PV covers 25% of the system. The installed capacity is 29.85kw.

Constructing a load profile and calculating the designed energy demand. From above results:

For Health center, =2.074 KWh/day

For schools, =3.611 KWh/day

For TV, 175.16 KWh/day

House hold equipment's, = 485.561 KWh/day

For refrigerator, = 494.4 KWh/day

$$\sum \text{energy} = (2.074 + 3.611 + 175.16 + 485.561 + 494.4\ )\ \text{KWh/day}$$

= 1157.195 KWh/day

Design for PV

25% of the energy will be (0.25 x 1157.195 KWh/day) = 289.29 KWh/day

Estimation of the system energy loss

Assuming 10% loss on the system, System loss= 0.1x 289.29 KWh/day= 28.93 KWh/day

Calculate the total energy demand (E_d)

Total energy demand =loss +energy to be consumed

= 28.93 KWh/day+289.29 KWh/day= 318.22 KWh/day

Select system voltage

Since solar energy with 12V DC system is more available, it is selected

Calculating the required daily system charge requirements

The required daily system charge = $\frac{\text{Total energy demand}}{\text{System voltage}}$ ……………………………….eq. (5.4)

The required daily system charge =$\frac{318.22\ \text{KAVh/day}}{12\text{V}}$=26.5 (kAh)/day

Select the designed solar in-solation value

Solar insolation at the Kedemesa site during the worst month at the optimal tilt angle is

At July is = 3.86kWh/m^2/dfrom above table.

Calculating the system designed charging current

System designed charging current = $\frac{\text{daily system charge requirement}}{\text{designed solar insolation}}$ =$\frac{26.5\ (\text{kAh})}{3.86\ kw\text{h}}$= 6.87 A

Estimating the output of a single PV module

A PV module with the following characteristics is chosen

Peak power module of Brand of Astronergy model of CHSM 6612P module 305-watt

Peak power temperature coefficient (ɤ=0.0038%perdegc.)

Manufacturing power output tolerance ($f_{\text{manf}} = 3\%$)

The average day time ambient temperature is at the Kedemesa site is 28deg.cet, the effective PV cell Temperature is [**30**]

$T_{\text{cell,eff}} = T_{\text{amb,site}}$+25 ……………………………………………………………...eq. (5.5)

$T_{\text{cell,eff}} = T_{\text{amb,site}}$+25=28 +25= 53deg.cel

A MPPT (Maximum Peak Power Tracking) controller will be used; the temperature derating factor is [**32**]

$f_{temp} = 1 - \gamma(T_{cell.eff} - T_{stc})$... eq. (5.6)

Where

T_{stc}= is the temp under standard test conditions (25^0C)

f_{temp}= 1 −0.0038(53 −25)= 0.894

$P_{mod} = P_{stc} \times f_{temp} \times f_{manf} \times f_{dirt}$..eq. (5.7)

Where

P_{mod} = is the de-rated power output of the PV module using A MPPT charge controller (w)

P_{stc} = is the nominal module power under standard test condition (w)

f_{dirt} = is the derating factor for dirt/soiling (for clean = 1.0, for medium = 0.97, for low 0 .98)

$P_{mod} = (305x0.894x0.97x0.97)$ w = 256.55w

Sizing the PV Array

The number of PV module required for the PV array [**33**]

$N=\frac{E_d \times f_o}{p_{mod} \times G \times \eta_{pv,ss}}$...eq. (5.8)

Where

N=the number of PV module required

$p_{mod} =$ is the derated power out put of PV module $= 256.55$w

E_d = is the designed total energy (kwh) = 318.22 KWh/day

$f_o =$ is the assumption of over supply coeffient (pv) $= 1.1$

G = is the worst solar insolation value at the Kedemesa site location = 3.86

$\eta_{pv,ss}$ = is the effeciency of pv subsystem =85%

$$N = \frac{318.22\text{kwh} \times 1.1}{256.55\text{w} \times 3.86 \times 0.85} = 416 \text{ modules}$$

Design the Area Solar Panels

The PV panel of the solar home system must be sized with the annual minimum of daily available PV electric energy. In Kedemesa village, it occurs in month of July (with the value of 3.86) as determined in table above .Hence the required PV panel area will be

$$A_p = \frac{\text{Daily energy demand}}{G} \quad \text{.........eq. (5.9)}$$

Where,

A_p= the required PV panel area

Daily energy demand = 318.22kwh

G= the worst solar insolation value =3.86kWh/m^2

$$A_p = \frac{318.22 \text{ kwh}}{3.86 \text{ kwh}/m^2} = 82.44m^2. \text{ (Say } A_p = 83m^2\text{)}$$

5.2.2. Design of Each Components of Biomass Energy

Design of Cylindrical Fixed Dome Biogas Digester Plant

a) Number of cows in the village in average are = 135

b) The average cow dung discharge is = 8- 10 kg / cow-dung/day

c) Take average cow dung discharge = 10 kg / cow-dung/day

Total discharge for the village is determined

TS_d= 135 × 10 =1350 kg / cow-day

Therefore, the daily biomass input is 1350 kg.

. Total solid content of night soil is, TS = 0.16

Volatile solid content of night soil is, VS = 0.13

The amount of biogas generated each day is calculated on the basis of the specific gas yield of the substrate and the daily substrate input. The estimation can be based on [**16**]

The volatile solids content VS

$G_d = VS \times G_y \text{ (solids)} \left[{m^3}/{day} = \text{kg} \times {m^3}/{(\text{day} \times \text{kg})} \right]$……………………………..eq. (5.10)

The weight of the moist mass

$G_d = W_{\text{biomass}} \times G_y \text{ (moist)} \left[{m^3}/{day} = \text{kg} \times {m^3}/{(\text{day} \times \text{kg})} \right]$……………………………………eq. (5.11)

$G_d = n_{LSU} \times G_y \text{ (species)} \left[{\text{m}^3}/{\text{day}} = \text{number} \times {\text{m}^3}/{(\text{day} \times \text{number})} \right]$…………eq. (5.12)

Where,

G_d = Daily biogas generated

G_y = Specific biogas yield

n_{LSU} = Number of Livestock Unit

So now it wills that a higher degree of sizing certainty can be achieved by comparing and averaging the results.

The volatile solids content VS

$G_d = VS \times G_y \text{ (solids)} \times W_{\text{biomass}} = 1350 \text{ kg.} \times 0.13 \times 0.16 {\text{m}^3}/{\text{day, kg}} = 28.08 {\text{m}^3}/{\text{day}}$

The weight of the moist mass

$G_d = W_{\text{biomass}} \times G_y \text{ (moist)}$

$G_y\text{(moist)} = 10\% = 0.1 {\text{m}^3}/{\text{day, kg}}$ (i.e. cow dung)

$= 1350 \text{ kg} \times 0.1 {\text{m}^3}/{\text{day, kg}} = 135 {\text{m}^3}/{\text{day}}$

Standard gas-yield values per livestock unit LSU

$G_d = n_{LSU} \times G_y$ (species) = $135 \times G_y$ (species)

Take the value for the cow G_y (species) = 0.036

$= 135 \times 0.036\ {m^3}/{day,\ nomberoftotalcow} = 48.6\ {m^3}/{day}$

Averaging the daily biogas yield:

$$G_d = \frac{28.08 + 135 + 48.6}{\mathbf{3}} \left({m^3}/{day} \right) = 70.6\ {m^3}/{day}$$

Sizing Biogas Digester

Digester volume is determined on the basis of the chosen retention time and daily substrate input quantity. The retention time, in turn, is determined by the digesting temperature.

There is 1350kg weight of moist biomass (i.e.$TS_d = 1350kg$)

Dry matter (D_m) of fresh discharge:

$D_m = TS_d \times TS = 1350\ kg/day \times 0.16 = 216\ kg/day$

- To make favorable condition for fermentation the concentration of organic dry matter should be 8% i.e. 8 kg Organic dry matter should be available in 100 kg influent.

8 kg/day = 100 kg/day

216 kg/day = x

X = 2700 kg/day

Water should be added to make the discharge 8% concentration of organic dry matter is:

$m_{water} = 2700 - 1350 = 1350\ kg/day$

Assuming the density of slurry approximately to $1000 kg/m^3$, the volume of daily discharge of substrate is:

$v_s = \frac{m_{slurry}}{\rho_{slurry}} = \frac{2700\ kg}{1000\ kg/m^3} = 2.7\ {m^3}/{day}$

Hence, **volume of digester:**

$v_d = v_s \times RT = 2.7\ \mathrm{m^3/day} \times 60\ \mathrm{day} = 162\ \mathrm{m^3/day}$

Since the biogas will be stored in pressure vessel outside digester, the volume required for digester can be as small as possible. Therefore, the digester volume is:

$v_d = 162\ \mathrm{m^3/day} - 70.6\ m^3/day = 91.4\ \mathrm{m^3}$

Selecting the Type of Fixed Dome Plant

Part of digester below the ground level is subjected to heavy compressive load due to the earth pressure, which increases with depth. In this design due to hydrostatic pressure cylindrical digester was selected.

- ✓ Constructing the digester underground reduces the negative impacts resulted from atmospheric temperature changes,
- ✓ Raw substrate from the cow dung has odour, hence it should be beneath under earth.
- ✓ Availability of construction materials such as: cement, sand, small stones etc. with reasonable prices.
- ✓ It distributes forces uniformly on surface area
- ✓ For the sight fixed dome plant application is well disseminated in Ethiopia.

Inlet and Out let pipe

Size of inlet and outlet pipe is equal to the diameter of the tube that directly connected to the septic tank i.e. (90 – 100mm) by making some stepped angle to make turbulence to avoid scum formation in digester.

Expansion Chamber

Size of expansion chamber is equal to the volume of gasholder in fixed dome biogas plant, but biogas stored in pressure vessel out of digester. However, the design of expansion chamber is in order to avoid over flow of raw substrate (unfermented substrate)

Compost Tank

Compost tank is an integral part of the biogas plant; no plant is complete without it. Enough earth body must exist, at least one meter, between the compost tank and the outlet chamber to avoid cracking of the chamber walls.

Description of technology and design

Where.(1) Inlet chamber with inlet pipe, (2) Digester, (3) Dome (gas storage),(4) Gas outlet, (5) Compensation /expansion chamber with overflow-point described in theFigure14 below.

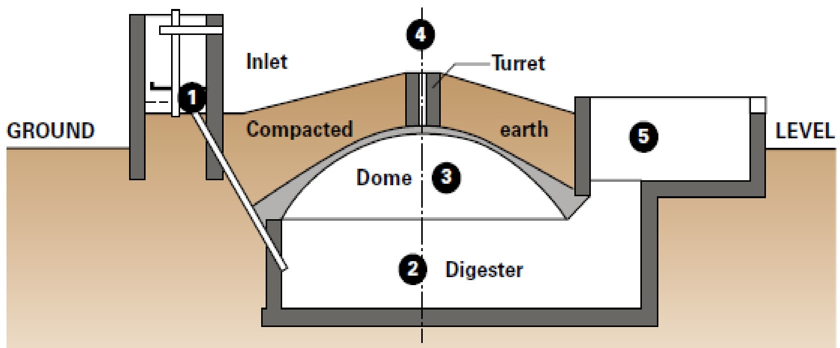


Figure 14 biogas digester models [**32**]

The Design Calculation and Dimension Relationship

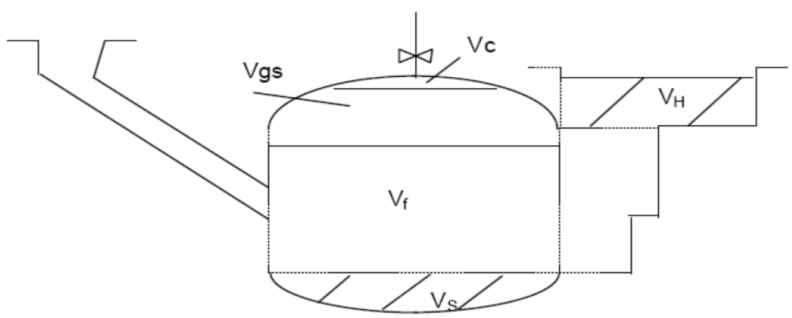


Figure 15 Cross-section of a Digester [**33**]

Where

V_c= Volume of gas collecting chamber

V_{gs}= Volume of gas storage chamber

V_f= Volume of fermentation chamber

V_H= Volume of hydraulic chamber

V_s= Volume of sludge layer

Total volume of digester:

$V = V_c + V_{gs} + V_f + V_s$

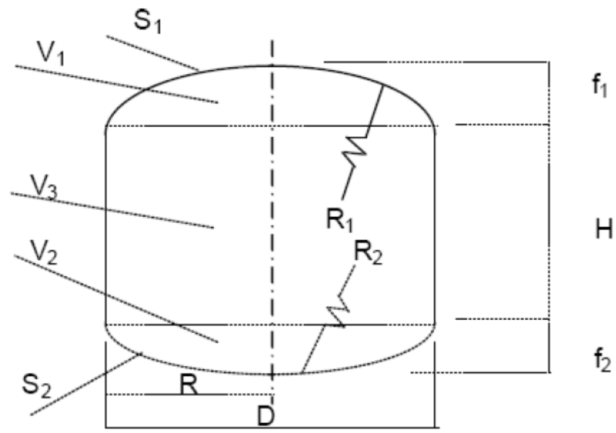


Figure 16 Geometrical dimensions of the cylindrical shaped biogas digester body [**33**]

Where,

V_1= Volume of gasholder

V_2= Volume of sludge layer

V_3 = Volume of fermentation=

S_1= Surface area of top dome

S_2= Surface area of bottom dome

D = Diameter of the cylinder

Table 15 Volume and Geometrical dimensions

Volume	Geometrical dimensions
$V_c \leq 5\%\ V$ $V_s \leq 15\%\ V$ $V_{gs} + V_f = 80\%\ V$ $V_{gs} = V_H$ $V_{gs} = 0.5\ (V_{gs} + V_f + V_s)\ K$ Where K = Gas production rate per m^3 digester volume per day. K= 0.4	$D=1.3078 * V^{1/3}$ $V_1=0.0827* D^3$ $V_2= 0.05011 *D^3$ $V_3= 0.3142 *D^3$ $R_1= 0.725 *D$ $R_2= 1.0625 *D$ $f_1= D/5$ $f_2= D/8$ $S_1 = 0.911\ D^2$ $S_2= 0.8345\ D^2$

The Working Biogas Digester Volume

$W_v=V_{gs} + V_f$ . . ……………………………………………………………………eq. (5.13)

From geometrical assumptions: I have

$V_{gs} + V_f = 80\%\ V$

$V_{gs} + V_f = 91.4\ m^3$

Therefore

$80\%\ V = 91.4\ m^3$

$V = \frac{91.4\ m^3}{0.8} = 114.25\ m^3$

Now the calculation will be

$D=1.3078 * V^{1/3} = 1.3078 * 114.25^{1/3} = 6.4\ m$

$V_1=0.0827* D^3=0.0827* 6.4^3= 21.7\ m^3$

$V_2= 0.05011 *D^3 = 0.05011 *6.4^3= 13.14\ m^3$

$V_3= 0.3142 *D^3= 0.3142 *6.4^3= 82.4\ m^3$

From

V_3= we can calculate the value of 'H'

$V_3 = \frac{\pi D^2 H}{4} = \rightarrow H = \frac{4 \times 82.4}{\pi \times 6.4^2} = 2.5$ m

$R_1 = 0.725 * D = 0.725 * 6.4 = 4.64$ m

$R_2 = 1.0625 * D = 1.0625 * 6.4 = 6.8$

$f_1 = D/5 = \frac{6.4}{5} = 1.3$ m

$f_2 = D/8 = 6.4/8 = 0.8$ m

And also

$V_c \leq 5\%\ V \sim V_c = 5\%\ V$

$V_c = 5\%\ V = 0.05\ V = 0.05 \times 114.25\ m^3 = 5.7\ m^3$

Pressure Developed In the Digester

The pressure of a gas mixture is equal to the sum of the pressure each gas would exert if it existed alone at the mixture temperature & volume. Dalton's law

$P_m = \sum_i^k P_i(T_m, V_m)$……………………………………………………………eq. (5.14)

The partial pressure of a gas is the pressure exerted by a particular component of a mixture of gases. It is given by

$P_i V_i = n_i RT$…………………………………………………………………eq. (5.15)

Where,

P_i = Pressure developed by each gas of mixture

V_i = Volume of particular component of gas

T = Temperature of mixture in Kelvin

R =Ideal gas constant n = number of moles of component

Based on the maximum volume of biogas produced per a day it is possible to find the maximum gas pressure developed in the digester dome. $70.6\ \mathrm{m}^3$ Biogas can be produced per a day.

