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SCHOOL OF GRADUATE STUDIES

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DEPARTMENT OF ENERGY TECHNOLOGY

APPLICATION OF SOLAR-WIND HYBRID FOR WATER LIFTING

(in Borena zone, oromia region)

A thesis submitted to the School of Graduate Studies of Addis Ababa University in Partial fulfillment of the Degree of Masters of Science in Energy Technology

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ABSTRACT

Water is the primary source of life for mankind and one of the most basic necessities for rural development. The rural demand for water for crop irrigation and domestic water supplies is increasing. At the same time, rainfall is decreasing in many arid countries, so surface water is becoming scarce. Groundwater seems to be the only alternative to this dilemma, but the groundwater table is also decreasing, which makes traditional hand pumping and bucketing difficult. As these trends continue, mechanized water pumping will become the only reliable alternative for lifting water from the ground.

Diesel, gasoline, and kerosene pumps have traditionally been used to pump water. However, the non-renewable energy is on the way of depleting from the world and due to this cost of the oils are increasing from time to time, in addition to these the exhausting gases from them is polluting the environment. So due to the cost of the oils, the developing country such as Ethiopia may not able to buy to generate water from the ground for the people and livestock. Since our country is reach in renewable energy, it is the must to replace for generation of power to the renewable one such as solar energy, wind energy, and others.

Currently, hybrids of PV and wind with or without backup generators are more promising for supplying uninterrupted power because they work independently of each other. Such systems do not require each component to be oversized.

For the Semento kebele, Liban woreda, which has the problem of drinking water for the people and livestock the solar-wind hybrid system with the specification 270kw PV, 11BWC Excel-s, 110kw inverter, Total net present cost (NPC) $1,305,958, levelized cost of energy (COE) $0.458/kwh, and operating cost $47,179/yr is selected after optimizing by using the HOMER software. The demand of water for the site is 2200m^3/d and this is easily fulfilled by installing two systems for the kebele. From the installed hybrid system there is excess electrical power which is used for the lighting purpose by using battery and there is also excess water which we use it for the irrigation purpose. So even if our aim is to solve the problem of drinking water there is also problems that are solved with the system.

Chapter One

1.1 Introduction

Water is the primary source of life for mankind and one of the most basic necessities for rural development. The rural demand for water for crop irrigation and domestic water supplies is increasing. At the same time, rainfall is decreasing in many arid countries, so surface water is becoming scarce. Groundwater seems to be the only alternative to this dilemma, but the groundwater table is also decreasing, which makes traditional hand pumping and bucketing difficult. As these trends continue, mechanized water pumping will become the only reliable alternative for lifting water from the ground. Diesel, gasoline, and kerosene pumps (including windmills) have traditionally been used to pump water. However, reliable solar (photovoltaic [PV]) and wind turbine pumps are now emerging on the market and are rapidly becoming more attractive than the traditional power sources. These technologies, powered by renewable energy sources (solar and wind), are especially useful in remote locations where a steady fuel supply is problematic and skilled maintenance personnel are scarce. [18]

Although traditional windmills have been used to pump water for centuries, small wind turbines are especially appealing because they can be located further from the borehole, where the wind is strongest. Because these turbines can directly produce alternating current (AC) power, they lend themselves to applications such as lighting and other infrastructure services when water does not need to be pumped. Similarly, PV technology converts the sun's energy into electricity through electromagnetic means when the PV module (array) is exposed to sunlight. PV produces direct current (DC) power, and an inverter can be used to convert DC power to AC power. PV is especially suitable for water pumping because energy need not be stored for night pumping. Instead, water can be stored to supply water at night. Currently, hybrids of PV and wind (with or without backup generators) are more promising for supplying uninterrupted power because they work independently of each other. Such systems do not require each component to be oversized. However, hybrid systems are generally more complex and require better qualified technicians. [19]

As we know majority of our people lives in the rural area in which there is no drinking water or scarce water is existing for drinking. Especially livestock are killed due to the lack of drinking water in the winter season. Almost all the livestock are found in the rural areas. In contrast to this our country has enough wind and solar that can solve the problem of water in the remote area. In the urban area clean water is available for the livestock and people due to there are accessibility of electricity to pump water or divert water to the desired place. Due to the lack of purified water in the rural area most of our people are attached by different disease that comes from unclean water and most of the livestock are dying. As a result the people that live in the rural area will shift to the urban area and become workless.

When we see specifically the Borena zone they are highly attached by the drought and there is no the availability of water easily. So due to this there is some projects done by the government and the nongovernmental organization to pump water by using solar pump, hand pump [14]. But still it is not enough to solve the problem of the society. Because the depth of the availability of water is increasing from time to time, due to this it becomes too difficult to get water easily by simple technology. Due to this we have preferred to use solar-wind hybrid to pump from the deepest place.

The reason why I selected this site and this topic is listed as follow:

- There is livestock production in that zone
- There is lack of drinking water around the site
- There is high solar and wind existence around the place.
- Since there is no another source of energy that is used for pumping water.
- There is no water that is used for the livestock and people living around the zone.

So, these points make me to do my thesis on the given topic and on the mentioned place.

From the Borena zone the selected site for this thesis is Semento peasants which are living in the Liban woreda. It is located around UTM0577873 North 571212 East along wachile road about 24km from Negele town. The accessibility of the infrastructure of the Semento peasants is good for the construction of the solar-wind hybrid and pumping systems equipments. The inhabitants of the area are pastoral farmers. Most of the family members of the communities move from place to place in search of water and grazing land for their animals. The villages are located far apart and the houses are also scattered over wide areas. There are 2344 people living in the peasant association and those who are living in Semento village and the surrounding areas are estimated to be about 100 families. The general area is about 1500ma.s.l and it has kola type of climate. There is one primary school in the village. [14]

Their main economic activity for livelihood is cattle rearing. They rear cattle, sheep, camels and goats. Few grow sorghum and maize. The region has recurrent drought and sometimes the people face shortage of food grains and grazing lands and water for their animals.

Fig.1.1. Map of Borena Zone [25]

1.2 The existing water supply sources for the Semento villages

The community members of the village use flood water and other intermittent sources such as ponds during wet seasons. Some of the wet season sources last up to the months of October-November after the end of the big rainy season. The water from the intermittent sources and ponds are used for both domestic purposes and watering animals.

Water well was drilled by NGO two years ago about 4km east of the school compound. The well was abandoned due to low yield. A second well was drilled in Bora valley about 1.5 km from the school compound. The well is fitted with a hand pump and it serves as the main perennial water supply source for the community members of the village. This is because of the insufficient depth of the well and the problem of power required extracting from the deep well. Since there is no adequate water supply source people move with their cattle in search of grazing areas and water during the dry seasons.

Women and girls fetch water for domestic uses of their families. Some families who have donkeys and camels use them to transport water for domestic uses. They use 10 and 25 liters capacity plastic Jerrycans to carry water and a household uses about 40 liters of water per day for domestic uses. The community members have shortage of adequate and safe water supply sources. Water born and water related diseases are common in the village.

Results from geophysical survey interpretations and other information gathered from the surrounding areas show that ground water sources should be developed in the village. The estimated depth of the well is about 180m. [24]

So to pump the water from 180m we need sufficient power to fulfill the demand of the people and livestock during the drought season, and this is what motivated me to do the research on this topic.

1.3 Objective of this thesis

1.3.1 General objective

The general objective of this thesis is to solve the problem faced by rural people due to the lack of water by using the existing resource around them. That is to solve the lack of drinking water for both the livestock and people living around the Borena zone.

1.3.2 Specific objective

The specific objective of this thesis is explained as the following

- Determine the water needed by the livestock and people living in the site
- Determine the wind and solar resource available for the specific site
- Design the pumping system and the water storage
- Design the wind-solar hybrid system to power the water pumping system
- Make financial evaluation by using appropriate software

1.4 Methodology

The methods to be employed to achieve the objectives of the research are:

- Literature review;
- Collection of wind data and solar data from the metrological agency, and collecting the data of the livestock and people living around the site from the bureau of oromia;
- Analysis of the collected data;
- Design of the pumping systems and water storage;
- Design of the solar-wind hybrid system for powering the water pumping system;
- Financial analysis by using appropriate software;

1.5 Beneficial / Beneficiaries

The outcome of this thesis will have the following impact on the society living in Borena zone:

- Meeting the water need of the rural people of the site
- Sustainable development without releasing CO_2 to the environment
- Increase the livestock production due to the availability of water
- Reduction in poverty from the society by using the livestock as food or other use
- Improved health and social services by giving them pure water
- Creation of jobs to some people who will maintain and protect the systems

CHAPTER 2

Wind Energy Systems and wind system components

2.1 Wind energy systems

The main aim of this chapter is to give the awareness on the wind system such as: types of wind turbine, component of wind turbine, mechanisms how wind can produce the electricity, and knowing this is the base to select the type of wind we use for our design system and which mechanism is appropriate for our system. So this chapter is important for this purpose.

Wind is the movement of air caused by pressure differences within the atmosphere. This pressure differences exert a force that causes air masses to move from a region of high pressure to one of low pressure. That movement of air is referred as wind. Such pressure differences are caused primarily by uneven heating effects of the sun on the Earth's surface. Thus, wind energy is an indirect form of solar energy. Wind power is the transformation of wind energy into more utilizable forms, typically electricity using wind turbines [8].

The wind turbine captures the wind's kinetic energy of air mass by a rotor consisting of two or more blades which is mechanically coupled to an electrical generator. Most of the time the turbine is mounted on a tall tower to enhance the energy capture. The sites with steady high wind produce more energy over the year [19].

2.1.1 Power Extracted from the Wind

The actual power extracted by the rotor blades is the difference between the upstream and the downstream wind powers.

The mechanical power extracted by the rotor, which is driving the electrical generator, is:

$$P_o = \frac{1}{2}\left[\rho * A * \frac{v+v_o}{2}\right] * (v^2 - v_o^2) \quad \text{2.1}$$

The above expression can be algebraically rearranged:

$$P_o = \frac{1}{2}\rho A v^3 \frac{\left(1+\frac{v_o}{v}\right)\left[1-\left(\frac{v_o}{v}\right)^2\right]}{2} \quad \text{2.2}$$

Where P_o = mechanical power extracted by the rotor, i.e., the turbine output power

v = upstream wind velocity at the entrance of the rotor blades

v_o= downstream wind velocity at the exit of the rotor blades.

The power extracted by the blades is customarily expressed as a fraction of the upstream wind power as follows:

$$P_o = \frac{1}{2}\rho A v^3 c_p \quad \text{2.3}$$

Where $c_p = \frac{\left(1+\frac{v_o}{v}\right)\left[1-\left(\frac{v_o}{v}\right)^2\right]}{2}$ 2.4

The c_p is the fraction of the upstream wind power, which is captured by the rotor blades. The remaining power is discharged or wasted in the downstream wind. The factor c_p is called the power coefficient of the rotor or the rotor efficiency. Power varies linearly with the density of the air sweeping the blades, and with the cube of the wind speed. All of the upstream wind power cannot be extracted by the blades, as some power is left in the downstream air which continues to move with reduced speed.

2.1.1.1 Rotor Swept Area

As seen in the power equation, the output power of the wind turbine varies linearly with the rotor swept area. For the horizontal axis turbine, the rotor swept area is given by:

$$A = \frac{\pi}{4} D^2 \quad \text{..........} 2.5$$

Where D is the rotor diameter

For the Darrieus vertical axis machine, determination of the swept area is complex, as it involves elliptical integrals. However, approximating the blade shape as a parabola leads to the following simple expression for the swept area:

$$A = \frac{2}{3}.(Maximum\ rotor\ width\ at\ the\ center\ ).(height\ of\ the\ rotor) \text{..........} 2.6$$

2.1.1.2 Air Density

The wind power varies linearly with the air density sweeping the blades.

The air density ρ varies with pressure and temperature in accordance with the gas law:

$$\rho = \frac{p}{R.T} \text{..........} 2.7$$

Where p = air pressure, T = temperature on the absolute scale, R = gas constant.

The air density at sea level, one atmospheric pressure and 15.6°c is 1.225 kg/m^3. Using this as the reference, ρ is corrected for the site specific temperature and pressure. The temperature and the pressure both in turn vary with the altitude. Their combined effect on the air density is given by the following equation, which is valid up to 6,000 meters (20,000 feet) of site elevation above the sea level:

$$\rho = \rho_o . e^{-\left\{\frac{0.297 H_m}{3048}\right\}} \text{..........} 2.8$$

2.1.1.3 Wind Speed Distribution

Having the cubic relation with the power, the wind speed is the most critical data needed to appraise the power potential of a candidate site. The wind is never steady at any site. It is influenced by the weather system, the local land terrain, and the height above the ground surface. The wind speed varies by the minute, hour, day, season, and year. Therefore, the annual mean speed needs to be averaged over 10 or more years. Such a long term average raises the confidence in assessing the energy-capture potential of a site. However, long-term measurements are expensive, and most projects cannot wait that long. In such situations, the short term, say one year, data is compared with a nearby site having a long term data to predict the long term annual wind speed at the site under consideration. This is known as the “measure, correlate and predict technique. [18]

Since wind is driven by the sun and the seasons, the wind pattern generally repeats over the period of one year. The wind site is usually described by the speed data averaged over the calendar months. Sometimes, the monthly data is aggregated over the year for brevity in reporting the overall “windiness” of various sites. The wind-speed variations over the period can be described by a probability distribution function.

Weibull Probability Distribution

The variation in wind speed are best described by the Weibull probability distribution function ‘h’ with two parameters, the shape parameter ‘k’, and the scale parameter ‘c’. The probability of wind speed being v during any time interval is given by the following: [18]

$$h(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-c} e^{-\left(\frac{v}{c}\right)^{k}} for\ 0 < v < \infty \qquad 2.9$$

2.2 Wind System Components

The wind power system is comprised of one or more units, operating electrically in parallel, having the following components:

- The tower.
- The wind turbine with two or three blades.
- The yaw mechanism.
- The mechanical gear.
- The electrical generator.
- The speed sensors and control.

The modern system often has the following additional components:

- The power electronics.
- The control electronics, usually incorporating a computer.
- The battery for improving continuous the load availability in stand-alone mode.
- The transmission line connecting to the area grid.

Because of the large moment of inertia of the rotor, the design challenges include the starting, the speed control during the power producing operation, and stopping the turbine when required. The eddy current or other type of brake is used to halt the turbine when needed for emergency or for routine maintenance. In the multiple tower wind farm, each turbine must have its own control system for operational and safety functions from a remote location.

2.2.1 Tower

The wind tower supports the turbine and the nacelle containing the mechanical gear, the electrical generator, the yaw mechanism, and the stall control.

Both steel and concrete towers are available and are being used. The construction can be tubular or lattice.

The main issue in the tower design is the structural dynamics. The tower vibration and the resulting fatigue cycles under wind speed fluctuation are avoided by design. This requires careful avoidance of all resonance frequencies of the tower, the rotor and the nacelle from the wind fluctuation frequencies.

2.2.2 Turbine Blades

The turbine blades are made of high-density wood or glass fiber and epoxy composites. Modern wind turbines have two or three blades. The steady mechanical stress due to centrifugal forces and fatigue under continuous vibrations make the blade design the weakest mechanical link in the system. Extensive design effort is needed to avoid premature fatigue failure of the blade.

The mechanical stress in the blade under gusty wind is kept under the allowable limit. This is achieved by controlling the rotor speed below the set limit. This not only protects the blades, but also protects the electrical generator from overloading and overheating. One method that has been used from the early designs and continues to be used today is the stall control.

At stall, the wind flow ceases to be smooth around the blade contour, but separates before reaching the trailing edge. This always happens at high pitch angle. The blades experience high drag, thus lowering the rotor power output. The high pitch angle also produces high lift. The resulting load on the blade can cause a high level of vibration and fatigue, possibly leading to the mechanical failure. Regardless of the fixed or variable speed, the design engineer must deal with the stall forces.

2.2.3 Yaw Control

The yaw control continuously orients the rotor in the direction of the wind.

It can be as simple as the tail vane or more complex on modern towers.

Theoretical considerations dictate free yaw as much as possible. However, rotating blades with large moments of inertia produce high gyroscopic torque during yaw, often resulting in loud noise. Too rapid yaw may generate noise exceeding the local ordinance limit. Hence, a controlled yaw is often required and is used.

2.2.4 Speed Control

The wind turbine technology has changed significantly in the last 25 years.

Large wind turbines being installed today tend to be of variable speed design, incorporating the pitch control and the power electronics. Small machines on the other hand must have simple, low cost power and speed control. The speed control methods fall into the following categories:

- No speed control whatsoever. In this method, the turbine, the electrical generator, and the entire system are designed to withstand the extreme speed under gusty wind.
- Yaw and tilt control, in which the rotor axis is shifted out of the wind direction when the wind speed exceeds the design limit.
- Pitch control, which changes the pitch of the blade with the changing wind speed to regulate the rotor speed.
- Stall control. In this method of speed control, when the wind speed exceeds the safe limit on the system, the blades are shifted into a position such that they stall. The turbine has to be restarted after the gust has gone.

Variable-Speed Operation

At a given site, the wind speed can vary from zero to high gust.

We defined the tip-speed ratio as follows:

$$TSR = \frac{linear\ speed\ of\ the\ blade\ of\ a\ wind\ turbine\ rotor\ \ outer\ most\ tip}{free\ upstream\ wind\ velocity} = \frac{\omega.R}{v} \ldots\ldots\ldots\ldots\ldots\ldots\ 2.10$$

Where R and ω are the rotor radius and the angular speed, respectively

For a given wind speed, the rotor efficiency C_p varies with tip speed ratio (TSR) as shown in the figure. To capture the high power at high wind, the rotor must also turn at high speed, keeping the TSR constant at the optimum level.

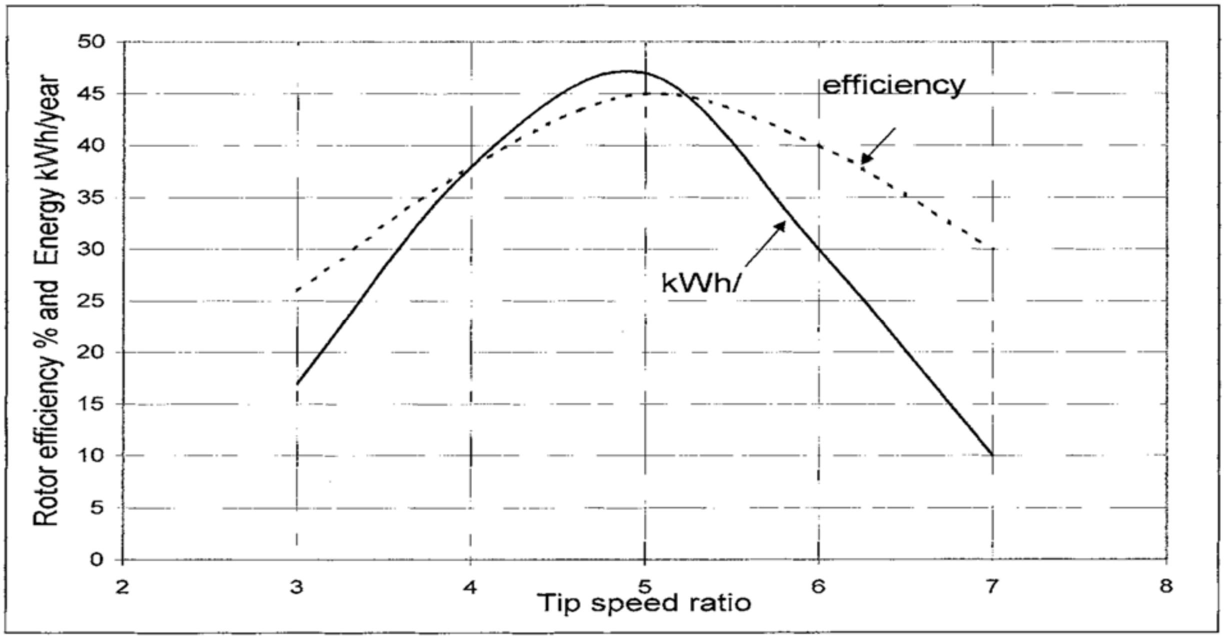

Fig.2.1. Rotor efficiency and annual energy production versus rotor tip-speed ratio [18]

The wind power system design must optimize the annual energy capture at a given site. The only operating mode for extracting the maximum energy is to vary the turbine speed with varying wind speed such that at all times the TSR is continuously equal to that required for the maximum power coefficient C_p. The theory and field experience indicates that the variable speed operation yields 20 to 30 percent more energy than with the fixed speed operation. Nevertheless, cost of the variable-speed control is added.[18]

When variable speed control system is compared with fixed speed system, it can be seen as given below;

Fixed-Speed System	**Variable-Speed System**
Simple and inexpensive electrical	system Higher rotor efficiency, hence, higher energy capture per year
Fewer parts, hence higher reliability	Low transient torque
Lower probability of excitation of mechanical resonance of the structure	Fewer gear steps, hence inexpensive gear box
No frequency conversion, hence, no current harmonics present in the electrical system	Mechanical damping system not needed, the electrical system could provide damping if required
Lower capital cost	No synchronization problems Stiff electrical controls can reduce system voltage sags

Table 2.1.Advantages and disadvantage of Fixed and Variable Speed Systems [18]

2.2.5 Wind System Design Features

The following additional design trade-offs are available to the system engineer:

Number of Blades

This is the first decision that the designer must identify. Wind machines have been built with the number of blades ranging from 2 to 40 or more. The high number of blades was used in old low, tip-speed ratio rotors for water pumps, and the application which needs high starting torque. The modern high tip-speeds ratio rotors for generating electrical power have two or three blades. The major factors involved in deciding the number of blades are as follows:

- The effect on power coefficient
- The design tip-speed ratio
- The cost
- The nacelle weight
- The structural dynamics
- The means of limiting yaw rate to reduce gyroscopic fatigue

2.2.6 Rotor Upwind or Downwind

Operating the rotor upwind of the tower produces higher power as it eliminates the tower shadow on the blades. This also results in lower noise, lower blade fatigue, and smoother power output. The downwind blades, on the other hand, allow the use of free yaw system. It also allows the blades to deflect away from the tower when loaded. Both types are used at present with no clear trend.