- Based on their composition, it is possible to find particular volume & molar number of biogas.

Table16 Composition of biogas [**33**]

Substance	Symbol	Percentage (%)
Methane	CH_4	50-70
Carbon Dioxide	CO_2	30-40
Hydrogen	H_2	5-10
Nitrogen	N_2	1-2
Water Vapor	H_2O	0.3
Hydrogen Sulphide	H_2S	Traces

- According to their composition the volume of each gas in the mixture can be determined.

The Volume Calculation Composition For Biogas Digester Plant

The volume of methane:

$V_{CH_4} = \%\ CH_4 \times G_d = 0.6 \times 70.6\ \mathrm{m}^3/day = 42.4\ \mathrm{m}^3/day$

The volume of Carbon dioxide:

$V_{CO_2} = \%\ CO_2 \times G_d = 0.35 \times 70.6\ \mathrm{m}^3/day = 24.7\mathrm{m}^3/day$

The volume of Hydrogen

$V_{H_2} = \%H_2 \times G_d = 0.05 \times 70.6\ \mathrm{m}^3/day = 3.53\ \mathrm{m}^3/day$

The volume of Nitrogen

$V_{N_2} = \%N_2 \times G_d = 0.01 \times 70.6\ \mathrm{m}^3/day = 0.71\ \mathrm{m}^3/day$

The volume of Water Vapor

$V_{H_2O} = \%\ H_2O \times G_d = 0.003 \times 70.6\ \mathrm{m}^3/day = 0.21\ \mathrm{m}^3/day$

The volume of Hydrogen Sulphide

$V_{H_2S} = \%\ H_2S \times G_d = 0.01 \times 70.6\ \mathrm{m}^3/day = 0.71\ \mathrm{m}^3/day$

The mass calculation of Composition of biogas

Each biogas components density is given by in the appendix

- Mass of **methane** from above will be

$\mathrm{Density}_{CH_4} = \frac{m_{CH_4}}{V_{CH_4}}$

$$m_{CH_4} = \mathrm{Density}_{CH_4} \times V_{CH_4} = 0.67 \frac{kg}{m^3} \times 42.4 \ m^3/day = 28.41 \ kg/day$$

- Mass of **Carbon Dioxide** from above will be

$\mathrm{Density}_{CO_2} = \frac{m_{CO_2}}{V_{CO_2}}$

$$m_{CO_2} = \mathrm{Density}_{CO_2} \times V_{CO_2} = 1.84 \frac{kg}{m^3} \times 24.7 m^3/day = 45.45 \ kg/day$$

- Mass of volume of **Water Vapor** from above will be

$\mathrm{Density}_{H_2O} = \frac{m_{H_2O}}{V_{H_2O}}$

$$m_{H_2O} = \mathrm{Density}_{H_2O} \times V_{H_2O} = 0.8 \frac{kg}{m^3} \times 0.21 \ m^3/day = 0.168 \ kg/day$$

- Mass of **Hydrogen Sulphide** from above will be

$\mathrm{Density}_{H_2S} = \frac{m_{H_2S}}{V_{H_2S}}$

$$m_{H_2S} = \mathrm{Density}_{H_2S} \times V_{H_2S} = 1.4 \frac{kg}{m^3} \times 0.71 \, m^3/day = 0.994 \ kg/day$$

- Mass of **Hydrogen** from above will be

$\mathrm{Density}_{H_2} = \frac{m_{H_2}}{V_{H_2}}$

$$m_{H_2} = Density_{H_2} \times V_{H_2} = 0.0898 \frac{kg}{m^3} \times 3.53\, m^3/day = 0.32\ kg/day$$

- Mass of **Nitrogen** from above will be

$Density_{N_2} = \frac{m_{N_2}}{V_{N_2}}$

$$m_{N_2} = Density_{N_2} \times V_{N_2} = 1.251 \frac{kg}{m^3} \times 0.71\, m^3/day = 0.889\ kg/day$$

The number of mole calculation of Composition of biogas

Mole = $\frac{mass}{Molecularweight}$

- **The number of mole calculation for methane**

$$n_{CH_4} = \frac{m_{CH_4}}{M_{CH_4}}$$

Where

n_{CH_4} = The number of mole for methane

m_{CH_4}= the mass of for methane

M_{CH_4} = the Molecularweight of for methane

$$n_{CH_4} = \frac{m_{CH_4}}{M_{CH_4}} = \frac{28.41\ kg/day}{16.04\ g/mol} \times \left(\frac{1000g}{1kg}\right) = 1771.2\, mol/day$$

- **The number of mole calculation for Carbon Dioxide**

$$n_{CO_2} = \frac{m_{CO_2}}{M_{CO_2}}$$

Where

n_{CO_2} = The number of mole for Carbon Dioxide

m_{CO_2}= the mass of for Carbon Dioxide

M_{CO_2} = the Molecularweight of for Carbon Dioxide

$$n_{CO_2} = \frac{m_{CO_2}}{M_{CO_2}} = \frac{45.45\ kg/day}{44\ g/mol} \times \left(\frac{1000g}{1kg}\right) = 1032.95\ mol/day$$

- **The number of mole calculation for Water Vapor**

$$n_{H_2O} = \frac{m_{H_2O}}{M_{H_2O}}$$

Where

n_{H_2O} = The number of mole for Water Vapor

m_{H_2O}= the mass of for Water Vapor

M_{H_2O} = the Molecularweight of for Water Vapor

$$n_{H_2O} = \frac{m_{H_2O}}{M_{H_2O}} = \frac{0.168 \ \text{kg}/day}{18.02 \ \text{g/mol}} \times \left(\frac{1000\text{g}}{1\text{kg}}\right) = 9.32 \ \text{mol}/day$$

- **The number of mole calculation for Hydrogen Sulphide**

$$n_{H_2S} = \frac{m_{H_2S}}{M_{H_2S}}$$

Where

n_{H_2S} = The number of mole for Hydrogen Sulphide

m_{H_2S}= the mass of for Hydrogen Sulphide

M_{H_2S} = the Molecularweight of for Hydrogen Sulphide

$$n_{H_2S} = \frac{m_{H_2S}}{M_{H_2S}} = \frac{0.994 \ \text{kg}/day}{34 \ \text{g/mol}} \times \left(\frac{1000\text{g}}{1\text{kg}}\right) = 29.24 \ \text{mol}/day$$

- **The number of mole calculation for Hydrogen**

$$n_{H_2} = \frac{m_{H_2}}{M_{H_2}}$$

Where

n_{H_2} = The number of mole for Hydrogen

m_{H_2}= the mass of for Hydrogen

M_{H_2} = the Molecularweight of for Hydrogen

$$n_{H_2} = \frac{m_{H_2}}{M_{H_2}} = \frac{0.32 \ \text{kg}/day}{2.02 \ \text{g/mol}} \times \left(\frac{1000\text{g}}{1\text{kg}}\right) = 158.4 \ \text{mol}/day$$

- **The number of mole calculation for Nitrogen**

$$n_{N_2} = \frac{m_{N_2}}{M_{N_2}}$$

Where

n_{N_2} = The number of mole for Nitrogen

m_{N_2}= the mass of for Nitrogen

M_{N_2} = the Molecularweight of for Nitrogen

$$n_{N_2} = \frac{m_{N_2}}{M_{N_2}} \frac{= 0.889\,\text{kg}\,/day}{28.02\ \text{g/mol}} \times \left(\frac{1000\text{g}}{1\text{kg}}\right) = 31.73\ \text{mol}\,/day$$

The biogas saturates with water vapor and now the total pressure inside the digester is the sum of two pressures the dry gases and the water vapor.

Table 17 Water vapor pressure at specific temperature [**35**]

Temp (℃)	**Vapor Pressure (mmHg)**	**Temp (℃)**	**Vapor Pressure (mmHg)**
-10	2.15	40	55.3
0	4.58	60	149.4
5	6.54	80	355.1
10	9.21	95	634
11	9.84	96	658
12	10.52	97	682
13	11.23	98	707
14	11.99	99	733
15	12.79	100	760
20	17.54	101	788
25	23.76	110	1074.6
30	31.8	120	1489
37	47.07	200	11659

Partial Pressure for Each Gas in Biogas Digester Plant

If the number of particles in moles is given or desired, use the most common form of the ideal gas equation. [**36**]

PV = nRT…………………………………………………………………………eq. (5.16)

Where P = for pressure, V = for volume, R = the universal gas constant $\left(\mathbf{i.e.}\, R = \frac{8.31\ L.kPa}{K.mol}\right)$

T = for temperature and n=for moles

The partial pressure of a methane gas:

Take the value of T=33℃ = 306K

V = $70.6\ m^3/day$

$n_{CH_4} = 1771.2\ mol\ /day$

$$P_{CH_4} = \frac{n_{CH_4} R\, T_{system}}{V_{system}}$$

$$P_{CH_4} = \frac{1771.2 mol\ /day \times \frac{8.31\ L.kPa}{K.mol} \times 306K}{70.6\ m^3/day \times} \times \left(\frac{1\ m^3}{1000\ L}\right) = 63.8\ kPa$$

But $1\ m^3 = 1000\ L$

The partial pressure of a carbon dioxides gas:

Take the value of T=33℃ = 306K

V = $70.6\ m^3/day$

$n_{CO_2} = 1032.95\ mol\ /day$

$$P_{CO_2} = \frac{n_{CO_2} R\, T_{system}}{V_{system}}$$

$$P_{CO_2} = \frac{1032.95\ mol\ /day \times \frac{8.31\ L.kPa}{K.mol} \times 306K}{70.6\ m^3/day \times} \times \left(\frac{1\ m^3}{1000\ L}\right) = 37.2\ kPa$$

The partial pressure of a water vapor gas:

Take the value of T=33℃ = 306K

V = $70.6\ m^3/day$

$n_{H_2O} = 9.32\ mol\ /day$

$$P_{H_2O} = \frac{n_{H_2O} R\, T_{system}}{V_{system}}$$

$$P_{H_2O} = \frac{9.32 \text{ mol}/day \times \frac{8.31 \text{ L.kPa}}{\text{K.mol}} \times 306\text{K}}{70.6 \text{ m}^3/day \times} \times \left(\frac{1 \text{ m}^3}{1000 \text{ L}}\right) = 0.336 \text{ kPa}$$

<u>The partial pressure of a hydrogen sulphide gas:</u>

Take the value of T=33℃ = 306K

And at V = $70.6 \text{ m}^3/day$

$n_{H_2S} = 29.24 \text{ mol}/day$

$$P_{H_2S} = \frac{n_{H_2S} R\, T_{system}}{V_{system}}$$

$$P_{H_2S} = \frac{29.24 \text{ mol}/day \times \frac{8.31 \text{ L.kPa}}{\text{K.mol}} \times 306\text{K}}{70.6 \text{ m}^3/day \times} \times \left(\frac{1 \text{ m}^3}{1000 \text{ L}}\right) = 1.05 \text{ kPa}$$

<u>The partial pressure of a hydrogen gas:</u>

Take the value of T=33℃ = 306K

And at V = $70.6 \text{ m}^3/day$

$n_{H_2} = 158.4 \text{ mol}/day$

$$P_{H_2} = \frac{n_{H_2} R\, T_{system}}{V_{system}}$$

$$P_{H_2} = \frac{158.4 \text{ mol}/day \times \frac{8.31 \text{ L.kPa}}{\text{K.mol}} \times 306\text{K}}{70.6 \text{ m}^3/day \times} \times \left(\frac{1 \text{ m}^3}{1000 \text{ L}}\right) = 5.53 \text{ kPa}$$

<u>The partial pressure of a nitrogen gas:</u>

Take the value of T=33℃ = 306K

And at V = $70.6 \text{ m}^3/day$

$n_{N_2} = 31.73 \text{ mol}/day$

$$P_{N_2} = \frac{n_{N_2} R\, T_{system}}{V_{system}}$$

$$P_{N_2} = \frac{31.73 \quad mol\ /day \times \frac{8.31\ L.kPa}{K.mol} \times 306K}{70.6\ m^3/day \times} \times \left(\frac{1\ m^3}{1000\ L}\right) = 1.14\ \ kPa$$

- The biogas saturates with water vapor and now the total pressure inside the digester is the sum of two pressures the dry gases and the water vapor.

<u>At 33℃ temperatures, I can obtain by interpolation:</u>

At $T_1 = 30$ ℃ , P_1 = 31.8mmHg

At $T_2 = 37$℃ , P_2= 47.07mmHg

ΔT = 7℃, Δp = 15.27mmHg

ΔT= 3℃, Δp =x = 6.54mmHg

1 mmHg = 133.3 Pa

<u>At 33℃temperature,</u>

$P_{H_2O} = 31.8 + 6.54 = 38.34$mmHg= 5.11 kPa

<u>Total pressured developed in gasholder (P_{total})</u>

$$P_{total} = P_{CH_4} + P_{CO_2} + P_{H_2O} + P_{H_2S} + P_{N_2} + P_{H_2}$$

$$P_{total} = 63.8\ kPa + 37.2 kPa + 5.11\ kPa + 1.05\ \ kPa + 1.14\ \ kPa + 5.53\ \ kPa$$

$$P_{total} = 113.83\ kPa$$

Pressure Drop inside the Gas Pipes

The pressure system of the gas must be controlled whenever designed gas distribution system. Biogas is available at a gauge pressure of about 981pascal in conventional biogas plants and for efficient use in burners and lamps it should be available at the point of use at a pressure of not less than 785-981pascal. Due to friction effect when gas flows through pipe there is loss. So properly designed pipe line is one which does not cause pressure drop of more than 196-294pascal under any circumstances. For determining the proper size of the pipe line, the gas is considered as incompressible fluid during the flow its density changes to a very small extent.

Q =VA ……………………………………………………………………………eq. (5.17)

Where,

Q = Discharge (m^3/s)

V = Gas velocity (m/s)

A = Cross sectional area (m^2)

Pressure drop of the gas is computed using Bernoulli's equation

$$\frac{P}{\rho g} + \frac{v^2}{2g} + Z = \text{constant} \quad \text{eq. (5.18)}$$

Where,

P= Biogas pressure (N/m^2),

ρ = Biogas density (kg/m^3),

V = Biogas velocity (m/s),

g = Acceleration due to gravity ($9.81m/s^2$)) and

z = Head (m)

Bernoulli's theorem essentially states that for an ideal gas flow, the potential energy due to the pressure, plus the kinetic energy due to the velocity of the flow is constant. In practice, with gas flowing through a pipe, Bernoulli's theorem must be modified. An extra term must be added to allow for energy loss due to friction in the pipe:

$$\frac{P}{\rho g} + \frac{v^2}{2g} + Z + h_f = \text{constant} \quad \text{eq. (5.19)}$$

Where,

h_f= head loss due to friction

Head Loss in Biogas Plant

The head loss in a pipe circuit falls into two categories:

a) That due to viscous resistance extending throughout the total length of the circuit

b) That due to localized affects such as valves, sudden changes in area of flow and bends. The overall head loss is a combination of both these categories.