2.2.7 Horizontal Axis versus Vertical Axis

Most wind turbines built at present have a horizontal axis. The vertical axis Darrieus machine has several advantages. First of all, it is Omni directional and requires no yaw mechanism to continuously orient itself toward the wind direction. Secondly, its vertical drive shaft simplifies the installation of the gearbox and the electrical generator on the ground, making the structure much simpler. On the negative side, it normally requires guy wires attached to the top for support. This could limit its applications, particularly for the offshore sites. Overall, the vertical axis machine has not been widely used because its output power cannot be easily controlled in high winds simply by changing the blade pitch. With modern low-cost, variable-speed power electronics emerging in the wind power industry, the Darrieus configuration may revive, particularly for large capacity applicati

CHAPTER 3

Photovoltaic Power System

This chapter will give us the general working principle of PV, the components of PV, the materials that PV can be produced, and this is very important to know before we use the PV for water pumping purpose.

The photovoltaic (PV) effect is the electrical potential developed between two materials which are not similar when their common junction is illuminated with radiation of photons. The photovoltaic cell, thus, converts light directly into electricity. The pv effect was discovered in 1839 by French physicist Becquerel. It remained in the laboratory until 1954, when Bell Laboratories produced the first silicon solar cell. Then after application in the U.S. space programs for its high power capacity per unit weight. Since then it has been an important source of power for satellites. Having developed maturity in the space applications, the pv technology is now spreading into the terrestrial applications ranging from powering remote sites to feeding the utility lines.[19]

3.1 The pv Cell

The pv cell is very similar to the classical p-n junction diode as shown in fig, 3.1. When light is absorbed by the junction, the energy of the absorbed photons is transferred to the electron system of the material, resulting in the creation of charge carriers that are separated at the junction. The charge carriers may be electron-ion pairs in a liquid electrolyte or electron hole pairs in a solid semiconducting material. The charge carriers in the junction region create a potential gradient, get accelerated under the electric field and circulate as the current through an external circuit. The current squared times the resistance of the circuit is the power converted into electricity. The remaining power of the photon elevates the temperature of the cell.

The origin of the photovoltaic potential is the difference in the chemical potential, called the Fermi level, of the electrons in the two isolated materials. When they are joined, the junction approaches a new thermodynamic equilibrium. Such equilibrium can be achieved only when the Fermi level is equal in the two materials. This occurs by the flow of electrons from one material to the other until a voltage difference is established between the two materials which have the potential just equal to the initial difference of the Fermi level. This potential drives the photocurrent.[19]

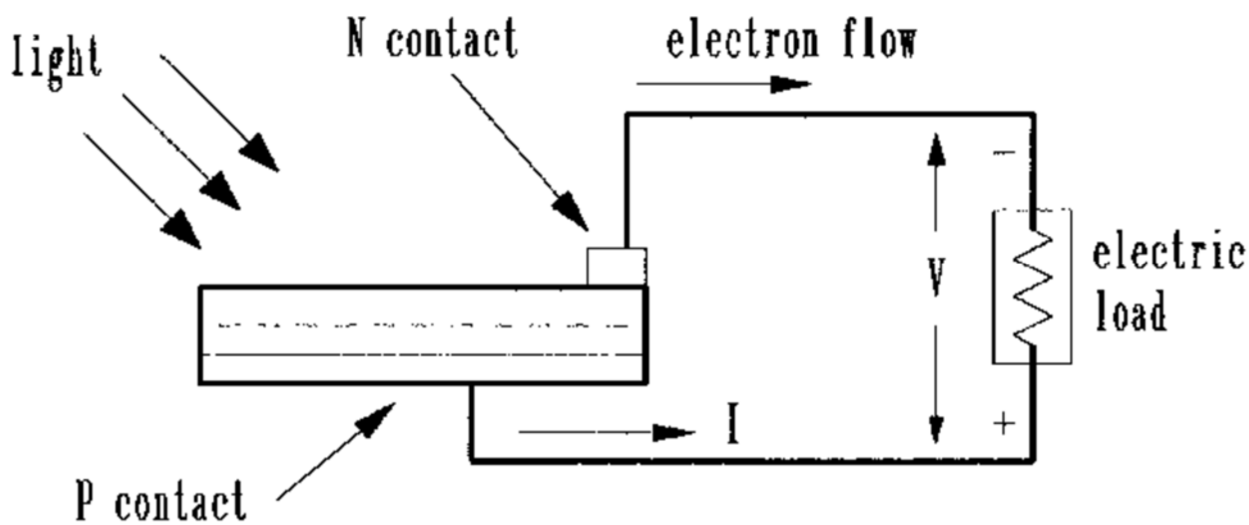

Fig.3.1. Photovoltaic effect converts the photon energy into voltage across the p-n junction. [19]

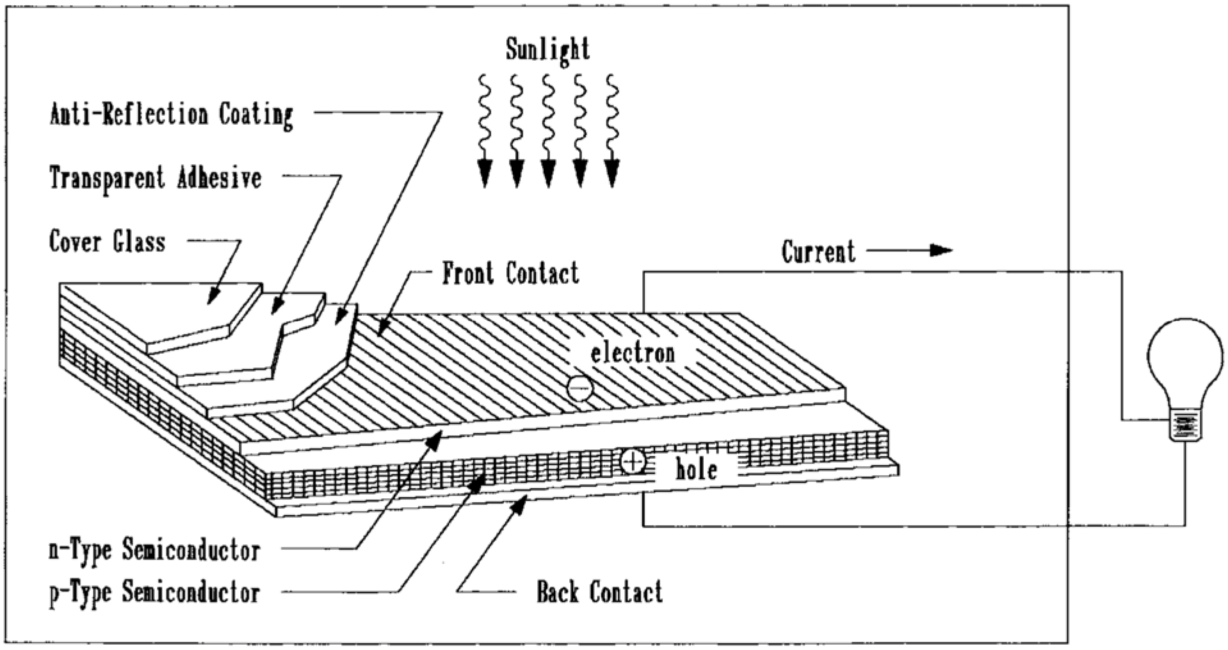

Fig.3.2. Basic construction of pv cell with performance enhancing features (current collecting mesh, anti-reflective coating and cover glass protection).[19]

Figure 3.2.shows the basic cell construction. For collecting the photocurrent, the metallic contacts are provided on both sides of the junction to collect electrical current induced by the impinging photons on one side. Conducting foil (solder) contact is provided over the bottom (dark) surface and on one edge of the top (illuminated) surface. Thin conducting mesh on the remaining top surface collects the current and lets the light through. The spacing of the conducting fibers in the mesh is a matter of compromise between maximizing the electrical conductance and minimizing the blockage of the light. In addition to the basic elements, several enhancement features are also included in the construction. For example, the front face of the cell has anti-reflective coating to absorb as much light as possible by minimizing the reflection. The mechanical protection is provided by the cover glass applied with a transparent adhesive.

3.2 Module and Array

The solar cell described above is the basic building block of the pv power system. Typically, it is a few square inches in size and produces about one watt of power. For obtaining high power, numerous such cells are connected in series and parallel circuits on a panel (module) area of several square feet (fig.3). The solar array or panel is defined as a group of several modules electrically connected in series-parallel combinations to generate the required current and voltage.

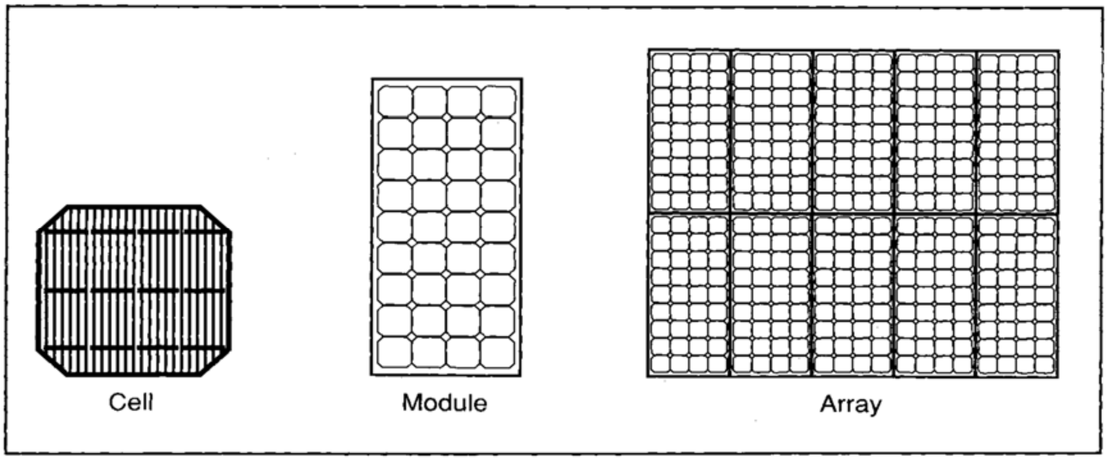

Fig.3.3. several pv cells make a module and several modules make an array. [19]

3.3 Equivalent Electrical Circuit

The equivalent electrical circuit of PV is shown below.

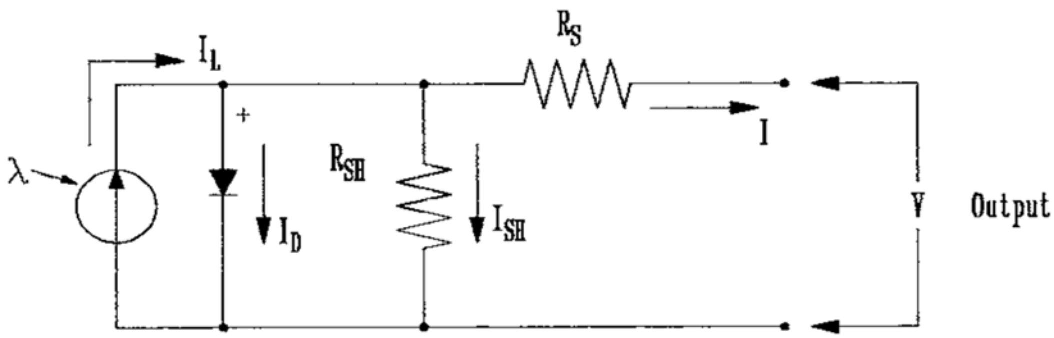

Fig.3.4. Equivalent electrical circuit of pv module, showing the diode and ground leakage currents.[18]

Where, I= is the output-terminal current, which is equal to I_l,

I_l= the light-generated current,

I_d= the diode-current, which is less,

I_{sh}= the shunt-leakage current

R_s=the series resistance which represents the internal resistance to the current flow, and depends on the p-n junction depth, the impurities and the contact resistance.

R_{sh}= the shunt resistance which is inversely related with leakage current to the ground.

In an ideal pv cell, R_s= 0 (no series loss), and $R_{sh} = \infty$ (no leakage to ground).

The open circuit voltage (V_{oc}) of the cell is obtained when the load current is zero, and is given by the following:

$V_{oc} = V + R_{sh}$ ………………………………..……………………………….....................3.1

The diode current is given by the classical diode current expression:

$I_d = I_D \left[\frac{QV_{oc}}{AKT} - 1\right]$ …………...…………...…………………......………………………………..3.2

Where I_D= the saturation current of the diode

Q = electron charge = $1.6 \cdot 10^{-19}$ Coulombs

A = curve fitting constant

K = Boltzmann constant = $1.38 \cdot 10^{-23}$ Joule/°K

T = temperature on absolute scale °K

The load current is therefore given by the expression:

$I = I_L - I_D \left[\frac{QV_{oc}}{e^{AKT}-1}\right] - \frac{V_{oc}}{R_{sh}}$…………………………………………………………………3.3

The last term, the ground-leakage current, in practical cells is small compared to I_L and I_D, and can be ignored. The diode-saturation current can, therefore, be determined experimentally by applying voltage V_{oc} in the dark and measuring the current going into the cell. This current is often called the dark current or the reverse diode-saturation current.

3.4 Open Circuit Voltage and Short Circuit Current

The two most important parameters widely used for describing the cell electrical performance are the open-circuit voltage v_{oc} and the short circuit current I_{sc}. The short-circuit current is measured by shorting the output terminals, and measuring the terminal current under full illumination. Ignoring the small diode and the ground-leakage currents under zero-terminal voltage, the short-circuit current under this condition is the photocurrent I_L.

The maximum photo voltage is produced under the open-circuit voltage. Again, by ignoring the ground-leakage current, Equation above with I = 0 gives the open-circuit voltage as the following: [16]

$v_{oc} = \frac{AKT}{Q} \log_n(\frac{I_L}{I_D} + 1)$ ……………………………………………………………………3.4

3.5 Array Design

The major factors influencing the electrical design of the solar array are as follows:

- The sun intensity.
- The sun angle.

- The load matching for maximum power.
- The operating temperature.

These factors are discussed below.

3.6 Sun Intensity

The magnitude of the photocurrent is maximized under full bright sun. On a partially sunny day, the photocurrent diminishes in direct proportion to the sun intensity. The I-v characteristic shifts downward at a lower sun intensity as shown in figure 3.5. On a cloudy day, therefore, the short circuit current decreases significantly. The reduction in the open-circuit voltage, however, is small.

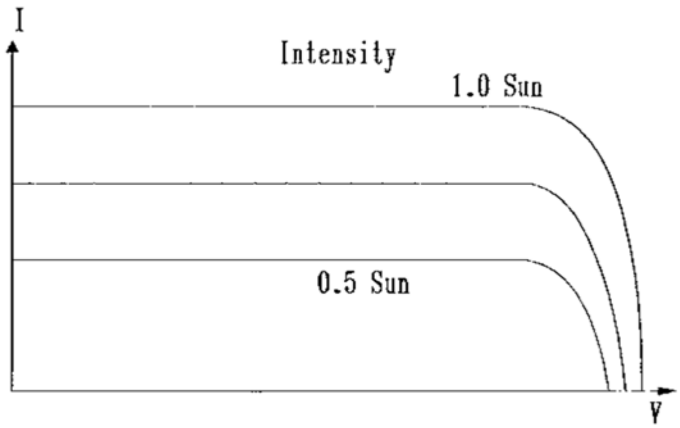

Figure 3.5 I-v characteristic of pv module shifts down at lower sun intensity, with small reduction in voltage.[18]

3.7 Sun Angle

The cell output current is given by $I = I_o cos\emptyset$, where I_o is the current with normal sun (reference), and $\emptyset$ is the angle of the sun line measured from the normal. This cosine law holds well for sun angles ranging from 0 to about 50°.

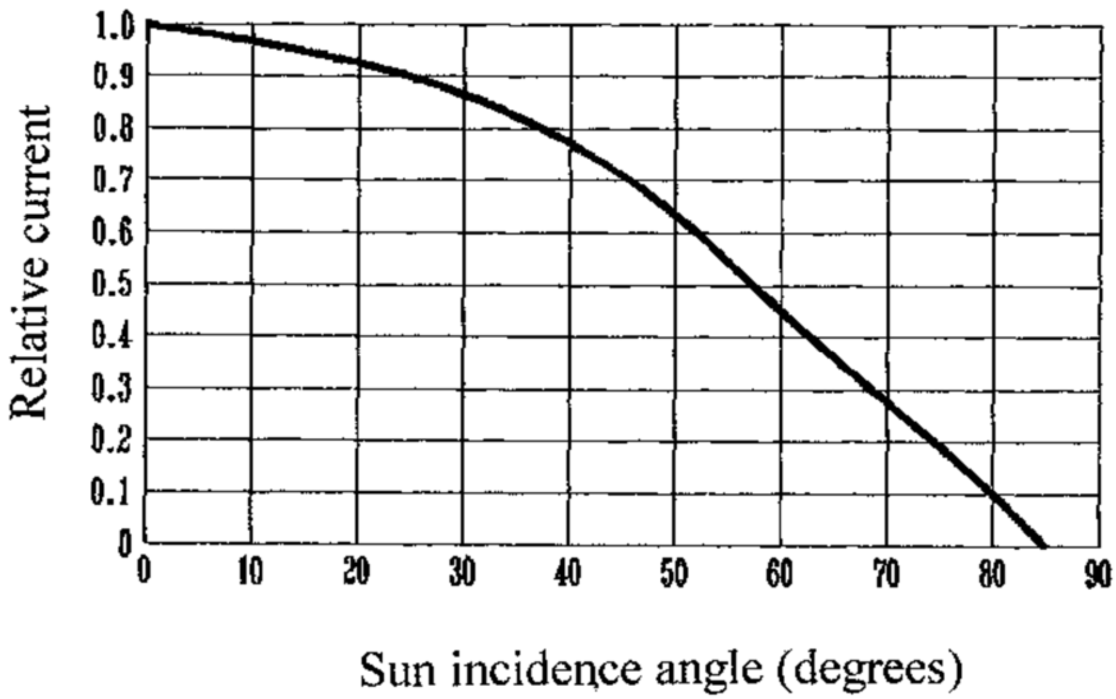

Figure 3.6 Kelley cosine curve for pv cell at sun angles from 0 to 90°. [18]

CHAPTER 4

Water Pumping Technologies Options

4.1. Wind Pumps

Wind power has been used to pump water since the early thirteenth century, when the technology was employed for dewatering polders in the Netherlands. Then after expand to different country. Later the American wind pump, made of steel, with a multi bladed fan-like rotor, became the most popular water pumping technology. It was introduced initially to pump water for domestic purposes and for use by railroads between 1860 and 1900. In the early 1900s the wind pumps were used to water livestock on the North American Great Plains. [21]

During the last 100 years, more than eight million windmills have been manufactured in the United States alone, and since the design is successful it expand to another countries. Today over one million windmills are estimated to be in use, mostly in United States, Argentina, and Australia. This type of pump drives a piston (reciprocating) pump linked to reduction gear directly below in the borehole. In general, the traditional windmills are much less efficient than electrical wind turbines because the blades are not true airfoils.

Traditional windmills have a peak rotor efficiency of 25% to 30%, as compared to 35% to 45% for electrical wind turbines with true airfoils. The main difference is that windmills with numerous blades, typically 12–18, produce a high starting torque, which is required to operate the piston pump. The overall wind-to-water efficiency for water pumping windmills is 4–8%.

In all cases, wind water pumping units have been designed beginning with the pump and then the rotor and gearing. The Dutch windmill uses a screw pump that has a medium starting torque and low speed requirement; thus uses a thick heavy rotor with four sails. The American and Australian windmills use a piston pump that has a high starting torque and a slow operating speed; thus uses a multi bladed rotor that furls to slow down when wind speeds exceed 10 m/s. Electric wind pumpers use centrifugal pumps with low starting torques, requiring high operating speeds. For these pumps, a two- or three-bladed rotor with airfoils is designed to give high rotational speeds.

Development of electrical wind turbines to generate either DC or AC current began in the late 1920s. these types of turbines are designed to produce electricity ranging from a few watts (for charging batteries) to a few megawatts. The maximum-size turbine currently made is 1.5 MW in Europe and 5 MW in United States. The minimum common-size wind turbine is 50 W; however, there are also extremely small turbines that produce only few watts and can be erected and taken down by a single person. These turbines can be used for charging batteries on sailboats and recreational vehicles.[22]

4.1.1. Mechanical Wind Pumps

The old American windmills have evolved in terms of weight, cost, and efficiency. Two major improvements include the development of a counterbalance on the weight of the sucker rod and the variable-stroke design. These improvements could double the water output of the traditional farm windmill. One of the problems with traditional windmills was their tendency to speed up when the sucker begins to go down, and then slow down on the upstroke, a result of lifting the weight of both the rod and the water. This speed variation changes the tip-speed ratio of the rotor and its efficiency. Adding a counterbalance weight on the suck rod or springs could solve this problem. In this way, steady rotor speed is maintained with a more optimum relationship between the wind speed and the rotor. This concept was tried experimentally, but windmills incorporating the improvement have not yet been manufactured.

A second basic problem with traditional wind pumps was the relationship between wind speed and stroke. The power in the wind increases cubically with wind speed, while the water discharge rate of the piston pump increases linearly. This relationship affects the performance of the wind pump because the stroke of the old wind pumps had a fixed position. If the stroke is adjusted for optimum production at high speed for a given well depth and pump size, then the pump performs is very poor during the wind speed is low and vice versa. So the stroke should be able to vary along with the wind speed for better matching of the pumping rate with the available power of the wind. By considering the above condition, modern wind pumps are designed with variable stroke ability.

The principle of operation in the piston pump is that when water is sucked into the cylinder through a check valve on the upstroke, the piston valve is held closed by the weight of water above it, and simultaneously, the water above the piston is pumped out of the cylinder. On the down stroke, the lower check valve is held closed by both its weight and water pressure, while the piston valve is forced to open to displace the trapped water through the piston.

Then, the upstroke follows to repeat the next cycle.

Modern wind pumps are designed to use only 6 to 8 blades of true airfoils, while the traditional windmills have 12 to 18 curved steel plates. (Traditional wind pumps rotor diameters are from 2 to 5 m (6 to 16 ft) and Australia's Southern Cross wind pumps are available up to 8 m (25 ft). As a result of the number and shape of blades and their sizes change during the design, the efficiency of modern wind pumps increase twice as that of traditional wind pumps. Similarly, the cost of wind pumps also decreases by using fewer blades.[21]

4.1.2. Electrical Wind Pumps

A more promising technology than mechanical wind pumps is the development of electric wind turbine pumps. Modern wind generators can produce AC- or DC-electric output and can be used to pump water directly connected to AC or DC motors. Centrifugal pumps are used for this technology, since electric wind turbines are designed for low-solidity rotors. This technology eliminates the use of batteries and inverters by directly coupling the wind turbine with an AC motor, which then drives the centrifugal pump at varying speed.