Head loss in straight pipes

The head loss due to friction in pipes may be obtained by using the Darcy-Weisbach's equation

$h_f = \frac{fLv^2}{2gd}$……………………………………………………………………………..eq. (5.20)

Where,

h_f= head loss due to friction

f= Friction factor depending upon the surface of the pipe (dimensionless)

L = Length of the pipe in meters

V = Velocity of gas

d= Diameter of pipe

- Friction factor for pipe: The value of friction, for smooth pipes, may be obtained by using the following expression:

i. For laminar flow ($R_e < 2300$)

$f = \frac{64}{R_e}$……………………………………………………………………eq. (5.21)

ii. For turbulent flow ($R_e > 2300$)

$f = \frac{0.3164}{{R_e}^{0.25}}$…………………………………………………………………………eq. (5.22)

Where,

$$R_e = \frac{VD}{\gamma}$$

V = Velocity of gas

D = Diameter of pipe

γ = kinematic viscosity

- At p = 1.013bar, and T = 300K Assuming the biogas kinematic viscosity equal to air

$\gamma = 1.568\times 10^{-5}\ m^2/s$

<u>From continuity equation</u>

Q =AV …………………………………………………………………………eq. (5.23)

Assume Eight hours usage time, discharge is

$Q = \frac{V_{digester}}{\text{time (hour)}}$

$Q = \frac{70.6\ 70.6\ m^3/day}{8\ hour} = 8.83\ m^3/hour$

Area of the pipe will be

Assume, d= 3.54 cm = 0.0354m

$A = \frac{\pi d^2}{4} = \frac{\pi (0.0354\text{m})^2}{4} = 0.000984\text{m}^2 = 9.84\times 10^{-4}\text{m}^2$

Therefore,

$Q = AV \rightarrow V = \frac{Q}{A}$

$V = \frac{8.83\ \text{m}^3/\text{hour}}{9.84\times10^{-4}\text{m}^2}\left(\frac{1\text{hour}}{3600\ \text{sec.}}\right) = 2.49\ m/s$

Therefore,

$$R_e = \frac{VD}{\gamma} = \frac{2.49\ \text{m/s}\times0.0354\text{m}}{1.568\times10^{-5}\text{m}^2/\text{s}} = 5621.56$$

So that

$R_e \geq 2300$, Implies turbulent flow

$f = \frac{0.3164}{{R_e}^{0.25}} = \frac{0.3164}{5621.56^{0.25}} = 0.037$

Where,

L = 15m

$h_f = \frac{fLv^2}{2gd} = \frac{0.037\times15\text{m}\times(2.49\ m/s)^2}{2\times9.81\frac{m}{s^2}\times0.0354\text{m}} = 4.95\text{m}$ (say h_f= 5 m)

Head loss due to Bends

The head loss due to a bend is given by expression

$h_{m,b} = \frac{K_b V^2}{2g} \times n_{elbow}$……………………………………………………………...eq. (5.24)

Where,

$h_{m,b}$= minor loss due to bending of pipe

K_b= a dimensionless coefficient which depends on the bend radius/pipe radius ratio and the angle of the bend.

K_b= 0.5 for elbow connection and considering the average number elbow 20.

V = velocity of the pipe (i.e.V =2.49 m/s)

n_{elbow} = The average number elbow = 20.

$h_{m,b} = \frac{0.5 \times (2.49\, m/s)^2}{2 \times 9.81 \frac{m}{s^2}} \times 20 = 3.16$ m

Head loss due to Valves

The head loss due to a valve is given by expression

$h_{m,v} = \frac{K_v V^2}{2g} \times n_{valve}$……………………………………………………………eq. (5.25)

$h_{m,v}$= Minor loss due to valve

K_v= Loss coefficient depends upon the type of valve and degrees of opening

n_{valve} = average number of valves = 30

Table 18 Typical valves of loss coefficients for gate and globe valves [**37**]

Valve type	K_v
Globe valve, fully open	10
Gate valve, fully open	0.2
Gate valve, half open	5.6

- For gate value, fully open K_v= 0.2 average number of valves = 30

  $h_{m,v} = \frac{0.2 \times (2.49\, m/s)^2}{2 \times 9.81 \frac{m}{s^2}} \times 30 = 1.896$ m

Head loss Due to Sudden Changes in Area of Flow

1. **Sudden Expansion:** The head loss at a sudden expansion is given by:

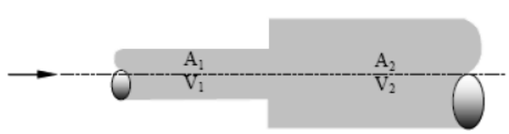


Figure 17 sudden Expansion [**38**]

$h_{m,e} = \frac{v_1{}^2 - v_2{}^2}{2g}$……………………………………………………………………...eq. (5.26)

Where,

$h_{m,e}$= minor loss due to expansion=

v_1=Velocity at cross sectional area 1

v_2=Velocity at cross sectional area 2

g = gravity (i.e. g=9.81$\frac{m}{s^2}$)

In this design there is no sudden expansion of pipe. Since the main gas pipe is divided in to the appliance gas pipe.

2. **Sudden contraction** - The head loss at a sudden contraction is given by

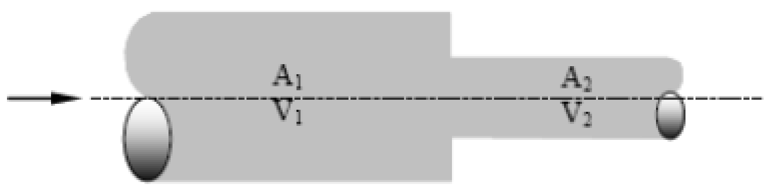


Figure 18 sudden contractions [**38**]

$h_{m,c}$= $\frac{KV_2{}^2}{2g}$

Where,

$h_{m,c}$ = minor loss due to sudden expansions

K= loss coefficient

Table19 Loss Coefficient for Sudden Contractions [**38**]

$\frac{A_2}{A_1}$	0	0.1	0.2	0.3	0.4	0.6	0,8	1.10
K	0.50	0.46	0.41	0.36	0.30	0.18	0.06	0

From continuity equation:

A_1V_1=A_2V_2 ……………………………………………………………………eq. (5.27)

$A_1 = \frac{\pi D_1^2}{4}$

$A_2 = \frac{\pi D_2^2}{4}$

Now the diameter will be

$D_1 = 0.0354$ m

$D_2 = 0.0177$ m

$V_1 = 2.49\ m/s$

$$\frac{\pi D_1^2}{4} \times V_1 = \frac{\pi D_2^2}{4} V_2$$

$$\frac{\pi \times (0.0354\ \text{m})^2}{4} \times 2.49\ m/s = \frac{\pi \times (0.0177\ \text{m})^2}{4} V_2$$

$V_2 = 9.96$ m/s

But

$$A_1 = \frac{\pi \times (0.0354\ \text{m})^2}{4} = 9.84 \times 10^{-4} m^2$$

$$A_2 = \frac{\pi \times (0.0177\ \text{m})^2}{4} = 2.46 \times 10^{-4} m^2$$

The ratio of

$$\frac{A_2}{A_1} = \frac{2.46 \times 10^{-4} m^2}{9.84 \times 10^{-4} m^2} = 0.25$$

So that the value of K will be find by interpolating the value of area ratio

At $\frac{A_2}{A_1} = 0.3$, the value of K= 0.36

At $\frac{A_2}{A_1} = 0.05$, the value of K= X = 0.06

At $\frac{A_2}{A_1} = 0.25$ = the value of K is

K= 0.36−0.06= 0.3

$$h_{m,c} = \frac{0.3(9.96\ \text{m/s})^2}{2 \times 9.81 \frac{m}{s^2}} = 1.52\ \text{m}$$

Total head loss ($h_{f,total}$)

$$h_{f,total} = h_{m,c} + h_{m,v} + h_{m,b} + h_f$$

$$h_{f,total} = 1.52\ m + 1.896\ m + 3.16\ m + 5\ m = 11.58\ m$$

- **Total pressure loss in pipes**

$$p_{f,total} = \frac{\rho f L V^2}{2d} = \rho g h_{f,total} \quad \text{eq. (5.28)}$$

$$p_{f,total} = \rho g h_{f,total}$$

Take the density of substances in the straight pipes

$$\rho = 1.23\ kg/m^3$$

$$p_{f,total} = 1.23\ kg/m^3 \times 9.81 \frac{m}{s^2} \times 11.58\ m = 0.1397\ kPa$$

Compression of Biogas Digester Plant

Compressing biogas reduces storage requirements, concentrates energy content, and increases pressure to the level needed to overcome resistance to gas flow. Sometimes the production pressure of a biogas source does not match the pressure requirements of the gas utilization equipment. Compression can eliminate the mismatch and assurance the efficient operation of the equipment. Moreover, large biogas systems rely on compression to reduce the size of the gas storage facility or to transport the biogas to a pipeline. The choice of either a blower or compressor depends on the amount of pressure increase needed [**39**]

Parameters for Selection of Compressor

In order to determine what type of compressor system is needed to accomplish the job, a variety of detailed data is needed to be discerned. As a minimum, a precise understanding of the following data is required:

- ✓ Gas being handled
- ✓ Flow rate
- ✓ Suction and discharge pressure
- ✓ Site elevation (or local barometric pressure)
- ✓ Suction temperature

- ✓ Capacity

Capacity: To size a compressor the capacity must be stated as the volume of gas flow at the compressor's suction condition. This volume is normally referred to as inlet cubic meters per hour (Nm^3/hr).

Calculating Compression ratio [**40**]

Compression ratio (R) is the ratio of discharge pressure to suction pressure:

$R = \frac{P_d}{P_s}$(Remember P_d&$P_s$must be absolute values)…………………………………eq. (5.29)

- ✓ A single stage compressor has only a single R value.
- ✓ A two stage compressor has three R values.

R = Total compression ratio for the compressor

R_1= Compression ratio for the first stage

R_2= Compression ratio for the second stage

$R = \frac{P_d}{P_s}$,$R_1 = \frac{P_i}{P_s}$ and $R_2 = \frac{P_d}{P_i}$

Where,

P_s= Suction pressure

P_d=Discharge pressure

P_i= Inter stage pressure- the pressure between $1^{st}$and 2^{nd} stage of the compressor.

Choosing one stage or two stage Compressor

The choice of the proper number of compression stages is largely based on the compression ratio. Here are some guidelines for choosing the proper number of stages:

Table 20 Compression ratio vs. Proper number of Stages [**41**]

R- value	No. of stage
1-3	Single stage
3-5	Single stage, occasionally two stage
5-7	Two stage, occasionally single stage
7-10	Two stage
10-15	Usually two stage, occasionally three stage
15+	Three stage

In this work, the Compressor fulfills the following criteria might be selected form catalogue for compression purpose.

- ✓ The gas being handled is biogas
- ✓ Flow rate = 162$\mathrm{m^3}/\mathrm{hr}$for compressor selected from catalogue
- ✓ Suction pressure: The pressure at the compressor inlet expressed (Total pressured developed in gasholder)

  P_s=113.83 kPa = 1.1383 bar
- ✓ Discharge pressure: The pressure at the compressor discharge expressed

  P_d= 11 bar
- ✓ Suction temperature =33℃

For selection of Compressor Cylinder material

Table 21 Compressor Specification [**41**]

BV8900										
Model	Code	Pump	Tank Lt.	Air displace l/min	Power		Max press.		Size mm	Weight kg
					HP	kW	bar	Psi		
BV800/1000 FT15	7PV9X5*	BV8900	1000	2016	15	11	11	160	2430x930x1770	584

Discharge pressure: The pressure at the compressor discharge expressed

P_d= 11 bar

So, now

$P_s = P_{\mathrm{total\ ,partial\ pressure\ of\ biogas}} + P_{\mathrm{atmospheric\ pressure}}$

P_s=1.1383 bar + 1.013bar =2.1513 bar-a

Discharge pressure: The pressure at the compressor discharge expressed

P_d= 11 bar

It also

$P_d = P_{\text{The pressure at the compressor discharge}} + P_{\text{atmospheric pressure}}$

$P_d = 11 \text{ bar} + 1.013\text{bar} = 12.013$ bar-a

Therefore,

$R = \frac{P_d}{P_s} = \frac{12.013 \text{ bar}-a}{2.1513 \text{ bar}-a} = 5.58$

At R =5.58, the best save chosen will be the two stage compressor is suited

Energy Density and Storage Volume of Plant

As biogas is compressed to higher pressures, its mass is pushed into smaller volume. This raises the energy density of the gas and reduces the required storage volume. Note that the energy densities are much higher for biogas that has the H_2S, CO_2 and water vapor removed (100% methane). The higher compression ratio, the costs associated with compressing biogas will increase. For adiabatic compression, with no heat transfer across the system boundary (Q = 0), the thermodynamic relation is given by [**42**]

$$P_1 V_1{}^K = P_2 V_2{}^K \quad \text{......eq. (5.30)}$$

Where,

k = Adiabatic ratio k= C_P/C_V= 1.3 for biogas

V_1 = Initial volume of biogas that the plant produces per day.

P_2 = Compressed raw biogas pressure (11bar) selected from catalogue

V_2 = Compressed volume

P_1 = total , partial pressure of biogas

Substituting the values

V_1 = 70.6 m^3/day

P_2 =11 bar = 1100kpa

P_1 = 1.1383 bar = 113.83 kPa

$P_1 V_1{}^K = P_2 V_2{}^K$

$$\frac{P_1}{P_2} = \frac{{V_2}^K}{{V_1}^K} = \left(\frac{V_2}{V_1}\right)^k$$

$$\frac{V_2}{V_1} = \sqrt[k]{\frac{P_1}{P_2}} \leftrightarrow V_2 = V_1 \times \sqrt[k]{\frac{P_1}{P_2}}$$

$$V_2 = V_1 \times \sqrt[k]{\frac{P_1}{P_2}} = 70.6\ m^3/day \times \sqrt[1.3]{\frac{113.83\ kPa}{1100kpa}} = 12.33\ m^3/day$$

Therefore, to ensure steady supply of compressed raw biogas to the households, it is first stored in a pressure vessel which has storage capacity of 12 m^3 since other volume is stored in compressor.

Choice of Engine for Fixed Dome Biogas Plant

An engine is mainly specified by its type and by its maximum (rated) power at its maximum speed (e.g. "Otto engine, 45 kW at 5200 1/min or rpm"). What this means is that it may well be operated at lower speeds and power output but not above the maximum data given. An operation at lower power and speed than the maximum will often be found more economic in terms of fuel consumption and engine life. When considering the purchase of an engine one should not confuse the maximum or rated performance as given in the technical specification of an engine with the optimum performance in economic terms. The engine's performance curves, i.e. power, torque and specific fuel consumption vs. speed, are much more useful in determining the point of operation and selecting an engine that will meet the driven machine's requirements while it operates at a high efficiency. The determination of the main operational parameters of an engine, i.e. range of power and speed, is largely a function of the requirements of the driven machine. The choice of engine type, however, follows the availability, the market situation (price) for fuel, spares and service and some other operational parameters like the required type of control, fuel availability, etc. [**43**]

Composition of biogas

CH_4 = 60% Vol, .i.e. V_{CH4} /$V_{tot.}$ = 0.6

CO_2 = 40% Vol, i.e. V_{CO_2}/$V_{tot.}$ = 0.4

Traces of other components negligible

- temperature: T = 298 K (= 25 °C)
- pressure, ambient: Pa = 950 mbar
- pressure in biogas plant: P_p = 20 mbar, gauge

Step 1: total pressure of biogas, P_T

P_T = 950 + 20 = 970 mbar 0.97×10^5 Pa

If humidity of biogas was not considered in the gas analysis so far, the value has to be corrected using the diagram.