Electrical wind pumps simplifies the problem of matching wind turbines with appropriate water pumps, by varying the load electrically instead of mechanically in much the same way as varying the stroke in windmills. It also allows wind turbines to be located where the winds are strongest, typically at the crest of hill. Traditional windmills must be located directly over the water source, usually at the foot of a hill.

Unlike traditional windmills, electric wind turbines require a higher starting wind speed and perform better in high winds than low ones. Electric wind pumps are twice as efficient as traditional windmills and are cost-competitive compared to diesels, PV systems, or traditional windmills. Modern electric wind turbines have fewer moving parts than traditional windmills, which keep maintenance costs low. Electric wind turbines are also quite versatile.

The theoretical maximum conversion efficiency of kinetic energy used by the perfect wind turbine is 59.3% (the Betz limit). In practice; however, wind turbine rotors convert much less energy than the Betz limit. Optimally designed rotors reach slightly above 40% efficiency. [22]

4.2. Photovoltaic Pumps

PV-powered water pumps are basically similar to wind turbine pumps as both of them use the intermittent power. When there is enough sunlight, the system functions well. Unless battery storage is available during absence of sun light, the system stops working.

The two basic design approaches for PV water pumping systems are to use battery backup or to use PV power directly. The simplest PV water pumping system consists of a PV array directly connected to a DC motor and a pump. This type of configuration is used for smaller applications and is economically competitive up to a hydraulic equivalent load (the product of the daily water production and the total pumping head) of $600\frac{m^4}{d}$. PV pumps using DC motors are useful for individual homes and small communities.

Unlike other PV systems, energy for water pumping systems can be stored in the form of water in water tanks. So, battery storage is not necessary for night pumping to minimize unnecessary lose. A PV array used directly to pump water can also be used to store water in tanks for use at night and on days when there is poor solar radiation.

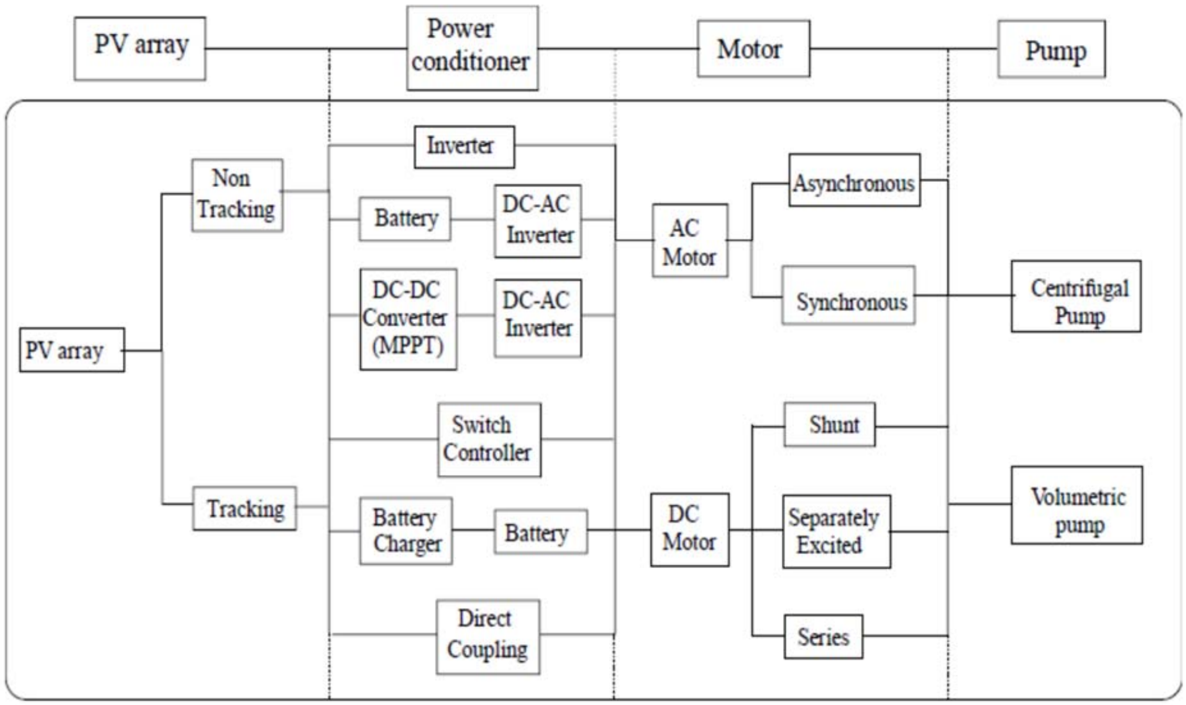

Figure 4.1 Typical PV water pumping systems. [21]

PV systems coupled with AC motors require DC/AC inverters. These types of PV systems can be used for higher capacities. Generally, motors powered by PV are connected to any variable-speed (centrifugal) pump.

PV pumps for rural applications should usually be as simple as possible, so they can be easily operated and locally maintained. Simpler systems are usually cheaper and, therefore, more attractive to rural communities.

The use of PV water pumping systems varies depending on the requirements and conditions under which pumping takes place. The volume of water required varies by season, time of day, and type of application. For example, water for irrigation is seasonal, while water for drinking requires a continuous supply. The availability of water from a PV pump over the course of a year also depends on several factors, such as the availability of solar radiation energy, the capacity of the water resource, borehole recovery rate, pumping head, and seasonal variability of static head. The availability of solar radiation energy varies seasonally and by time of day. Therefore, a PV pumping system must be properly configured and designed, based on the need and type of application. Selection of the most suitable components, configuration, and location of the system are critical to the system's economic viability and long-term performance.

4.2.1. Photovoltaic Arrays

PV cells are made of semiconductor materials that generate electricity by electromagnetic means when exposed to sunlight. If a minority electron-hole pair generated by absorption of photons in the semiconductor material (the holes in n-regions, and the electrons in p-region) diffuses into a boundary region in which there is an electric field, then the electron will be accelerated into the n-region, and the hole into the p-region. This causes the n-region to accumulate a negative charge, and the p-region a positive charge, which results in a photo voltage. If there is a closed external circuit, a photocurrent and photo voltage can be measured by the external resistance.

It is possible to shift the balance of electrons and holes in a silicon crystal lattice by doping it with other atoms. Atoms with one more valance electron than silicon are used to produce n-type semiconductor material. Atoms with one less valence electron result in p-type material. Once the n- and p-type semiconductor materials are created, the process mentioned above will produce photo voltage. The most common materials used in forming n- and p-type semiconductor materials are phosphorus (Group V) and boron (Group III). A p–n junction can be formed either through a high-temperature diffusion process or an ion implantation process. Diffusion can be made either from a vapor phase, or out of a solid phase.

4.2.2. Types of semiconductor materials used to produce PV cells

The most common semiconductor materials used are:

- Mono- (single) and polycrystalline silicon (c-Si),
- Amorphous silicon (a-Si),
- Gallium arsenide (GaAs),
- Copper-indium-diselenide (CuInSe2), and
- Cadmium telluride (CdTe).

Crystalline silicon and amorphous silicon are the most dominant semiconductor materials for commercial PV cells. The other semiconductor materials, GaAs, CuInSe2, and CdTe, do not play a big role in the short term for terrestrial purposes.

Crystalline silicon has an ordered crystal structure, ideally with each atom lying in a preordained position. Mono crystalline silicon is the most expensive type of silicon because of the careful and slow manufacturing processes required. The productions of multi or polycrystalline silicon are technically easy and with high speed of production when compared with that of Mono crystalline Silicon. So multi or polycrystalline silicon is cheaper than those for a single-crystal material. The grain boundaries reduce the cell performance by blocking carrier flows and allowing extra energy levels in the forbidden gap, thereby providing effective recombination sites and shunting paths for current flow across the p–n junction.

Amorphous silicon can be produced even more cheaply than polycrystalline. There is no long-range order in the structural arrangement of the atoms, which results in areas within the material that contain unsatisfied or dangling bonds. These in turn result in extra energy levels within the forbidden gap, making it impossible to dope the semiconductor when pure, or to obtain reasonable current flow in a solar cell configuration. The incorporation of atomic hydrogen to the level of 5–10% in amorphous silicon saturates the dangling bonds and improves the quality of the material. It also increases the band gap *EG* from 1.1 eV in crystalline silicon to 1.7 eV, and is much more strongly absorbing for photons of energy above the latter threshold. The thickness of material required to form a functioning solar cell is therefore much smaller.

Amorphous silicon and other thin-film technologies, in which films of very thin semiconductors are deposited onto glass or other substrates, are used for solar cells in many small consumer products, such as calculators, watches, and non-critical outdoor applications.

In principle, thin film provides a low-cost means of production. However, performance and lifetimes are not yet good enough to warrant large-scale applications.

Under laboratory conditions, single-crystal PV cells with higher than 23% efficiency can be produced. The efficiency of commercial modules using silicon cells is presently around 15%.

That efficiency will continue to increase gradually and is expected to be over 20% in coming years. General consensus is that 20% efficiency is feasible for commercial modules based on silicon technology. Crystalline silicon ingot technologies are most compatible, reaching 20% module efficiency. Multi crystalline ingot technologies are capable of further improvement, but are unlikely to exhibit the highest performance.[22]

4.2.3. Power Conditioning Devices

Electrical power can significantly deviate from the ideal as a result of overvoltage, under voltage, voltage spikes, chopped voltage waveform, harmonics, electromagnetic interference, etc. Power conditioners are used to suppress some or all of the electrical disturbances. Some of the power-conditioning devices for PV system applications include batteries, battery charge controllers, Maximum Power Point Tracker, DC-DC converters, DC-AC inverters, and switch controllers.

Blocking diodes are available to protect batteries from short circuits in the PV array, as well as to prevent discharge through the PV cells when they are not illuminated. Diode voltage droppers can also be used to ensure that the batteries do not supply excess voltages to the load. Battery voltage controllers are needed in PV-based power systems to limit discharge levels and overcharging. One of the main drawbacks with using batteries for water pumping is that battery efficiency can be as low as 60% through self-discharge; this offsets the benefit gained by operating the PV pump on poor solar radiation days or at night.

High-power processors can be classified into three categories: direct current (DC)-alternating current (AC) inverters, AC-DC rectifiers, and DC-DC converters. [21]

4.2.3.1 Inverter

The main functions of an inverter include:

- Inverting the DC voltage of a PV array output into AC output,
- Wave shaping the AC voltage output,
- Regulating the effective value of the voltage output, and
- Operating at or near array peak power point.

The input power source can be either a DC voltage source or a DC current source and deliver AC power to load impedance.

Inverters can be classified into two groups: voltage source inverters (VSIs) and current source inverters (CSIs). VSIs are fed by a DC voltage source. If the load quality is sufficiently high, the current through the resonant circuit is sinusoidal and the currents through the switches are half-wave sinusoids. The voltages across the switches are square waves. This type of inverter operates independently, being activated solely by the input power source, such as PV and wind power sources. In contrast, the CSIs are fed by a DC current source. The voltage across the resonant circuit is sinusoidal for high values of the loaded quality factor. The voltages across the switches are half-wave sinusoids, and the currents through the switches are square waves. CSIs can function only when the output AC line voltage is present. The source of this voltage can be the utility grid or any other power source tied to the inverter output. One of the main advantages of VSIs is the low voltage across the transistors, which is equal to the supply voltage.

The CSIs are used only for high-horsepower applications. They typically operate at a poor lagging power factor and have high harmonic distortion at their AC output. They are also susceptible to commutation faults during AC line failures, but are cheaper than high frequency types. On the other hand, the VSI has an inherent stand-alone operating capability and with proper design and control, operates at a high power factor. Most VSIs exhibit low harmonic distortion.

VSIs can be further divided into three general categories:

- Pulse-width-modulated (PWM) inverters;
- Square-wave inverters; and
- Single-phase inverters with voltage cancellation.

The input DC voltage in PWM inverters is essentially constant in magnitude when a diode rectifier is used to rectify the line voltage. The inverter must control the magnitude and frequency of the AC output voltages. This is achieved by pulse-width modulation of the inverter switches; hence such inverters are called PWM inverters.

The output AC voltage has a waveform similar to a square wave; hence these inverters are called square-wave inverters. In the case of single-phase inverters, it is possible to control the magnitude and frequency of the inverter output voltage, even though the input to the inverter is a constant DC voltage and the inverter switches are not pulse-width modulated (so the output voltage wave-shape resembles a square wave). These inverters combine the characteristics of the two previously described inverters. The voltage cancellation technique works only with single-phase inverters, not with three phase inverters. [21]

4.2.3.2 Rectifier

Rectifiers convert an AC voltage or current into a DC voltage. At low frequencies of 50, 60, and 400 Hz, peak rectifiers are widely used. The ratio of the diode peak current to the diode average current; however, is very high in these rectifiers, and the diode current waveforms contain a large amount of harmonics. Therefore, peak rectifiers are not used at high frequencies.

4.2.3.3 Converter

DC-DC converters are widely used in regulated switch-mode DC power supplies and in DC motor drive applications. A DC-DC converter is a combination of inverter and rectifier.

The functions of DC-DC converters are to:

- Convert a DC input voltage into a DC output voltage,

- Regulate the DC output voltage against load and line variations,
- Reduce the AC voltage ripple on the DC output voltage below the required level,
- protect the supplied system from electromagnetic interference, and
- Provide isolation between the input source and the load, where it is required.

DC-DC converters can have two distinct modes of operations, which are based on continuous and discontinuous current conduction. In practice, a converter may operate in both modes, which have significantly different characteristics. [22]

4.3. Hybrid Water Pumping Systems

Hybrid water pumping systems can consist of several combinations, including wind with PV; wind, PV, and another renewable energy source; wind with diesel; or PV with diesel. Each combination can have battery storage and/or inverters with or without a backup generator or utility power line.

Hybrids offer greater reliability than either wind or PV technology alone, because each power source from wind or solar is independent of the other. For instance, in winter, when solar energy is low, sufficient wind energy is usually available to compensate for the loss from a PV power source. Another advantage of a hybrid system over an individual wind or PV system is the use of the technology's reliability for integrated applications. With a hybrid system, the entire community can get reliable power for individual home lighting, street lighting, TV and radio, and such community services as water pumping, health clinics, school lighting, telecommunications, and many other infrastructure functions. [22]

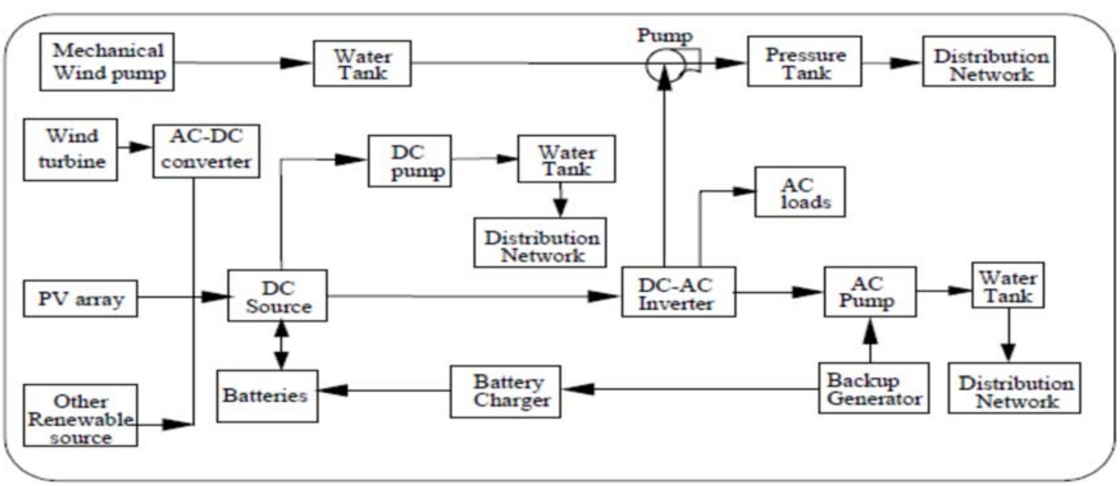

Figure 4.2 Schematic diagram of stand-alone hybrid system with a backup generator for water pumping applications. [21]

As wind and PV powered water pumping technologies advance, the use of hybrid systems as stand-alone is becoming preferable and less expensive than individual wind or PV systems. Hybrid systems do not need to be designed for worst-case scenarios, because the power is not from a single source.

Hybrid systems permit the use of smaller component sizes, and this lowers the cost of the system. Although hybrid systems are improving in reliability and are reducing the overall size of the power system, their initial costs are still high. Maintenance of hybrid systems also requires a highly skilled person. Therefore, hybrid systems are especially suitable for economically strong communities with well-equipped, skilled manpower for maintaining the systems.

So as explained in the introduction part and above the hybrid system is used for the site that I have selected and to minimize its maintenance cost just after the completion of the project just we train the expert that is living in the woreda from the concerned office and they will maintain.

4.4. Pump and Motor Technology

The motor–pump subsystem includes:

- The motor,
- The pump, and
- The couplings.

Different types of coupling are used for water pumping purposes depending on the type of application and the water demand. Different types of pumps and motors are available for water pumping application depending on:

- The daily water requirement,
- The pumping head,
- The suction head for surface mounted units, and
- The water source.

The most common types of coupling used to pump water are belt and pulley, feed screw, direct coupling (rack and pinion or bolt and flange), and gear transmission.

The efficiency of the driving mechanism depends on the coupling ratio, which is the ratio of the torque of the motor to the torque of the load.

The most common commercially available configurations of motor–pump subsystems are

a. Submerged motor-pump unit:

This is often called a submersible centrifugal motor–pump; because it is simple to install and safe. This is the most common and suitable type of pumping system for village water supplies.

b. Submerged centrifugal pump with surface mounted motor:

Although this type of subsystem is advantageous for maintenance of the motor, the power losses in the shaft bearings and its high cost make it unattractive.

c. Floating motor–pump:

This type of pumping unit is recommended for pumping surface water for irrigation and drainage. It is portable and the chance of dry running is minimal.

d. Positive displacement pump (volumetric pump):

This type of pump is driven by a shaft from a surface-mounted motor, and is suitable for high head and low flow rate applications.

e. Surface mounted motor–pump unit:

This type of unit has a self-priming mechanism and is recommended for low head duties. The suction head should be as long as 6 meters. The pump may be centrifugal or positive displacement.

4.4.1. Motors

Motors are usually divided into two types: DC and AC. DC motors are categorized further into two types: permanent magnet (brushed or brushless type) and wound-rotor-field.

Similarly, AC motors are divided into induction (asynchronous) and synchronous types.

Induction motors are further divided into squirrel-cage and wound-rotor types. Wound-rotor motors are generally used for industrial applications, thus only the permanent-magnet DC motors and the squirrel-cage induction motors will be discussed.

All PV-powered pumping systems have, as a minimum, a PV array, a motor, and a pump. The array can be coupled directly to a DC motor or, through an inverter, to an AC motor. The motor is connected to any one of a variety of variable-speed pumps. Normally, the choice of a motor for a PV-powered system depends on the size required, the water source type (borehole or surface water), and the availability of electronics that go with it. DC motors are attractive and efficient for low water demand and for a short cable distance between the PV array and the motor. DC motors are not attractive for long-distance cabling, because the power loss in the cable increases as the location of the water well becomes farther from the PV array. In terms of simplicity, DC motors are appealing for PV pumping, because PV modules produce direct current and can be directly coupled to the DC motor with or without power conditioning.

Permanent-magnet (brushed) types of DC motors are typically used for PV applications because the rotation of the motor is caused by the brushed commutation without inducing the surrounding magnetic field electrically. No power is consumed in the field windings, which leads to a higher efficiency and smaller PV array sizes. One disadvantage to using brushed motors is the need for new brushes about every 2,000–4,000 hours (about every two years for PV pumps). This is considered to be costly maintenance. On the other hand, brushless motors have a permanent magnet rotor and electronically switched field windings that operate by means of a rotor position sensor. Although these types of motors have no special maintenance requirements, they are relatively new for PV pumping applications and are not yet reliable. The extra electronic circuit for the rotor position sensor also adds to the cost. During the last few years; however, designs have improved greatly and they are likely to be attractive for small pumping applications in the future.

AC motors are typically used for medium- to high-power demand applications. Induction motors with squirrel-cage rotors are most commonly used, because of their low cost and rugged construction. An induction motor operates at nearly constant speed, although it is possible to vary the speed using electronic converters (inverters). The use of inverters for controlling induction motor speeds is highly efficient over wide speed and load ranges.

Brushless DC motors are the most attractive for smaller pumping applications and AC motors incorporated with inverters are more attractive for larger installations.

Efficiencies of a motor–pump subsystem are 40%–60%, depending on the motor, pump, and power transmission. The optimum efficiency for motors is about 85%; for the pump about 70%; and for the suction and delivery pipe about 80%. The friction loss in pipes depends on the diameter and pressure the pipe, as well as the amount and type of fittings used in the system.

4.4.2. Pumps

There are two basic types of pumps:

4.4.2.1. Positive displacement pump

These pumps operate by mechanically advancing a sealed quantity of water by using several mechanisms such as pistons, cylinders, and elastic diaphragms. The flow rate or speed of a positive displacement pump is directly proportional to the motor speed and power output. At low power input a positive displacement pump will pump a quantity of water to the same vertical lift as high power input, except at slower rate. Because of this, positive displacement pumps have a high starting torque as they must always work against the full system pressure even at low speeds.

There are two commercially available positive displacement pumps. Those are submersible (diaphragm) and non-submersible (jack, piston, and rotary vane). The most common is the Jack pump. All positive displacement pumps have seals or mating surfaces that can wear, so most require regular maintenance to replace or repair worn parts. Such parts can easily wear with dirty water even though pre-pump filters are sometimes used.

a. Diaphragm pumps: are sometimes called submersible positive displacement pumps and are often used for small applications, such as pumping small quantities of water from deeper wells or water tanks where surface pumps are limited by their suction head. Such pumps can also be used for pressurized storage tanks to lift water to a discharge head above the ground surface. Diaphragm pumps generally use DC motors. They require periodic maintenance depending on the depth of head pumped and their operational hours. The brushes of the DC motor must be changed every 2,000–4,000 hours and the elastic diaphragm must be replaced every 12 to 24 months depending on the hours of use.

b. Jack pumps: functions like windmills except that they are powered by electric motors. Like the windmill, the reciprocating jack is connected by a long sucker rod to a cylinder. Jack pumps require regular maintenance, especially because the leathers on the plunger at the end of the long sucker rod can wear out easily and must be replaced every 6 to 24 months depending on the hours of use. The leather is used to create seal against the cylinder. Jack pumps are generally used for medium applications at medium depth.

c. Piston pumps: are generally connected to a surface-mounted motor and used to pump water from shallow wells, surface water sources, and pressurized storage tanks, or through long pipes. The suction head is limited to 6 meters. They are not tolerant to silt, sand, or abrasive particles because the piston seals are easily damaged. Filters may be used to remove the dirt.

d. Rotary vane pumps: which is sometimes called helical rotor pumps is operate according to a displacement principle for lifting or moving water by using a rotating form of dispenser.