Step 2: density ρ of CH_4 in mixture at actual pressure p and temperature T, calculated on the basis of the table values at standard conditions

Temperature correction:

$$\rho_2 = \rho_1 \times \frac{T_1}{T_2} \quad \text{eq. (5.31)}$$

Pressure correction

$$\rho_2 = \rho_1 \times \frac{P_2}{P_1} \quad \text{eq. (5.32)}$$

$$\rho_{CH_4,act.} = \rho_{CH_4,std} \times \frac{P_{act.}}{P_{std.}} \times \frac{T_{std.}}{T_{act.}} \quad \text{eq. (5.33)}$$

$$\rho_{CH_4,act.} = 0.72\,\text{kg/m}^3 \times \frac{970\ \text{mbar}}{1013\ \text{mbar}} \times \frac{273\ \text{K}}{298\ \text{K}} = 0.63\text{kg/m}^3$$

Step 3: actual calorific value of given biogas [**44**]

$$H_{u,act.} = \rho_{CH_4,act.} \times \frac{V_{CH_4}}{V_{tot..}} \times H_{u,n.}$$

$$H_{u,act.} = 0.63\,\text{kg/m}^3 \times 0.6 \times 50\,000\ \text{kJ/kg} = 18900\ \text{kJ/m}^3$$

Biogas emerging from the plant is usually fully saturated with water vapor, i.e. has a relative humidity of 100%. Depending on the course of the gas piping between plant and consumer, part of the water vapor will condense when the gas is cooled. The humidity can be reduced by cooling and warming again of the gas with a drain trap for the condensate at the cooler.

The gas analysis often either does not consider the humidity or it is done at the plant, not at the consumer. In those cases the humidity needs to be considered for the establishment of the calorific value. This can be done by subtraction of the partial pressure p' of the water vapor from the total gas pressureP_t. The remainder is the corrected pressure value pc to be considered in the above calculations of the calorific value.

$P_c = P_t - p'$ ………………………………………………………………eq. (5.34)

The partial pressure of water vapour itself is a function of the gas temperature and the relative humidity as given below.

<u>Manufacturer's engine specification:</u>

- power rating P = 20 kW
- fuel consumption at rated power f_c = 10 m³ n/h
- biogas used 70% CH_4, 30% CO_2

Specification of biogas

$H_{u,act.} = 18\,900\ kJ/m^3$

- ✓ Calorific value of biogas used in specification of manufacturer:

$H_{u,n.} = 2500\ kJ/m^3$n (at standard conditions)

- ✓ Energy consumption (flow) of the engine at rated power

$\dot{E} = f_c \times H_{u,n.}$..eq. (5.35)

$= 10\ m^3\ n/h \times 25000\ kJ/m^3 n$

$=250000\ kJ/hr$

- ✓ Actual biogas consumption(The volumetric fuel consumption or supply) f_c of engine at rated power

$$f_c = \frac{\dot{E}}{H_{u,act.}} = \frac{250000\ kJ/hr}{18900 kJ/m^3}$$

$$f_c = 13.23\ m^3/hr$$

Stoichiometric air/fuel ratio

On a mass basis at which the combustion of CH_4 with air is complete but without unutilized excess air

$$\frac{m_{CH_4}}{m_{air}} = \frac{1\ kgCH_4}{14.5\ kg\ air}$$

$$\frac{m_{CH_4}}{m_{air}} = 0.0689$$

Properties of Biogas as Fuel for Internal Combustion Engine

Biogas is the product of fermentation of man and animals' biological activity waste products when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Since biogas is a mixture of methane (also known as marsh gas or natural gas) and carbon dioxide it is a renewable fuel produced from waste treatment

Biogas contains 50% to 70% of CH_4, 2 % of H_2 and up to 30 % ofCO_2. After being cleaned of carbon dioxide, this gas becomes a fairly homogeneous fuel containing up to 80 % of methane with the calorific capacity of over $25MJ/m^3$. The most important component of biogas, from the calorific point of view, is methane, CH_4. The other components are not involved in combustion process, and rather absorb energy from combustion of CH_4, as they leave the process at higher temperature than the one they had before the process. Requirements to remove gaseous components depending on the biogas utilization are table below [**44**]

- H_2S Content should be at 0.15 Vol % (1500 ppm), but never more than 0.5 Vol % (5000 ppm)
  - Calorific value of biogas by methane content 100% CH_4: Hu = 36 000 kJ/m³ n = 10 kWh/m³n each 10% of CH_4 content in biogas: Hu = 3600 kJ/m³ n = 1 kWh/m³ n
- 65 % CH_4: Hu = 23 400 kJ/m³n = 6.5 kWh/m³n

<u>Thermodynamic properties of CH_4 at 273 K and 101325 Pa are:</u>

- specific treat c_p= 2,165 kJ/kgK
- molar mass M = 16,04 kg/kmol
- density ρ = 0.72 kg/m^3
- individual gas constant R = 0,518 kJ/kgK
- lower calorific value H_u= 50000 kJ/kg, $H_{u,n}$= 36000 kJ/ m^3n

The actual calorific value of biogas is function of the CH_4 percentage, the temperature and the absolute pressure, all of which differ from case to case. The actual calorific value of biogas is a vital parameter for the performance of an engine, and can be calculated by using the following equation. [**45**]

$$H_{u,,act} = \frac{V_{CH_4}}{V_{total}} \times \rho_{CH_4,act.} \times H_{u,n} \quad \text{eq. (5.36)}$$

V_{CH_4}= 42.4 m^3

$V_{total} = 70.6 m^3$

$\rho_{CH_4,act.}$ =0.72 kg/m^3

H_u= 50000 KJ/kg

$$H_{u,,act} = \frac{42.4\ m^3}{70.6m^3} \times 0.72\ kg/m^3 \times 50000KJ/kg$$

$H_{u,,act}$ =21620.4 KJ/m^3

The fuel consumption of IC engine using biogas is often specified in m^3n/h or m^3n/kWh. The standard cubic meter (m^3n) means a volume of 1 cubic meter of gas under standard conditions (273 K and 10132 Pa). The consumption of biogas in actual volume will differ from these data according to the actual conditions of biogas fed to the engine in terms of temperature, pressure and CH_4 content. Determining of actual biogas consumption is vital for dimensioning the engine. Technical parameters of biogas are very important because of their effect on the combustion process in an engine. Those properties are:

- Ignitability of CH_4 in mixture with air:

CH_4= 5-15 Vol. %

Air = 95-85 Vol. %

Therefore for my case I have select Ignitability of CH_4 in mixture with air:

CH_4= 10 % Vol.

Air = 90 % Vol.

Mixtures with less than 5 Vol. % and mixtures with more than 15 Vol. % of CH_4 are not properly ignitable with spark ignition.

- Combustion velocity in a mixture with air at p = 1 bar:

cc = 0.20 m/s at 7% CH_4

cc = 0.38 m/s at 10% CH_4

Combustion velocity in a mixture with air at p = 1 bar:

$$cc = 0.38\ m/s, \text{ at } 10\%\ CH_4$$

5.2.3 Design of Micro- Hydro Power Generation

The generating capacity of the Micro-hydro can obtained from structures as shown figure 19 below. And the power will be calculated by eq. (5.37) gives around 63 kW.

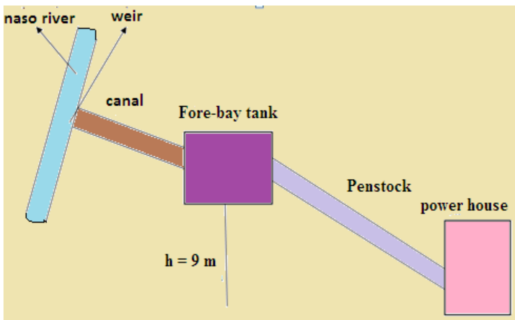


Figure 19 Micro-hydro power structures

$$P = \rho \times \eta \times g \times Q \times H \ldots\ldots \text{eq. (5.37)}$$

Where;

P = Power output (KW)

ρ = Density of water (take $1000 kg/m^3$)

η=Efficiency of small turbine

g = Gravity ($9.81 m/s^2$)

H= Head in meter (m) = 9 m

Designed parameters were indicated as per power requirements of the system. H=9m, assumed 10% head loss, h=9-0.1*9=8.1m, Designed flow rate =$1.22 m^3/s$, Efficiency of small turbine = 0.65 [**46**].

$P = 1000\,\text{kg/m}^3 \times 0.65 \times 9.81\,\text{m/s}^2 \times 1.22\,\text{m}^3\text{/s} \times 8.1\text{m} = 63\ \text{KW}$

The top width of weir wall (B') is given by [**47**]

$\dot{B} = \frac{H}{\sqrt{G-1}}$ ……………………………………………………………………………eq. (5.38)

Where

$\dot{B}$=top width of weir wall

H= head of water over the weir wall at the minimum flood

G= specific gravity of floor material = 2.4

First calculate as what will be the head over the weir when low flood discharge is passing.

Use $q = 1.7H^{3/2}$ ………………………………………………………………eq. (5.39)

Where

q= the discharge intensity in meter cube per second per meter = $\frac{Q}{L}$

Q= minimum discharge of Naso river= $1.22\frac{m^3}{s}$

L= length of weirs = 4m

$q = \frac{1.22\frac{m^3}{s}}{4m} = 0.305\,{m^2}/{s}$, Therefore

$q = 1.7H^{3/2}$

$0.305 = 1.7H^{3/2} \rightarrow H = \left(\frac{0.305}{1.7}\right)^{2/3} = 0.424\text{m}$

Now calculating the top width of the weir

$\dot{B} = \frac{H}{\sqrt{G-1}} = \frac{0.424\text{m}}{\sqrt{2.4-1}} = 0.36\text{m}$

Canal Sizing of Hydropower

Step 1: calculating the velocity [**47**]

$$V = \left(\frac{Qf^2}{140}\right)^{1/6} \text{...eq. (5.40)}$$

Where Q = the constant value for canal sizes flow rate = $1\frac{m^3}{s}$

V= is in m/s

f= is silt factor is given by

$$f=1.76\sqrt{d_{mm}} \text{..eq. (5.41)}$$

Where, d_{mm}= average particle size in mm

In Kedemesa site the types of soil is sandy and clay, so the average grain size

d_{mm}= 0.51mm

$f=1.76\sqrt{0.51}= 1.257$

$$V = \left(\frac{Qf^2}{140}\right)^{1/6}$$

$$V = \left(\frac{1\frac{m^3}{s}\times 1.257^2}{140}\right)^{1/6} = 0.47 m/s$$

Step 2: Area of canal section

$$A=\frac{Q}{V} \text{...eq. (5.42)}$$

$$= \frac{1\frac{m^3}{s}}{0.47 m/s} = 2.13 m^2$$

Step 3: The hydraulic mean depth (R)

$R = \frac{5}{2} \times \frac{v^2}{f}$……………………………………………………………………...eq. (5.43)

$R = \frac{5}{2} \times \frac{0.47^2}{1.257} = 0.44m$

Step 4: Computing the wetted perimeter (P)

$P = 4.75\sqrt{Q}$…………………………………………………………………….eq. (5.44)

$= 4.75\sqrt{1} = 4.75m$

Step 5: knowing the above values, the canal section is known and finally the bed slope S is determined by the equation

$S = \frac{f^{5/3}}{3340Q^{1/6}}$ ………………………………………………………………eq. (5.45)

Where

f= is the silt factor

Q = is the discharge in $\frac{m^3}{s}$

$S = \frac{1.257^{5/3}}{3340\times\left(1\frac{m^3}{s}\right)^{1/6}} = \frac{1}{2281}$

So the bed slope is 1 in 2281

Step 6: the length of canal is 12m (survey from the site)

Turbine Selection for Hydropower Generation

A turbine converts energy in the form of falling water in a rotating shaft power. The selection of best turbine for a particular micro hydro site depends on the site characteristics, the dominant factor is the head available and the power required. Selection also depends on the speed at which it is desired to run the generator or other devices loading the generator.

- From table appendix, a turbine type suitable for this site is **impulse turbine** typically **cross flow** type. [**48**]

Impulse turbine runner size (D)

Where, D = is diameter of impulse Turbine.

$D = K\left(Q_{\text{Impulse turbine}}\right)^{0.473}$ …………………………………………………………eq. (5.46)

Use, k = 0.46 and Q = $1\text{m}^3/\text{s}$

$D = 0.46\text{x}\left(1_{\text{Impulse turbine}}\right)^{0.473} = 0.46\text{m}$

Specific speed (n_q)

$n_p = n\,\frac{Q^{0.5}}{H^{0.75}}$ ……………………………………………………………………....eq. (5.47)

Where, n=the speed in rpm (1200rpm)

H= net head

Q=is the design flow rate (m^3/s)

h_s = is growth head= 9m

Assuming 10% head loss(h_l) =0.1x9= 0.9m

$h = h_s - h_l = 9\text{m} - 0.9\text{m} = 8.1\text{m}$

$n_p = 1200 \times \frac{1^{0.5}}{8.1^{0.75}} = 250$

Specific speed adjustment to peak efficiency $\left(e_{n,q}\right)$

$e_{n,q} = \left(\frac{n_p - 170}{700}\right)^2$ ……………………………………………………………………eq. (5.48)

$e_{n,q} = \left(\frac{250-170}{700}\right)^2 = 0.013$

Runner size adjustment to peak efficiency (e_d)

$e_d = (0.095 + e_{n,q}) \times (1 - 0.789D^{-0.2})$……………………………………………eq. (5.49)

$e_d = (0.095 + 0.013) \times (1 - 0.789 \times 0.46m^{-0.2}) = 0.023$

Turbine peak Efficiency (e_p)

$e_p = (0.905 - e_{n,q} + e_d) - 0.0305 + 0.035R_m$

Where

$R_m = \frac{\text{turbine manufacture}}{\text{design coefficient}}$…………………………………………………………eq. (5.50)

R_m= (2.8 to 6.1: default 2.8)

$e_p = (0.905 - 0.1 + 0.023) - 0.0305 + 0.035 \times 2.8 = 0.89$

Peak efficiency flow (Q_p)

$Q_p = Q_d = 1m^3/s$

Efficiency at flows below peak efficiency (e_q)

At minimum 95% of flow rate can be obtained

$Q = 0.95x1 = 0.95\ m^3/_s$

$e_q = \left\{1 - 1.25\left(\frac{Q_p - Q}{Q_p}\right)^{1.13}\right\} \times e_p$………………………………………………eq. (5.51)

Q=0.95(flow at any time t)

$e_q = \left\{1 - 1.25\left(\frac{1-0.95}{1}\right)^{1.13}\right\} \times 0.89 = 85\%$

Design of Penstock

Step 1: Steel penstock diameter is calculated as follows

$D_p = 0.72Q^{0.5}$, where Q is flow rate = $1\frac{m^3}{s}$

$D_p = 0.72\left(1\frac{m^3}{s}\right)^{0.5} = 0.72m$

Step 2: Determining the length of penstock [**47**]

Assuming there is only head loss due to friction in penstock (applying the manning formula) then

Head loss $= \left[10.29n^2\frac{Q^2}{D^{5.333}}\right] L_P$……………………………………………………eq. (5.52)

Where

n = manning coefficient = 0.012

In this thesis the head loss is assumed = 0.1x 9m= 0.9

$0.9 = \left[10.29\text{x } 0.012^2 \times \frac{1^2}{0.72^{5.333}}\right] L_P$

$L_P = 100m$

Battery Sizing

The Size of battery bank required will depend on the storage capacity required, the maximum discharge rate and the minimum temperature at which the battery will be used.