They contain spinning rotors with vanes that seal against the casing walls. Such pumps are mostly surface-mounted because of suction head limitations. The suction head is limited to 6 meters. They produce a continuous or sometimes a slightly pulsed water output.

A main advantage of helical rotor pumps is their ability to pump water at either low or higher motor speed levels, which correspond to higher or low, pump speeds, which lead to higher volumes of pumped water per day even at low motor speeds. Unlike reciprocating devices, rotary vane pumps have steady drive conditions, which may eliminate the problem of water hammer and cavitations. Rotary vane pumps are not tolerant to silt, sand, or abrasive particles, so filters may be used to remove dirt.

The unique advantage of helical rotor pumps over centrifugal pumps is their ability to operate efficiently over a wide speed ranges and heads, whereas the efficiency of centrifugal pumps deteriorates from the rated speed.

Generally, positive displacement pumps are best for low flows and high pumping heads.

4.4.2.2. **Centrifugal pumps**

These pumps are designed for a fixed head; if the pumping head deviates from the design point their efficiency decreases. Unlike the positive displacement pumps, decrease in pumps power supply can cause it to fail at delivering water from a borehole due to its vertical lifting capability is directly proportional to the power input.

The best type of equipment for a particular pumping application depends on the daily water requirement, pumping head, suction head for surface mounted pump-sets, and the water source. Submersible centrifugal pumps are best for high flow rates and medium heads.

Centrifugal pumps use a spinning impeller or rotor to propel water. Generally, two mechanisms pump water continuously; either using a single impeller or a combination, and they are spun either deflecting by the blades or by using centrifugal force when water is whirled into a circular path when the shaft holding the impellers or blades rotates at a high speeds. The water flow rate in the impeller is directly proportional to the speed of the impeller because the water movement in the impeller depends on the force created by the impeller, which in turn depends on the power supply to the motor. The motor speed may not be the same as the speed of the impellers, and there will be transmission losses at the coupling, depending on the kind of coupling used between the pump and the motor. Transmission losses between the pump and motor shafts using direct coupling are minimal; losses from a gear, belt, and pulley transmission combination are higher.

A single impeller on a centrifugal pump can lift water only through fairly low heads, so several impellers are stacked in a pump to create enough pressure to lift water to a higher head. For this reason, centrifugal pumps are good for pumping large volumes of water at low to medium heads. Centrifugal pumps require relatively low maintenance and are fairly tolerant of dirty water because they do not have seals or mating surfaces to wear.

However, the impeller can clog and erode if the water contains excessive sand or grit.

Commercially available centrifugal pumps are categorized into axial flow, radial flow, and mixed flow depending on the design of the impellers.

Unlike positive displacement pumps, centrifugal pumps are limited by their operating conditions; otherwise, efficiency will deteriorate when rated speed changes. However, wider ranges of heads and flows can be achieved using different types of impellers.

Axial flow pumps are sometimes called propeller pumps because the mechanism is similar to a propeller in a pipe. Because such impellers are designed for high flow and low head applications, they are most suitable for irrigation purposes. Axial flow pumps are generally designed for large flows at low heads. Large pipe diameters are required and concrete pipes are typically used instead of steel pipes to lower the high cost.

When high heads and low flow rates are required, radial flow impellers are the most suitable. For radial flow impellers, the ratio of discharge to inlet diameter of the impeller is very high, which produces a large radial flow component. In axial flow impellers, the ratio of the discharge to inlet diameter is very small because water flows by the lift generated by a moving streamlined blade fixed in a casing.

Radial flow pumps are often called centrifugal pumps because centrifugal force is applied when water is whirled into a circular path and when the shaft holding the impellers or blades rotates at high speeds. Centrifugal pumps, which are available with either AC or DC motors, can be surface-mounted, floated, or submersible depending on the requirement.

Such pumps can lift medium to large volumes of water approximately about 200 m3/d from shallow to deep wells (to 150–200 meters). Series of impellers are used for surface mounted and submersible centrifugal pumps to create a large pressure differential to attain the required pumping head. More than 20 impellers can be stacked, especially in submersible pumps.

However, floating centrifugal pumps use only a single impeller where the pump is suspended just below the water surface by a float.

The operational characteristics of radial flow (centrifugal) pumps are reasonably well matched with PV and wind systems. They can be directly coupled by carefully choosing the motor speed, voltage, coupling ratio, and pump characteristics.

On the other hand, the operational characteristics of volumetric pumps are not a good match to the output of PV and wind (electric) systems. The motor driving a volumetric pump requires a constant current for a given head, apart from the starting current, which tends to be higher. This condition does not match the PV and wind turbine characteristics where the current varies almost linearly with solar radiation and wind speed. Therefore, maximum power point tracking (MPPT) controllers are usually used with volumetric pumps.

Mixed flow pumps are sometimes called vertical turbine pumps. These pumps have internal blades in the impeller that partially propel the water, similar to the axial flow impeller, but the discharge from the impeller is at a greater diameter than the inlet so partial radial flow is involved to create velocity to the water from centrifugal forces that are generated. Vertical turbine pumps generally consist of submerged stacked impellers powered by a long drive shaft from a surface-mounted motor. Such pumps are not suitable for use with surface water sources and are best used in wells of shallow to moderate depth.

An advantage to mixed flow pumps is that the surface-mounted motor is easily accessed for repair and maintenance. However, pump efficiency is reduced by twisting, vibration, and friction in the drive shaft. These pumps may also have bearing problems. Installing them can be difficult and time consuming. There is now a move away from surface-motor shaft-driven submersible pumps for deep wells because of such difficulties. Submersible centrifugal pump-sets are now almost exclusively used in such cases.

Therefore from the above brief note, the radial flow centrifugal pump is used for the purpose of pumping water for the livestock and people living in the Semento kebele and its surrounding.

4.4.3. Water Storage and Distribution

4.4.3.1. Water Storage

Water storage tanks can be made of steel, polyvinyl chloride (PVC), concrete, or masonry.

Open ponds can also be used to store water, depending on the volume required and type of application. Steel, fiberglass, and PVC water tanks are those mostly used for wind and PV water supply applications. Small- to medium-sized concrete and masonry water tanks can also be used for wind and PV water supply schemes, but they can be more expensive than ready-made fiberglass, steel, and PVC water tanks. Larger concrete and masonry water tanks are usually more practical for large water supply schemes.

Water for livestock can be stored in an open tank made of steel or concrete. The number of cattle served determines the size of the tank. Three to five days' storage is typically recommended for livestock water storage.

Two mistakes are commonly made in selecting the proper size and type of water tank for wind and PV water pumping systems. First, the size of the water tank is often selected as if it were to be used for a conventional water supply scheme. Secondly, the material used to construct the tank does not take into consideration the local conditions. The size of a water tank is very important for wind and PV pumps because of the uncertainty of prevailing weather conditions. Solar radiation and wind energy, unlike conventional energy sources, are not available on demand, thus more water storage is necessary to be prepared for a worst condition. It is usually recommended that there be at least three days' of storage in an enclosed tank.

Water tank types should also be selected based on topography and local conditions. Although it may be less expensive to use locally made steel tanks, they can easily and quickly rust.

While antirust treatments can solve the problem, it is imperative to select the right type of painting chemical for drinking water storage. Another problem with steel tanks is the possibility of water in the tank getting hot during the day. In warm climates, the water inside steel tanks gets hotter more rapidly than in concrete or masonry tanks, which can increase the risk of bacterial growth and waterborne diseases.

For this thesis, just we construct reservoir which is covered by plastic material to prevent the water loss to the ground and the water that is lost due to the evaporation is substituted by the over designed water storage for livestock and assumed that water storage tank for two days are required for the people.[29]

Chapter 6

Need and data assessment and selection of pumping systems

6.1. Need and data assessment for water pumping system

Factors affecting the selection of a solar and wind powered pump include the following: [33]

- Total dynamic head (TDH).
- The water source (surface vs. well).
- The available electrical power (peak power) and total energy, i.e. power x time produced by the PV panel array and/or wind.
- The water requirement (flow rate and/or total volume in a given time period, including the storage requirement).
- The water quality (including the amount of sediment, organic content, sand, and total dissolved solids [TDS]) may also be a required consideration for selecting a pump, as per the manufacturer's specifications.

6.1.1. Need assessment for water pumping system

The following twelve steps are used in PV or/and wind powered water pump system. These steps will help to ensure that the system functions properly and that water is supplied for the operation in the amounts and at the locations required.

Step 1: Water Requirement

The first step in designing a solar or/and wind powered water pump system is to determine the overall water requirement for the operation. This can be done in part by using the average water requirement values for peoples and livestock.

Purpose	Consumption in liter per day
drinking	2.3
Cooking	4.5
ablution	18.2
Washing of utensils and houses	13.6
Flushing of washing cloth	13.6
Bathing	27.3
Total	**106.8**

Table 6.1 Water consumption of households [34]

In the kebele there are around 2444 households [24]. So the total water daily requirement for the site is calculated as:

$$107 \frac{l/_d}{hh} x2444hh = 261508\, l/_d$$

Where $\frac{l/_d}{hh}$ is represent liter per day per household, and $l/_d$ is liter per day

The above value is the average daily water requirement and the maximum water requirement is find as follow:

$261508\, l/_d\, x180\% = 470{,}714\, l/_d$

From the above 180% is taken from the research done by Haromaya University, in collaboration with the Ethiopia Public Health Training Initiative, The Carter Center, the Ethiopia Ministry of Health, and the Ethiopia Ministry of Education.[34]

Water requirement for one camel

For camels watered daily, with access to water once daily, camels drink on average:

17 ± 5 Liter/day

For camels watered every 4 day, the water deficit was compensated by drinking on average:

49 ± 5 on the 4^{th} day

For camels watered every 8^{th} day, the average water they drink is:

72 ± 5 L on 8^{th}day

For camels watered after 16 days, the average water they drink is:

88 ± 5 L on the 16^{th} day [32]

For the given site the camels should drink water once a day.

Livestock type	Average water consumption in (liter per day per livestock)	Maximum water consumption in (liter per day per livestock)
Equine	45.5	82
Cattle	68.5	120
Sheep	13.6	25
Goat	13.6	25
Camel	17	31

Table 6.2 Types of livestock exist in Semento kebele with their water consumption [26] and [34]

Variation in demand from average

Water consumption of the household and the livestock varies throughout the year. In certain hours, days and months, the demand increases. There are peak hours and days. Thus, the total water supply should be adequate for this peak demand. The average daily consumption of the people residing in the site can be found by dividing the total annual consumption by 365 days.

The maximum daily consumption is about 180% of daily consumption.

The maximum hourly demand may be 150% of average hourly demand.

The variations are very important to consider for the design of various units.