Battery load (BL) $= \frac{\text{average daily energy utilization}}{\text{battery voltage}}$…………………………eq. (5.53)

Where

$$\text{average daily energy utilization from above calculted } = 1157.195 \ \text{KWh}/\text{day}$$
$$= 1157.195 \ \text{KAVh}/\text{day}$$

BL $=\frac{1157.195 \text{ kAV}}{12\text{V}}$= 96.43kAh

The battery should supply the required load. It should also supply the load for two days of autonomy in the absent of the sun.

Battery Ampere hour (Total battery capacity) =

$\frac{\text{number of days of autonomy x battery load}}{\text{depth of discharge}}$……………………………………………………eq. (5.54)

$=\frac{2\times 96.43\text{kAh}}{0.5}$, (assuming maximum depth of discharge 50 %.)

= 385.73kAh

To determine the number of battery required

Number of battery $=\frac{\text{Total battery capacity}}{\text{Battery capacity of each}}$…………………………………………eq. (5.55)

<u>The battery type selected is Trojan L16P</u>

It has need the nominal capacity around 2.16 KWh

Trojan L16P= $\frac{385.73\text{kAh}}{1156\text{Ah}}$ = 333.68≈ 334

167 batteries in parallel will be connected with 2 strings.

Converter Sizing

Maximum Ac load =122.24 kW, Convertor constant= 1.25

Convertor rating = maximum Ac load x Convertor constant [**30**], rating = 122.24 kW x 1.25 = 152.8kw

Since total load is 152.8kw it is advisable to size the required to be 153kw as designed for this system design. Hence, 153kw pure sine convertor is recommended in the other to prolong the life span of the convertor.

Sizing of Charge Controller

Select one that is rated at system voltage. (Same nominal voltage all the way through the system) i.e. 12v

Divide the system wattage by system voltage

$$P = VI \qquad \text{eq. (5.56)}$$

Where

P= power supply= 122.24 kW

V= the battery voltage =12v

$$I = \frac{p}{v} = \frac{122.24\ \text{kW}}{12} = 10.19\ \text{kA}$$

Add 20% as a safety margin (multiply result of the current above by 1.2)

10.19 kA x 1.2 = 12.2 kA

Select charge controller rated at or above the result,

Because the value 12.2 kA charge controller is not readily available in the market then 15kA charge controller is selected.

CHAPTER SIX

6. RENEWABLE ENERGY SYSTEMS AND NECESSITY OF HYBRID

Hybrid power system consists of a combination of renewable energy resources such as: photovoltaic (PV), biogas and micro hydro to charge batteries, converter and provide power to meet the energy demand, considering the local geography and other detail of the place of installation. These types of systems, which are not connected to the main utility grid, are also used in standalone applications and operate independently and reliably. The best application for these systems is remote places, such as rural village. The importance of hybrid system has grown as the appeared to be the right solution for a clean distribution energy production. It has to be mentioned that new implementation of hybrid system require the special attention on the analysis and modeling. One issue is determined by the variable and unpredictable character of energy supply from renewable sources. A major importance for the optimal or economical study of hybrid systems, based on renewable energy, is the availability of HOMER software simulation. The Figure 20 below shows the hybrid system of this study.

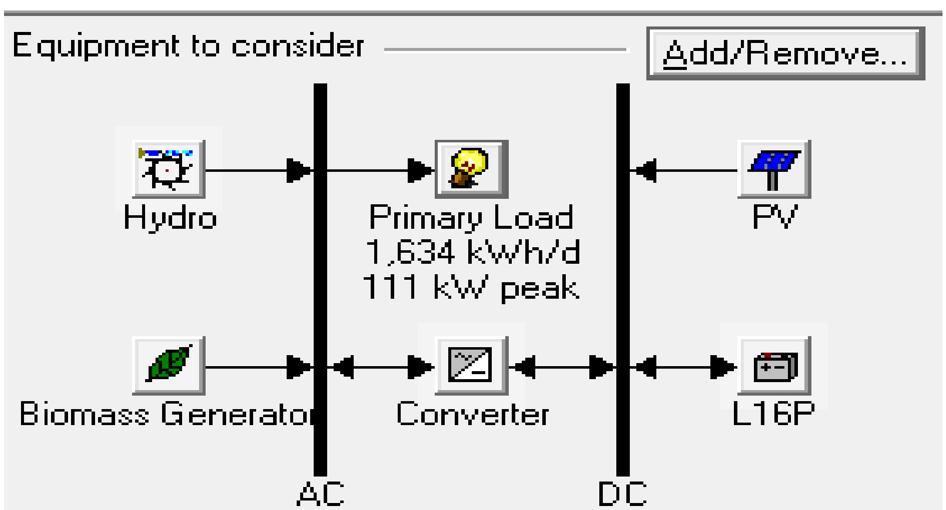


Figure 20 HOMER circuit for the hybrid system

The demand in the kedemesa Kebele is 122.24 kW depending on the population. In this area different renewable energy resources are found. It needs the most effective and efficient designed power system. Thus hybrid power system is selected for it. It is selected to increase the reliability of the supply and to minimize the cost. The availability of resources is different in selected area. Naso has enough flow rates throughout the year. Constructing only from Naso River, for more than 100kW (above micro hydro range), is too costly since it needs a storage system.

In Kedemesa Kebele there is a good solar radiation. But, the cost of PV modules is high and also it covers a lot of area for power system construction. Solar energy is obtained only in the noon, so it is better to use other renewable energy resource like hydro in the night time in addition to battery with day of processes. There is also a good biomass resource (i.e. animal dung). But, the cost of digester sizes is higher and also it covers a lot of area for power system construction. Biomass energy is obtained through the whole.

6.1 Modeling of Hybrid System with HOMER

HOMER performs three principal tasks: simulation, optimization, and sensitivity analysis. In the simulation process, the performance of a particular power system configuration for each hour of the year is modeled to determine its technical feasibility and life-cycle cost. In the optimization process, many different system configurations are simulated in search of the one that satisfies the technical constraints at the lowest life-cycle cost.

In the sensitivity analysis process, multiple optimizations are performed under a range of input assumptions to judge the effects of uncertainty or changes in the model inputs. Optimization determines the optimal value of the variables over which the system designer has control such as the mix of components that make up the system and the size or quantity of each. Sensitivity analysis helps assess the effects of uncertainty or changes in the variables over which the designer has no control, such as the average biomass capacity production or the future fuel price.

Figure below shows relationship between simulation, optimization, and sensitivity analysis

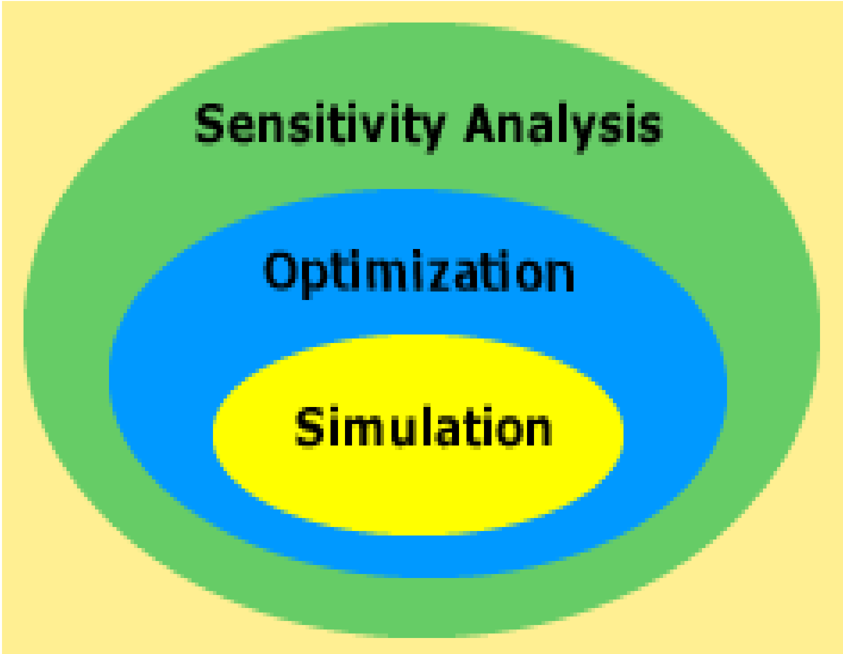


Figure 21 the relationships with simulation, optimization, and sensitivity analysis [**49**]

A generator system must comprise at least one source of electrical energy (such as SPV system, a biogas generator, hydro, or the grid), and at least one destination for that energy (electrical load). It may also comprise conversion devices such as a DC-AC converter and energy storage devices such as a battery bank.

6.2 Connected Electric Load

Electrical load is an electrical component or portion of a circuit that consumes electric power, the data were calculated for the total hourly basis daily electrical load requirement of a residential, the expected load consumption profile of the area is shown in Figure 22. The Daily load requirement of the intended village group is found to be 1634 kWh per day and the peak load is found to be 111 kW.

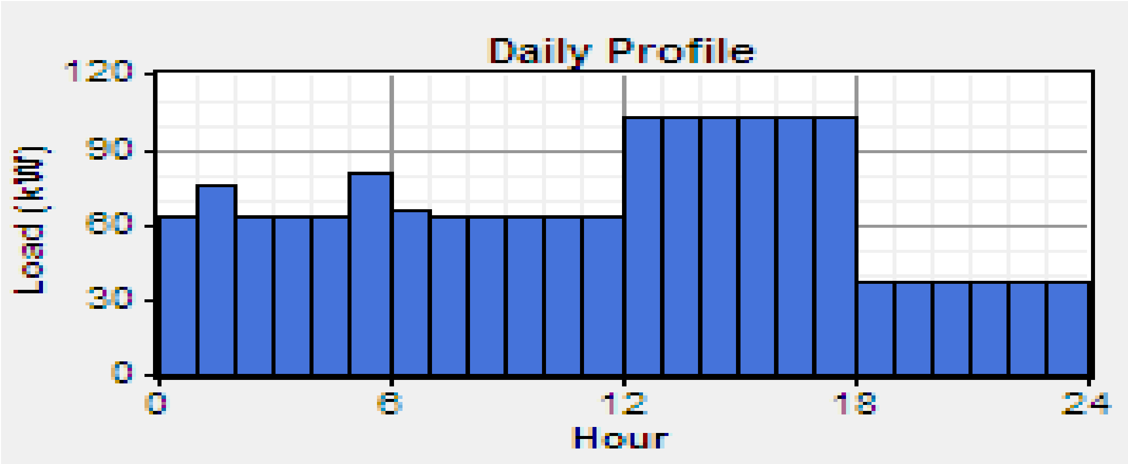


Figure 22 Hourly load consumptions

6.3 Inputs of Each Components of Hybrid to Homer Software

Micro hydro power generator in Kedemesa site has design, for site there are some specification inputs to homer in order to get optimized simulation result. These are related to sources, equipment and other devices used in the hybrid system. So that flow rate of 1220L/s, minimum flow ratio of 75, maximum flow ratio of 150, gross head is 9m, absolute head loss is 0.9m or relative head loss is 10%,100m of pipe length, efficiencies is 65 % and steel pipe is entered as a selected inputs for homer.

Solar PV power systems input for homer are lifetime 15 year, de-rating factor is 90% and ground reflectance is 20%.

Biomass generation input for homer will be for biomass source I have select biogas for generation system, life- time operation system is could be 40000 hours and the minimum load ratio is 30% and also average monthly biomass energy around 1.35 tonne/day input to homer software.

A battery of Trojan L16P flood lead -acid type, 6V, 1156Ah, 6.94 kWh has been chosen for this site. The minimum life time of the battery is set to be 4 years and the battery per string is one.

The converter is used as inverter and rectifier. The remaining inputs for the software to Kedemesa site are described in table 29 below.

The estimated cost only for 33kV single circuit transmission line without consideration of transformer, insulation, mounting pole, wire costs is \$9500/km. Estimated operating and maintenance cost is 3% of the capital cost (\$/km) that is \$285/yr/km and EEPCO"s average COE is \$0.025 /kWh for domestic and general application. Estimated transmission distances from nearby substations are about 35km to the sites.

Table 22 Size, cost, quantity and life time input for homer software

Component Type	Size(kw)	Capital($)	Replacement Cost($)	O&M Cost($/year)	Quantities	Life time (year)
PV Module	1	2000	1500	20	0,5,10,15,20,20,30	15
Biomass generator	1	200	150	0.05	0,5.10,20,30,35,40	4-5
Hydro	1	20000	6000	50	-	25
Trojan L16P	1	360	250	5	0,5,10,15,20,20,30 40,50.60,70,80	4
Converter	1	200	150	20	0,5,10,15,20,20,30	15

6.4. Cost Analysis of Components for Hybrid System

By referring different literatures and market surveying the prices of each components of hybrid system per the power generation should be determined below table 24. To produce 1W from solar PV module, the unit price would cost 0.86 $, but from the design total PV module found was 416 and the expected power out was 18 KW, the total cost could be 6,439,680$. To produce 1W from Battery, the unit price would cost 1.42$, but from the design total Battery selected was 334 and the expected power out was 108 KW, the total cost could be 51,222,240$. To produce 1W from Converter, the unit price would cost 0.56$, but from design total Converter selected would expect power out was 50 KW, the total cost could be 28,000$. To produce 1W from Micro hydro, the unit price would cost 0.96$, but from design total Micro hydro would expect power out was 63 KW, the total cost could be 60,480$. To produce 1W from Biogas, the unit price would cost 0.93$, but from design total Biogas would expect power out was 20 KW, the total cost could be 18,600$. All the cost should be determined by USA dollar.

Table 23Unit Price for components of hybrid system [**50**] [**51**] [**52**]

No	Description	Quantity	Unit Price ($/w)	Total Price ($)
1	PV Module(18kw)	416	0.86	6,439,680
2	Battery(108kw)	334	1.42	51,222,240
3	Converter(50kw)	1	0.56	28,000
4	Micro hydro(63kw)	1	0.96	60,480
5	Biogas (20kw)	1	0.93	18,600

6.5 Results and Discussion

6.5.1 Simulation Result

HOMER simulates system configurations for each of the 8,760 hours in a year with all of the combinations of components that were specified in the component input. The output consists of different combinations of each source, and offers a list of feasible schemes ranked on the basis of the NPC (net present cost).

The strategy taken in this simulation is to ensure the power generator provide enough power to meet the demand. The renewable energy sources (micro hydropower turbine, biogas & PV panel) to determine the feasibility of the system. The simulation result for this study included two main groups which are categorized result & overall optimization result. The Overall optimization results for Kedemesa site are shown in figure 23 below.

From the overall optimization result the first rank and other selected overall optimization result's; grid breakeven distance, annual electrical energy production, annual electrical load served, excess electricity, renewable energy fraction, and capacity shortage are evaluated in this topics. The grid breakeven distance is simulated to show the distance either the grid or standalone system is feasible.

Double click on a system below for simulation results.

PV (kW)	Hydro (kW)	Bio (kW)	L16P	Conv. (kW)	Disp. Strgy	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Biomass (t)	Bio (hrs)
18	63.0	20	50	50	CC	$ 116,000	8,465	$ 213,091	0.031	1.00	0.02	196	3,076
18	63.0	20	60	40	CC	$ 117,600	8,340	$ 213,261	0.031	1.00	0.02	197	3,076
18	63.0	20	61	40	CC	$ 117,960	8,354	$ 213,782	0.031	1.00	0.02	197	3,078
18	63.0	20	62	40	CC	$ 118,320	8,361	$ 214,222	0.031	1.00	0.02	197	3,077
18	63.0	20	63	40	CC	$ 118,680	8,368	$ 214,660	0.031	1.00	0.02	197	3,075
18	63.0	20	65	40	CC	$ 119,400	8,383	$ 215,556	0.032	1.00	0.02	197	3,073
18	63.0	20	70	40	CC	$ 121,200	8,400	$ 217,552	0.032	1.00	0.02	197	3,061
18	63.0	20	60	50	CC	$ 119,600	8,543	$ 217,588	0.032	1.00	0.02	196	3,063
18	63.0	20	50	60	CC	$ 118,000	8,691	$ 217,680	0.032	1.00	0.02	195	3,063
18	63.0	20	61	50	CC	$ 119,960	8,554	$ 218,070	0.032	1.00	0.02	196	3,064
18	63.0	20	62	50	CC	$ 120,320	8,560	$ 218,503	0.032	1.00	0.02	197	3,063
18	63.0	20	63	50	CC	$ 120,680	8,566	$ 218,934	0.032	1.00	0.02	197	3,061
18	63.0	20	75	40	CC	$ 123,000	8,399	$ 219,334	0.032	1.00	0.02	197	3,046
18	63.0	20	65	50	CC	$ 121,400	8,580	$ 219,815	0.032	1.00	0.02	197	3,059
18	63.0	20	70	50	CC	$ 123,200	8,595	$ 221,779	0.033	1.00	0.01	197	3,047
18	63.0	20	60	60	CC	$ 121,600	8,769	$ 222,184	0.033	1.00	0.02	196	3,042
18	63.0	20	50	70	CC	$ 120,000	8,918	$ 222,289	0.033	1.00	0.02	195	3,063
18	63.0	20	61	60	CC	$ 121,960	8,780	$ 222,663	0.033	1.00	0.02	196	3,043
18	63.0	20	62	60	CC	$ 122,320	8,786	$ 223,094	0.033	1.00	0.02	196	3,042
18	63.0	20	63	60	CC	$ 122,680	8,792	$ 223,523	0.033	1.00	0.02	196	3,040
18	63.0	20	75	50	CC	$ 125,000	8,590	$ 223,530	0.033	1.00	0.01	196	3,032
18	63.0	20	65	60	CC	$ 123,400	8,806	$ 224,399	0.033	1.00	0.01	196	3,038
18	63.0	20	70	60	CC	$ 125,200	8,819	$ 226,352	0.033	1.00	0.01	196	3,026
18	63.0	20	60	70	CC	$ 123,600	8,997	$ 226,792	0.033	1.00	0.02	196	3,042
18	63.0	20	50	80	CC	$ 122,000	9,145	$ 226,897	0.033	1.00	0.02	195	3,063
18	63.0	20	61	70	CC	$ 123,960	9,007	$ 227,271	0.033	1.00	0.02	196	3,043
18	63.0	20	62	70	CC	$ 124,320	9,013	$ 227,702	0.033	1.00	0.02	196	3,042
18	63.0	20	75	60	CC	$ 127,000	8,814	$ 228,093	0.033	1.00	0.01	196	3,011

Figure 23 HOMER overall simulation results

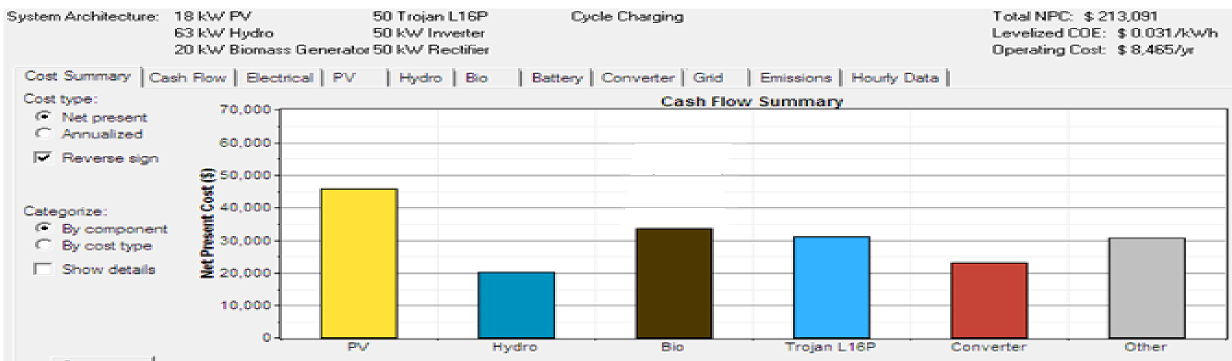
The breakeven grid extension distance, cost of components, monthly average electrical production, system architecture, annual electric power production and annual electric consumption for selected rows (1, 2,5,8,10,15,19,30,40 and 48) in table 24 below of the overall optimization result are described for Kebele.

Table 24 some simulation results captured from overall optimization result

Optimal Order	PV (KW)	Hydro (KW)	Biom. (KW)	L16P	Conv. (KW)	Total NPC($)	COE ($/kwh)	Ren.Frac.
1	18	63	20	50	50	213,091	0.031	1
2	18	63	20	60	40	213,261	0.031	1
5	18	63	20	61	40	213,782	0.031	1
8	18	63	20	62	40	214,222	0.031	1
10	18	63	20	63	40	214,660	0.031	1
15	18	63	20	65	40	215,556	0.032	1
19	18	63	20	70	40	217,552	0.032	1
30	18	63	20	60	50	217,588	0.032	1
40	18	63	20	50	60	217,680	0.032	1
48	18	63	20	61	50	218,070	0.032	1

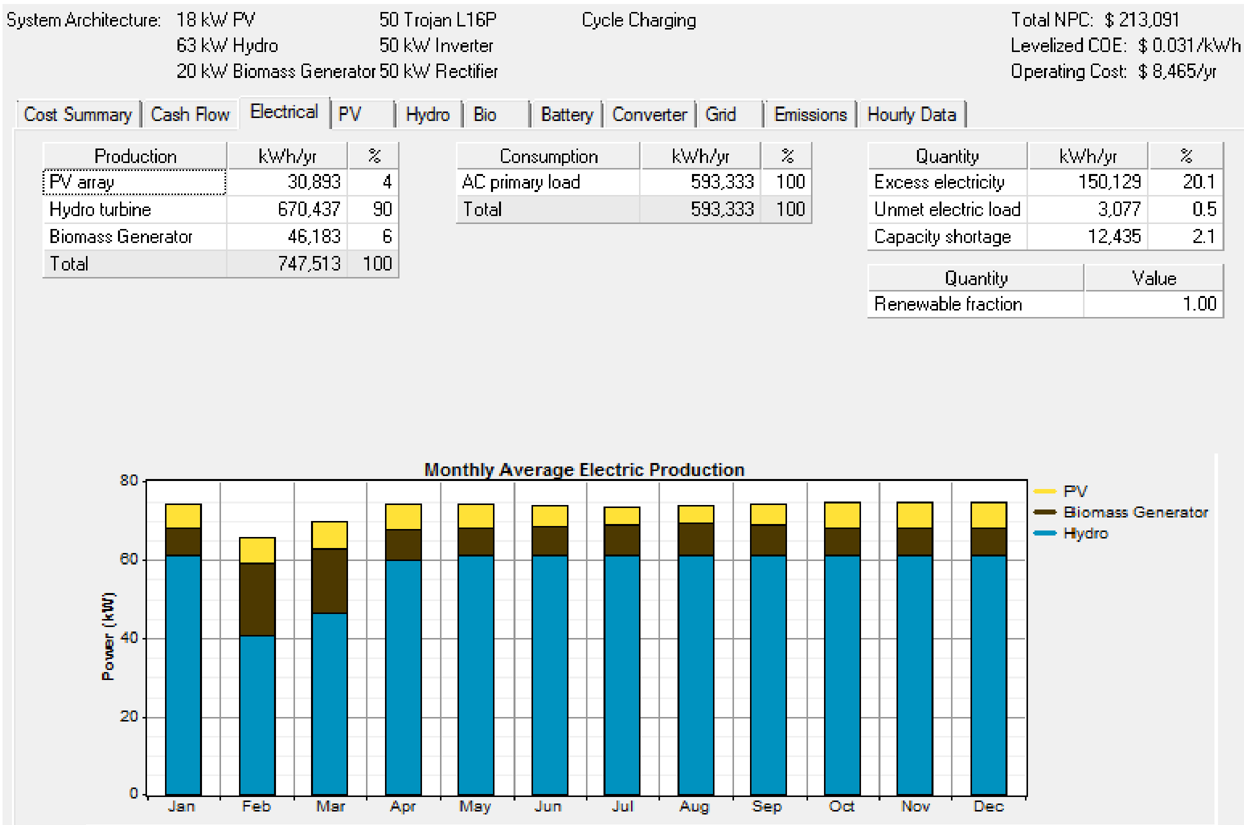
6.5.2 System Report for the First Row Overall Optimal Results

The first rank overall optimization result (row 1) in figure 25 below has 50kw lead acid batteries, 50 kW convertor, 20 kW biomass generations, 18kw PV and 63kW hydro. The total NPC of 213,091$ is the least cost for site in this simulation. Breakeven grid extension distance for the first overall optimal result for Kedemesa is 5.13 km as shown in figure 26. Comparison between grid extension and standalone system with HOMER has been done. The distance estimated for Kedemesa is about 35km from the grid, so that is better to use the standalone system.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	36,000	11,266	4,129	0	-5,612	45,783
Hydro	20,000	0	573	0	-374	20,199
Biomass Generator	4,000	937	35,281	22,442	-288	62,373
Trojan L16P	18,000	12,492	2,867	0	-2,263	31,096
Converter	10,000	3,129	11,470	0	-1,559	23,040
Other	28,000	0	2,599	0	0	30,599
System	116,000	27,825	56,920	22,442	-10,097	213,091

Figure 24 cash flow summaries in the first optimal result



System Architecture: 18 kW PV, 63 kW Hydro, 20 kW Biomass Generator, 50 Trojan L16P, 50 kW Inverter, 50 kW Rectifier, Cycle Charging

Total NPC: $ 213,091
Levelized COE: $ 0.031/kWh
Operating Cost: $ 8,465/yr

Cost Summary | Cash Flow | Electrical | PV | Hydro | Bio | Battery | Converter | Grid | Emissions | Hourly Data

Production	kWh/yr	%
PV array	30,893	4
Hydro turbine	670,437	90
Biomass Generator	46,183	6
Total	747,513	100

Consumption	kWh/yr	%
AC primary load	593,333	100
Total	593,333	100

Quantity	kWh/yr	%
Excess electricity	150,129	20.1
Unmet electric load	3,077	0.5
Capacity shortage	12,435	2.1

Quantity	Value
Renewable fraction	1.00

Figure 25 Monthly average electric energy productions in the first optimal result

From figure 26 above you can that the total electrical production that is produced by all the renewable sources amounts to 747,513kWh/yr; which encompasses 30,893kWh/yr or 4 % from solar PV, 670,437kWh/yr or 90 % from hydro and 46,183 kWh/yror 6 % biomass generation electric production, which covers large amounts of electric production.

It has excess electricity generation of 20.1%, no unmet electric load is 0.5% and capacity shortage is 2.1% and this set up can be a good choice also to implement at the site.

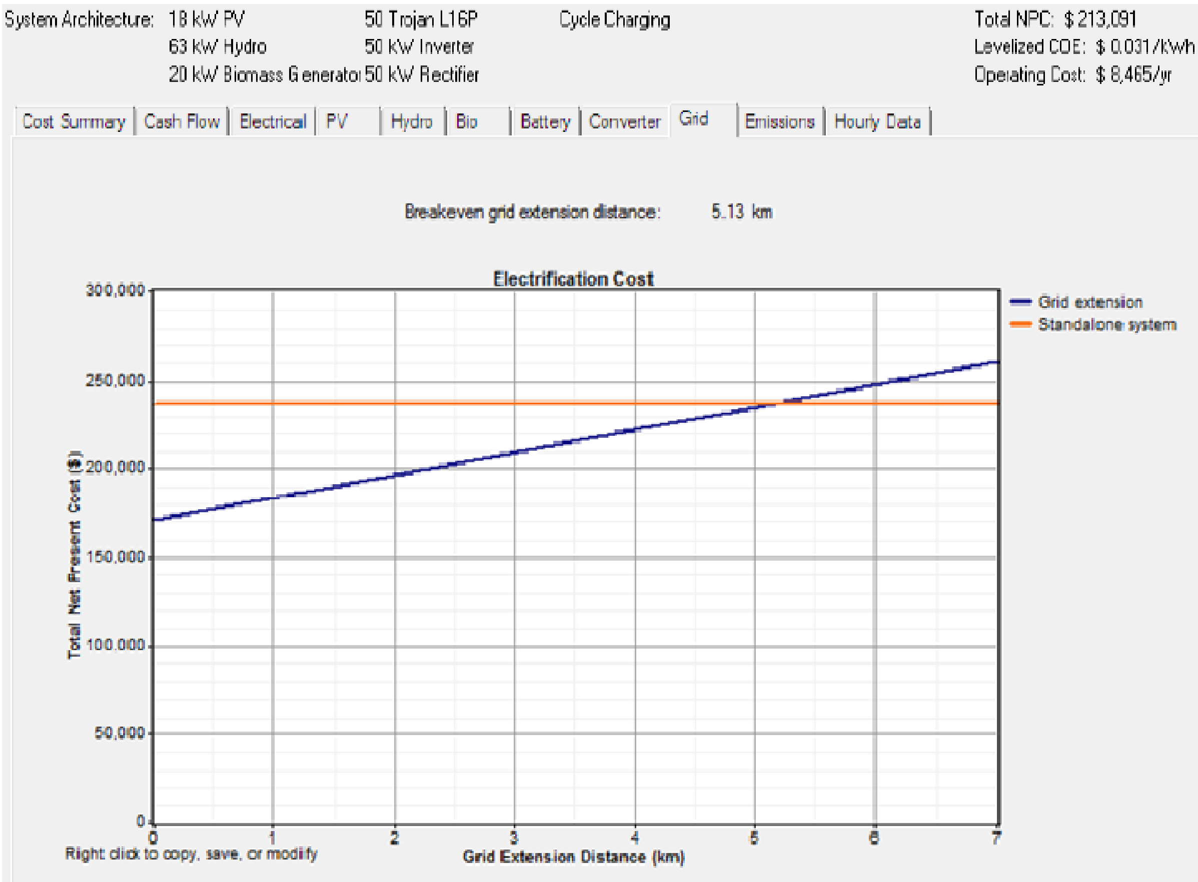
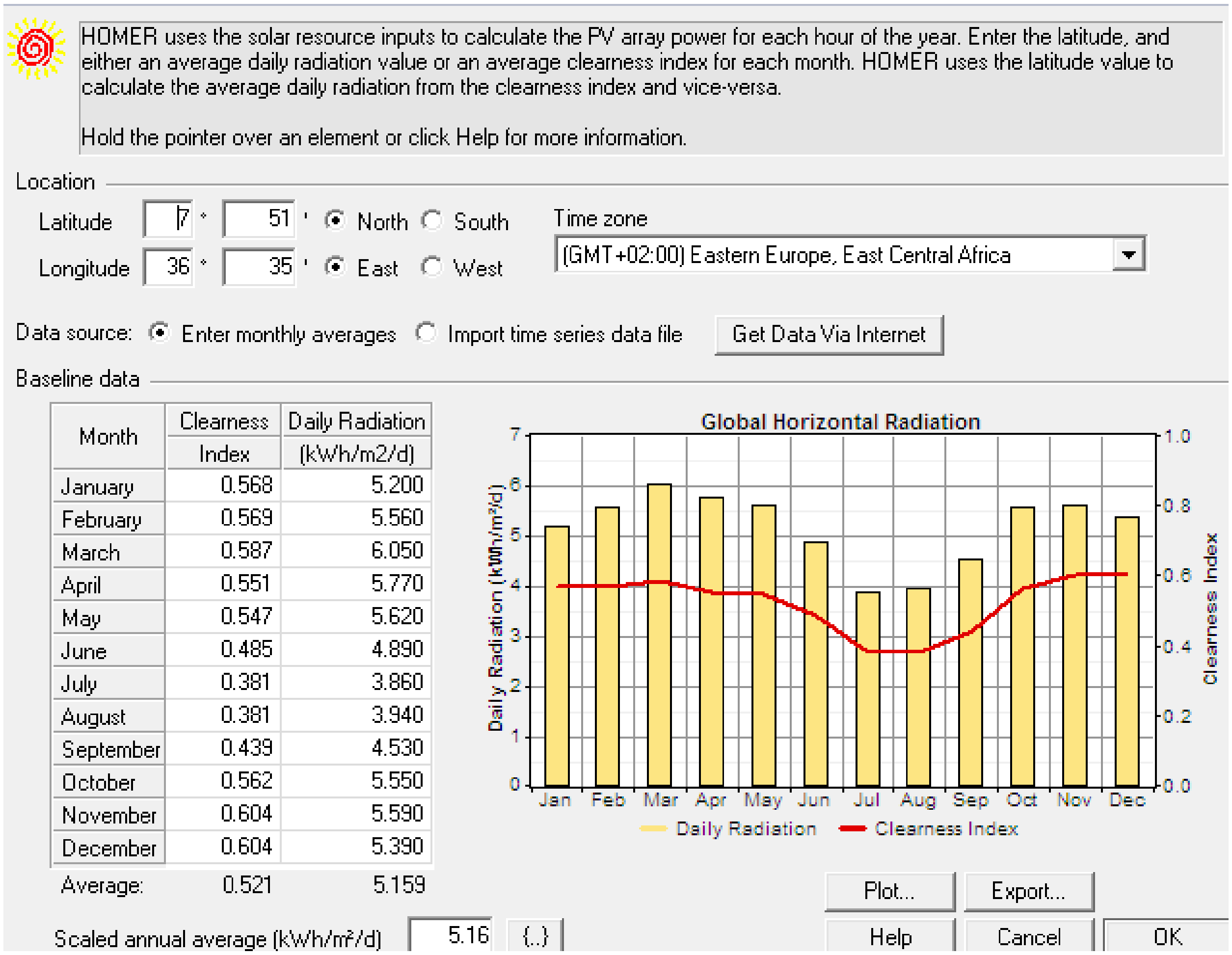


Figure 26 Breakeven grid extension distance in the first optimal result

Figure 26 above shows the costs comparison of the PV/micro hydro hybrid system with the grid extension in terms of breakeven grid extension distance given at 5.13 km (intersection between the grid extension cost in blue and the stand-alone cost in red). For the selected site, the shortest distance from the grid to the load center is about 37 km from Agaro consequently advantageous to use renewable rather than grid. So it shows the grid extension is possible up to 5.13 km whereas standalone renewable system is advantageous for a distance more than 5.13 km.

6.5.3 Solar PV Energy System in Homer Software

The solar energy potential of the site was put into HOMER and this is shows in Figure 27. This figure also shows the clearness index, the ratio of the solar radiation striking Earth’s surface to the solar radiation striking the top of the atmosphere, which HOMER generated from global solar radiation based on the data input for the analysis. Typical values for the monthly average clearness index range from 0.381 (cloudy month) to 0.604 (sunny month).



Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.568	5.200
February	0.569	5.560
March	0.587	6.050
April	0.551	5.770
May	0.547	5.620
June	0.485	4.890
July	0.381	3.860
August	0.381	3.940
September	0.439	4.530
October	0.562	5.550
November	0.604	5.590
December	0.604	5.390
Average:	0.521	5.159

Figure 27 Monthly average solar resources

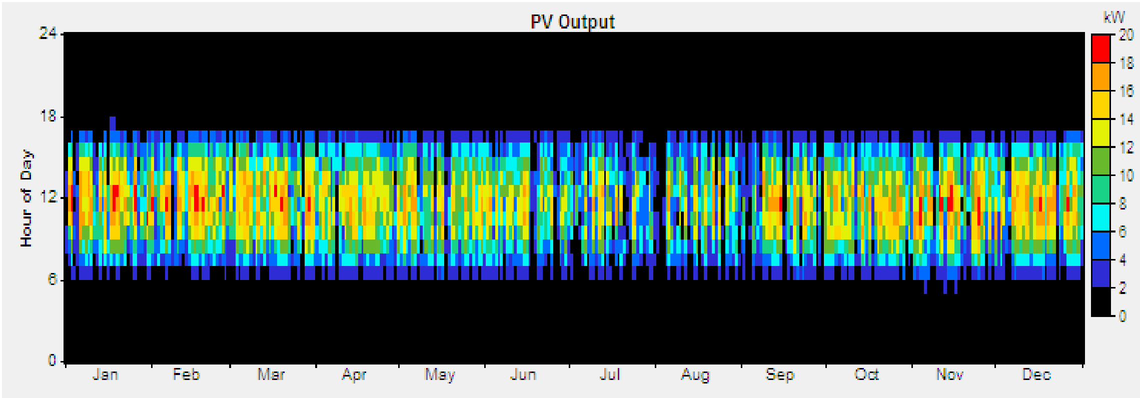


Figure 28 Annual electric energy productions by PV system

Figure 28 shows that differences of sunlight available throughout the hours of the day, with the minimum values registered in the beginning and the last hours of the times and the available peak during midday.

6.5.4 Hydropower Generation in Homer Software

The information gathered from the office of rural development and environmental protection of Agaro woreda. In this thesis Naso River was considered as the source of water for the Micro-hydro power generating system. The figure 30 below can give information of the data's the minimum and maximum flow rate of the sites of Naso River.

The generator selection for hydro power is induction generator, because of for micro-hydro power generation induction is the best chosen. Induction generator cost is less rather than others type.

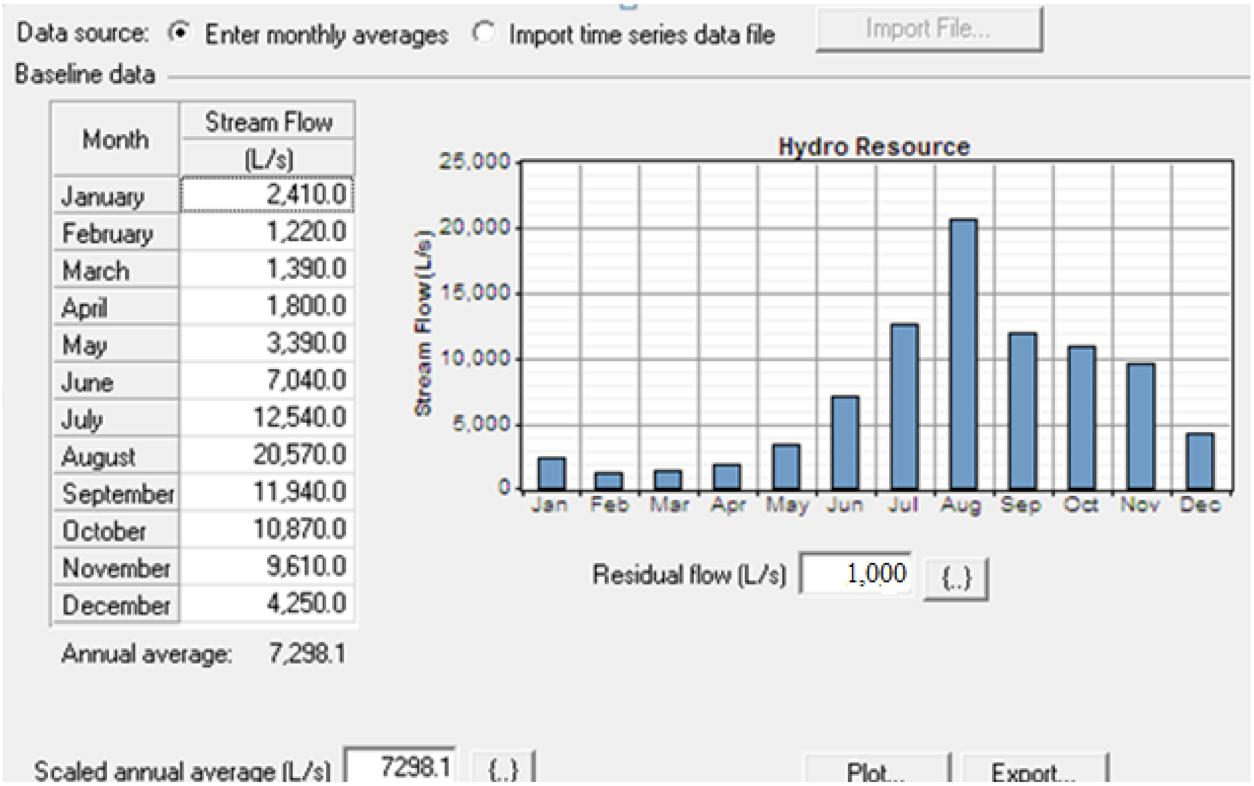


Figure 29 Average monthly flow rate of Naso River

As it is possible to see from the above Figure 29 the average flow rate of Naso River from January – May and December is less than 5,000L/s, whereas the average flow of this river from July-October is greater than 10,000L/s.

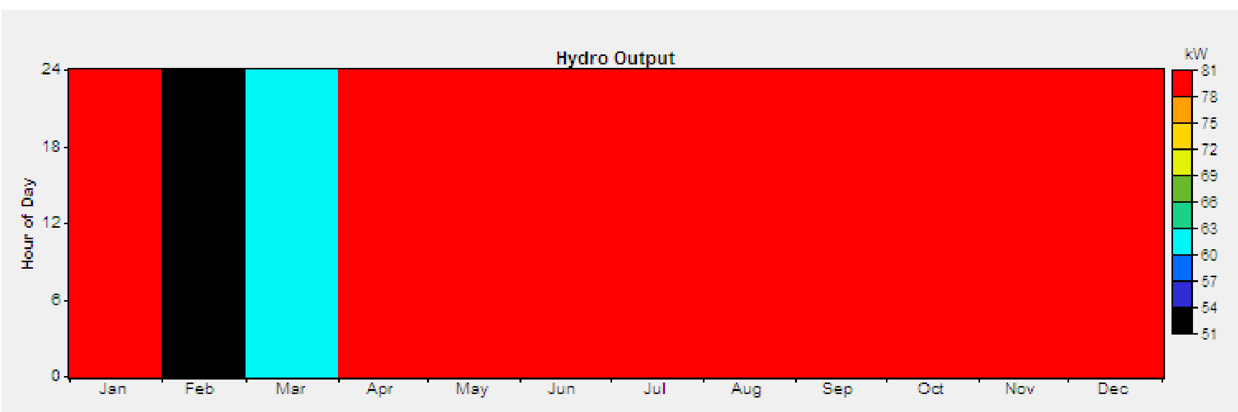


Figure 30 Annual electric energy productions by hydropower system

One can learn From Figure 30 above the potential electric generation over months of the year with the minimum amount of flow rate will be at February happened.

6.5.5 Biogas Energy Resource in Homer Software

The physical properties of a biogas fuel include its gasification ratio, lower heating value, carbon content and the average price. Gasification ratio is the mass of biogas produced per unit mass of feedstock consumed. Lower heating value is the heat content of biogas. The carbon content is the net amount carbon released per unit of feedstock consumed. The average price per tonnes of the biogas feedstock is taken 12 $ [**53**].

The monthly average biogas feedstock(cattle's manure) of the site, together with other related data, such as values of gasification ratio, carbon content, autocorrelation, average price per tonnes of the biogas feedstock, lower heating value etc, was fed into HOMER. Figure 31 shows the biogas feedstock resource.

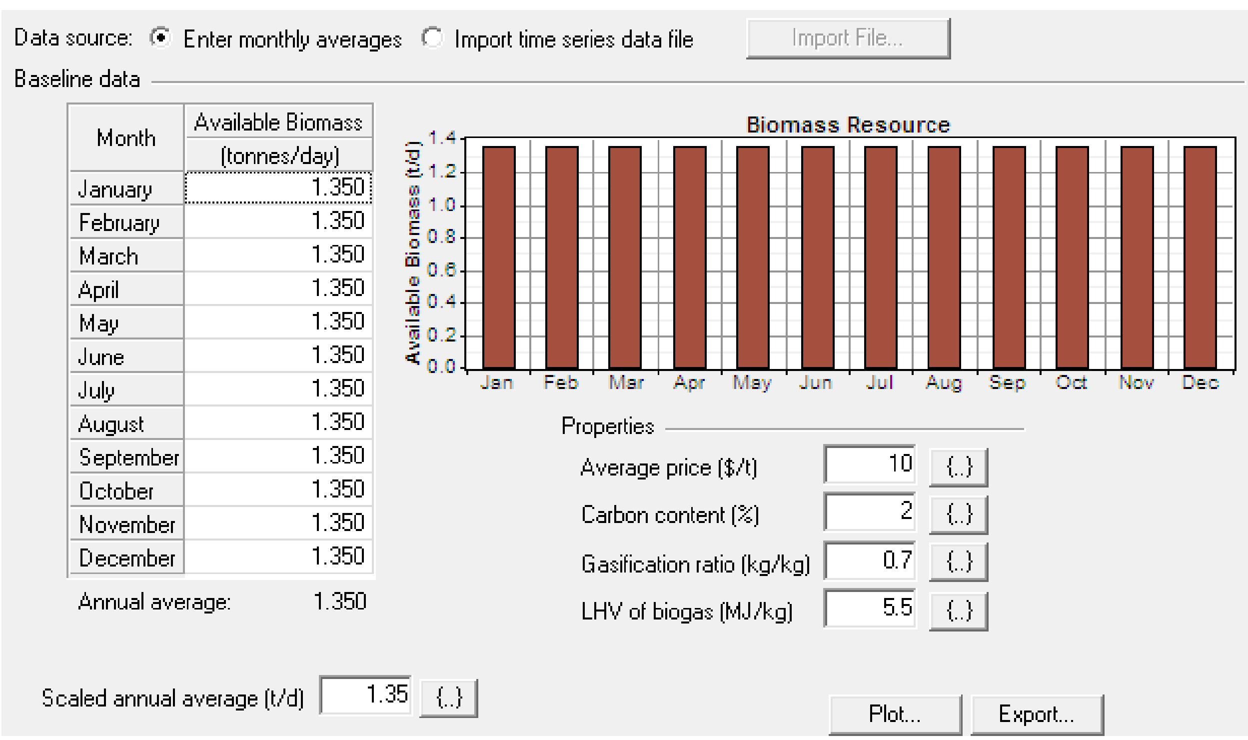


Figure 31Monthly average biogas feedstocks

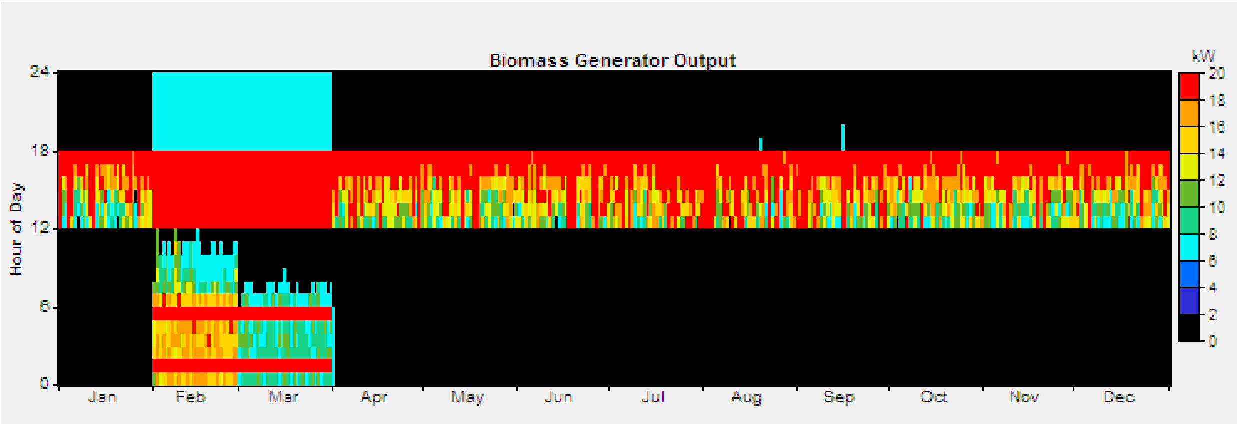


Figure 32 Annual electric energy productions by biomass generator system

One can learn From Figure 32 above the potential electric generation over months of the year almost will be the same except February and March.

Figure 33 monthly Statistical result of battery system

From above Figure 33 the battery is fully discharged in due of delivering power to loads because of the minimum generation capacity in component of the system during the same month. It's also evident that the battery becomes operational during 12:00-18:00pm hours of the day to compensate the unavailability of sunshine in night.

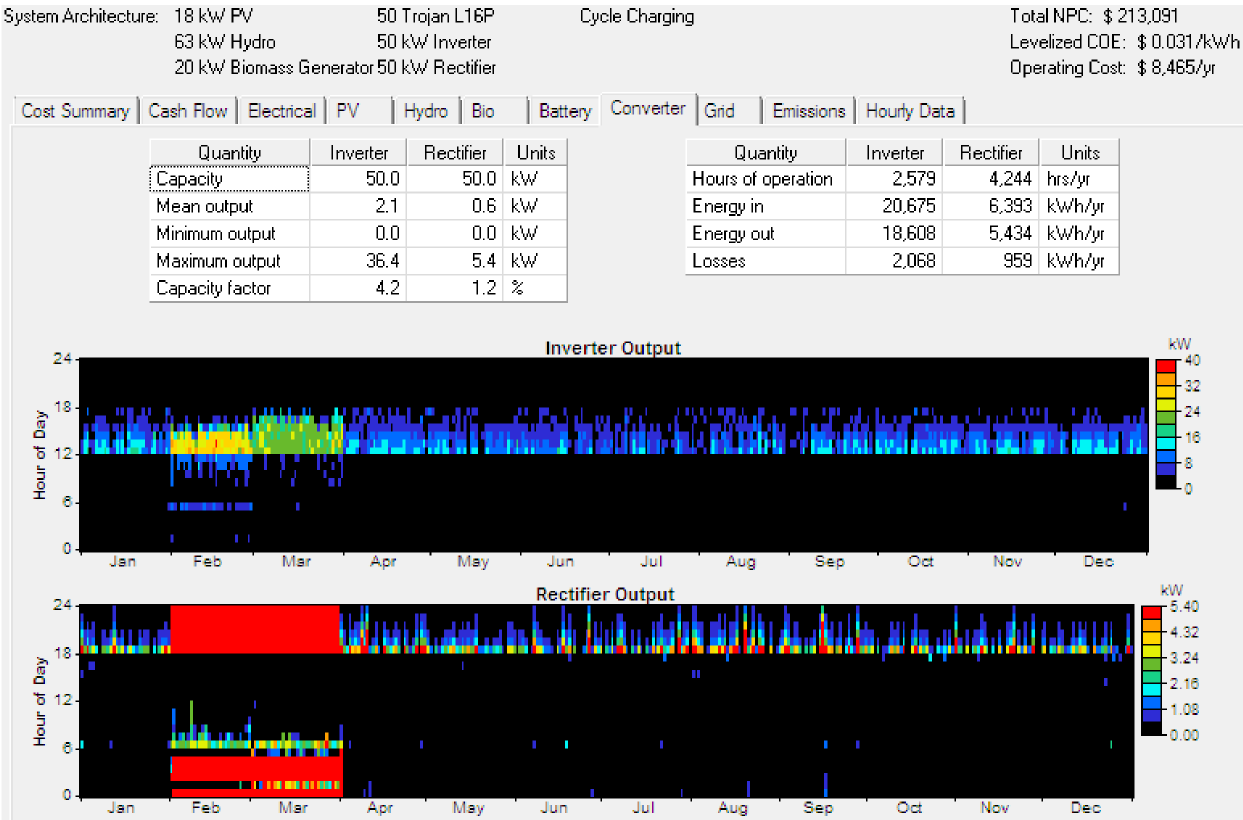


Figure 34 simulation result of convertor system

As indicated in Figure 34 the convertor is fully functional in due of delivering power to loads from 12-18pm during the pick load, also from February to march convertor is fully functional due to of decreasing of flow of water and biomass highly using PV and battery.

6.5.6. Sensitivity Result

The sensitivity result in this study is the average biomass available (tonnes/day) variation as shown in figure 35. It shows as there are two hybrid configurations for average biomass available from 1 up to 1.35 tonnes/day and diesel cost from 0.96$/L up to 1.4$/L. For average biomass available above 1 tonnes/day and for diesel cost from 0.96$/L up to 1.35$/L Hydro/solar/ Generator/Battery hybrid power supply is the choice whereas for biomass available less than 1 tonnes/day and diesel price less than 1.3$/L that is possible to use Hydro/solar/Generator/Battery hybrid to power supply.

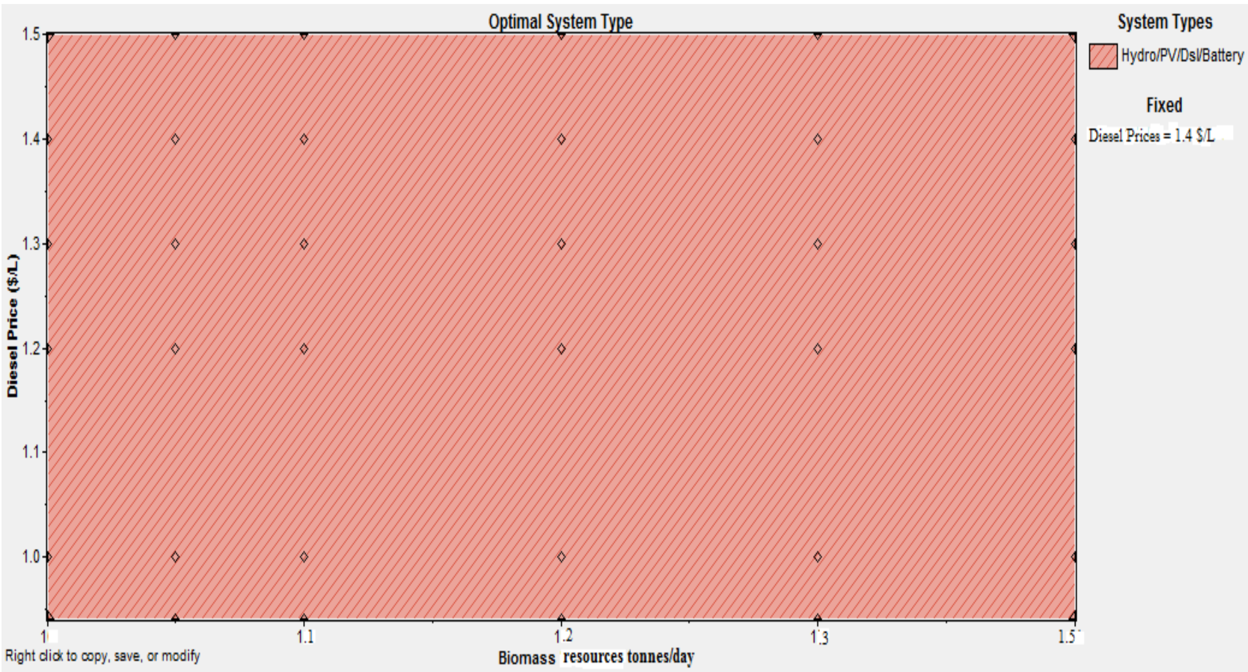


Figure 35 Sensitivity result of diesel price to PV capital multiplier variation

CHAPTER SEVEN

7. CONCLUSIONS AND RECOMMENDATION

Conclusion

Using the available resource such as micro hydro, biomass and solar PV hybrid energies system, it was possible production of electricity for Kedemesa kebele. Reliable power can be supplied for the forecasted ten years from 2016 to 2026 to this selected site. The micro hydro covers 60%, biomass 20% and solar photo voltaic 20% of the installed capacity. They can use the electric power for house hold equipment's, educational purpose and health center. This power plant is developed to supply electricity for the households of 530 in 2016 (base year) to 685 in 2026(forecasted year). This improves their life standard, by enabling them to get Evening Education and laboratory based health care.

Solar, hydro, biogas, battery and converter have been used to simulate the system design by using HOMER, in order to find the most optimize renewable energy at Kedemesa Kebele. The overall electricity production is 747,513 kwh/yr. With the total of net price cost is $213,091 and $8,465/yr of operating cost. From the simulation result the majority of the energy is obtained from hydropower, which accounts 90%, the PV module covers only 4% and biomass covers 6% of the total load consumption. From Economic Point of View the hybrid system is cost would found around 0.031$/kWh, which is much less than the capital cost for grid system extension for rural area that is 0.05$/kWh. This is less than the current grid price of Ethiopia 0.025$/kWh. Since EEPCO can sells for urban is 0.025$/kWh and for the rural is double price that is 0.05$/kWh because of by considering transmission line cost, maintenance cost and transportation cost. So that from Economic Point of View the hybrid system is feasible.

From Environmental Stand point, the renewable energy fraction of the project is 100%, which implies the total energy almost obtained from Renewable Energy Resources. Due to this study promoting clean energy and its contribution to the reduction of Pollutant emission released to the environment

Recommendation

From this thesis work, it has seen that Ethiopia has a huge potential for rural electrification through the off grid system. There are, however, formidable challenges like low purchasing power of the rural people and unfavorable public attitude towards the private sector. It is thus recommended that the government, non-governmental organizations and the public make combined efforts to overcome these challenges by using more flexible approaches to improve the current terrible state of rural electrification in Ethiopia.

Since the government cannot simply afford to electrify rural areas of Ethiopia where 85% of the total population reside, maximum effort must be exerted to change the prevailing attitude towards the private investors and help the private sector in all possible ways beyond designing policies.

This thesis shows only one selected site of Ethiopia and it doesn’t represent all areas of the country. So, the future engineers should expand this work in other sites and make the rural people beneficial.

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APPENDIX

Table 1 Densities, molecular weight and chemical formulas of some gases at normal Temperature and Pressure (20 ℃ and 1atm)

Gas	**Formula**	**Molecular weight $M = (\text{gram}/\text{mole})$**	**Density-ρ $(\frac{kg}{m^3})$**
Air (dry)	-	29	1.293
Methane	CH_4	16.04	0.67
Carbon Dioxide	CO_2	44	1.84
Hydrogen	H_2	2.02	0.0898
Nitrogen	N_2	28	1.251
Water Vapor	H_2O	18.02	0.8
Ammonia	NH_3	17.03	0.717
Hydrogen Sulphide	H_2S	34	1.4

Table 2 biogas Raw Materials of C/N Ratio

Raw Materials	**C/N Ratio**
Duck dung	8
Human excreta	8
Chicken dung	10
Pig dung	18
Cow dung/ Buffalo dung	24
Water hyacinth	25
Straw (rice)	70
Saw dust	above 200

Sources:http://www.wcasfmra.org/biogas_docs/Sustainable%20Biogas%201997.pdf

Table 3 Biogas yield

Types of Dung	**Gas Production Per Kg Dung (m3)**
Cattle (cows and buffaloes)	0.023 - 0.040
Pig	0.040 - 0.059
Poultry (Chickens)	0.065 - 0.116
Human	0.020 - 0.028
Source: Updated Guidebook on Biogas Development, 1984	

Table 4 Gas production from various types of dung (Anon 1997)

Feature	**Diesel**	**Otto**
Design data		
compression ratio e	15 - 21	6 - 9.5 petrol 6 - 12 alcohol
pressure after compression without ignition	35 - 60 bar	15 - 20 bar
temperature after compression without ignition	600 - 900 °C	400 - 600 °C
-excess air ratio λ	1.3 - 4.0	0.7 - 1.2
-efficiency	0.3 - 0.4	0.2- 0.35
specific fuel consumption	230 - 350 g/kWh	300 - 400 g/kWh
volumetric efficiency	0.7 - 0.9	0.3 - 0.9 (low values for partially closed throttle)
exhaust gas temperature	400 - 600 °C	500 - 900 °C
- stationary	1,300 - 2,500	1,300 - 2,500 (gas)
	- vehicle	1,300 - 5,000
- ignition type	self-ignition by injection of fuel into hot compressed air shortly before piston reaches TDC	spark ignition by spark plug

Sources:http://www.wcasfmra.org/biogas_docs/Sustainable%20Biogas%201997.pdf

Table 5 biogas and methane stoichiometric air/fuel ratio

fuel	**density**	**calorific value (kJ/kg)**	**ignitability**	**ignition temperature in air (°C)**	**stoichiometric air/fuel ratio (kg/kg)**	**methane no**
			(Vol % gas in air)			
methane	0.72	50000	5.0...15.0	650	17.2	100
			kg/m³ n			
biogas	1.2	18000	5.0...15.0	650	10.2	130
(60% CH_4)	kg/m³ n					

(Sources: https://www.google.com/searcfiles Engines for biogas pdf)

Energy equivalents of biogas

1 kWh biogas = 0.1 l diesel fuel = 0.11 l petrol

1 m³ n biogas = 0.6 l diesel fuel = 0.67 l petrol

1 m³ n biogas = 1.5 kWh mechanical energy = 1.3 kWh electrical energy

Table 6 Metric conversion

Energy				
	kcal	**kWh**	**kJ**	**kNm**
kcal	1	$1.163*10^{-3}$	4.187	4.187
kWh	860	1	3600	3600
kJ	0.239	kJ 0.239 0.278	1	1
kNm	0.239	0.278	1	1

(Sources: https://www.google.com/searcfiles Engines for biogas)

Table 7 Metric conversion

Power				
	kcal/h	**kW**	**kJ/h**	**HP**
kcal/h	1	$1.163*10^{-3}$	4.187	$1.6*10^{-3}$
kW	860	1	$3.6*10^{3}$	1.36
kJ/h	0.239	$0.27*10^{-3}$	1	$0.38*10^{-3}$
HP	633	$2.65*10^{3}$	0.736	1
1 HP = 745.70 W, HP metric = 735.49875 W				

ppm = parts per million (volume unit) (Sources: https://www.google.com/searcfiles Engines for biogas)

Table 8 Classification of micro hydro turbines according to head, flow rate and power output

Classification	Turbine name	Head range (m)	Flow range ($\frac{m^3}{s}$)	Power output(KW)
Impulse	Pelton	50-1000	0.2-3	50-15,000
	Turgo	30-200	0.5-3	20-5000
	Cross flow	2-50	0.01-2	0.1-600
Reaction	Kaplan	3-40	3-20	50-5000
	Propeller	3-40	3-20	50-500
	Francis radial-flow	40-200	1-20	500-15000
	Francis-mixed-flow	10-40	0.7-10	100-5000