The pipeline conveying water should be capable of meeting the maximum demand of the people and livestock. [34]

No	Livestock type	Number of livestock	Water consumption in (l/d/livestock)	Total water consumption(l/d)
1	Cattle	25,976	120	3,117,120
2	Goat	8,191	25	204,775
3	Sheep	5,754	25	143,850
4	Camel	10,747	31	333,157
5	Equine	1,482	82	121,524
Total water consumption				**3,920,426**

Table 6.3 Total water consumption of livestock exist in Semento kebele [26]

The total daily water required is:

$470714 + 3{,}920{,}426 = 4{,}391{,}140\, {}^{l}/_{d} = 4.4x10^{6}\, {}^{l}/_{d}$

The water consumption for the people and livestock is done for the dry season and is the maximum water consumption for the site. The existing water pumping by using PV and generator can serve for half of them [24] and since the depth of the water existing for that area is very deep and the infrastructural system of the site is not comfortable to use the large equipment such as wind turbine, it is impossible to use the crane. Due to this just we are just forced to solve the problem by dividing it into two. That is doing the analysis for half of the demand ($1.1x10^{6}\, {}^{l}/_{d}$) and multiplying it by two is best way. When we do this just the site is within the kebele and there may be the variation of site which is very negligible.

Step 2: Water Source

The configuration of the water system will be defined primarily by the type of water source used, as well as by the local topography and the location(s) of the delivery point(s). The water source may be either subsurface (a well) or surface (a pond, stream, or spring).

Since the water source is a well for our system, the following items will need to be determined:

- The static water level,
- The pumping rate and associated drawdown (along with any seasonal variation), and
- The water quality.

The existence of water from the well in the Semento Kebele is around 180m deep as explained by NGOs that have drilled the well around the site by using hand pump [24]. For our case due to there is loss, and the availability of water may decrease during the dry season drilling the well more than 180 is recommended.

Depending on the depth of the well and the demand of daily water consumption the pump, motor and the power required is selected. As we can conclude from the nearby water pumped from the well the quality of water has no problem to drink. So the water has no problem for the people or livestock living in the site.

Step 3: System Layout

The third step in the system development process is to determine the layout of the entire system, including the locations and elevations of the following components:

- Water source
- Pump
- PV panels and wind turbines
- Storage tanks
- Points of use (i.e. water troughs)
- Pipeline

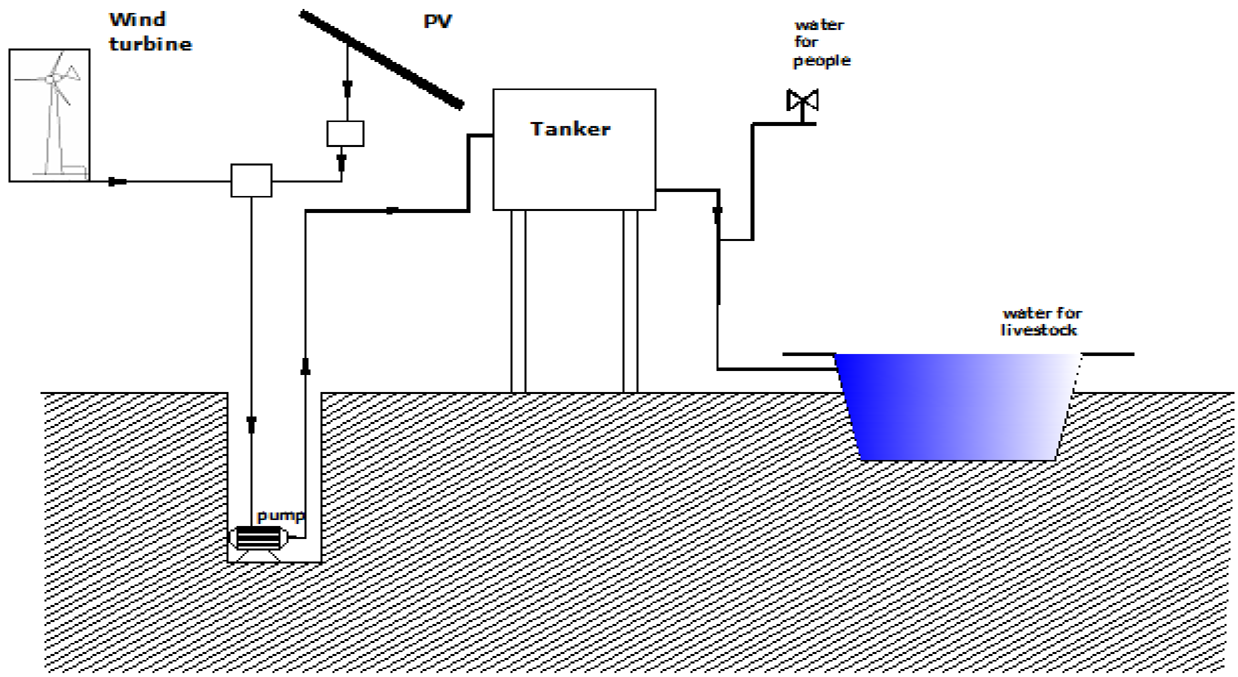

Figure 6.1Layout of the hybrid system

Step 4: Water Storage

A water storage tank is normally an essential element in an economically viable wind and /or solar-powered water pump system. A tank can be used to store enough water during peak energy production to meet water needs in the event of cloudy weather or maintenance issues with the power system. Ideally, the tank should be sized to store at least a three-day water supply for the solar or wind alone [33].

Normally, most of books recommend for solar water pumping or wind water pumping separately to store for 3-5 days for cloudy days. But, this research is solar-wind hybrid system and at the same time the wind and solar will not vary. Due to this storing water for 3-5 days is not mandatory. For this research the water storage must store for 2 extra days only, that is needed by the livestock and people.

The storage tank for the people is:

$$\mathbf{2dx117,678.5,{}^{l}/_{d} = 235,357litre = 235.357m^3\ or\ non-SI\ unit,\frac{235,357}{3.79} = 62,099.5\ Gal.}$$

From the Internet source the price of the storage tank with all its additional cost is approximately $10,000. [27]

The solar wind hybrid system is assumed to work effectively for 6hrs in a day. So the solar wind hybrid system should generate $1.1\text{x}10^6$ liter of water within one day. So the liter per day water pumped by the hybrid system can be changed to liter per second as follow:

$$\frac{\mathbf{1.1x10^6}}{\mathbf{6x60}} = \frac{\mathbf{1.1x10^6}}{\mathbf{360}} = \mathbf{3055.6lpm = 51lps = 183.3\,{}^{m^3}/_{h}\ or\ in\ non - SI\ unit = 806.2Gpm}.$$

Assuming the effective working hours of the solar wind hybrid and the watering time (the water pumped during the livestock drink water) of the livestock and the people is the same. The water required for the livestock is:

$$\mathbf{1.1x10^6 - 0.1176785x10^6 = 0.9823x10^6lpd = 982.3\,{}^{m^3}/_{d}}$$

Which means the amount of water pumped by the hybrid system with the effective time and the watering time is the same. So, the difference between the daily water required and the water pumped during the watering time is almost negligible [15]. So the reservoir should be store the capacity of water:

$$\mathbf{2dx982.3\,{}^{m^3}/_{d} = 1964.6m^3\ or\ in\ non\ SI\ unit,} \frac{\mathbf{1964600}}{\mathbf{3.79}} = \mathbf{518364.12Gal}$$

So the volume of the reservoir should be 1964.6$\mathbf{m^3}$

The cost of water storages ranges from about 5 cents per gallon to over $1.00 per gallon. [29], but for our country since the labor is cheap, 1 cents per gallon is enough. From different source, the approximated price of the storage tank on which the livestock drink and as the same time used as the storage is:

$$\mathbf{518364.12x0.01 = \$5184}$$

So, the total price of the storage tank is:

$$\mathbf{5,184 + 10,000 \;= \$15,184}$$

Where d= day, l= liters, Gal= gallon, $= dollar.

The dimension of the reservoir for the livestock is approximated depending on the volume of water required, according to the information that is given the on following site. http://www.thecattlesite.com/ and in case of this thesis its shape shown on the system layout and with volume of 1964.6$\mathbf{m^3}$

Step 5: Solar Insolation and PV Panel Location and wind velocity data

Appropriate data should be used to determine the amount of peak sun hours and wind velocity available at the site.

The average wind velocity at 10m for the site for 16 years are given in the following table

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1(1993)	2.96	2.83	2.92	2.12	2.01	2.96	3.27	3.09	2.87	2.05	2.46	2.72
2	3.03	2.93	2.80	2.08	2.47	2.94	3.33	3.19	2.77	2.12	2.28	2.81
3	3.05	2.84	2.61	2.03	2.33	2.79	3.36	3.26	2.76	2.12	2.21	2.77
4	2.70	2.76	2.22	1.80	2.15	2.87	3.30	3.21	2.66	1.77	2.16	2.52
5	2.73	3.18	2.64	1.88	2.10	2.79	2.90	2.89	2.35	1.67	2.19	2.02
6	2.10	1.98	1.92	2.19	2.14	2.91	3.11	3.21	2.78	1.91	2.19	2.77
7	3.03	3.36	2.19	1.98	2.27	2.85	3.54	3.49	3.06	2.02	2.52	2.55
8	3.01	3.39	2.90	2.24	2.48	3.36	3.25	3.60	2.74	2.02	1.85	2.43
9	2.22	2.35	2.06	1.94	2.62	2.99	3.42	3.53	2.25	1.94	2.09	-
10	2.83	2.92	2.31	2.38	2.51	3.26	3.50	3.79	2.72	1.83	2.24	2.12
11	2.25	2.49	2.65	2.09	2.24	2.89	3.13	3.02	2.70	2.14	2.33	2.74
12	2.45	2.67	2.55	1.80	2.31	2.91	3.64	3.62	2.61	2.27	2.02	2.35
13	2.32	2.69	2.34	2.17	2.06	2.75	3.39	3.11	3.08	1.75	2.07	2.75
14	2.78	2.54	1.97	1.93	1.97	3.12	3.23	3.21	2.85	1.78	1.98	2.17
15	2.55	2.51	1.94	2.30	3.09	3.06	3.16	3.00	1.70	2.47	-	-
16(2008)	2.85	2.97	2.45	2.00	2.70	3.12	3.69	-	-	-	-	-
Ave. Wind velocity (m/s)	**2.68**	**2.78**	**2.40**	**2.06**	**2.34**	**2.97**	**3.33**	**3.28**	**2.66**	**1.99**	**2.18**	**2.52**

Table 6.4 Average wind velocity for Semento Kebele [6]

Note that in table 6.4 the line (-) indicates that months which its wind velocity is not measured due to different reason.

The data that I have received from the Ethiopian meteorological agency is in $m/_{s}$, so that it is in SI unit no need of doing another calculation to use this data for the software that I will use in the next chapter. The wind data collected is almost for the same site, but it is not exact place and there is some deviation from the site. For both sunshine hour and wind velocity the result what we have used is the minimum result, because of the as we go from the Negele town to the site the sunshine hour increase.

As we give the input for the software, it will give the viability of the wind turbine, and the type of the wind turbine that is selected is specified by the person depending on the situation of the site such as the availability of the road, the price of the turbine, and other. More of it I will explain in the next chapter.

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	-	9.6	9.1	6.8	6.9	5.6	5.6	5.4	5.5	5.5	8.5	10.5
2006	-	8.5	8.1	6.6	7.1	6.8	3.6	5.7	5.9	4.4	7.7	8.9
2005	9	9.9	7.8	6.4	5.9	5.6	4.4	-	-	6.5	8.3	10.7
2004	7.9	9.9	8.7	5.5	7.4	5.8	5.9	6.3	7.3	6.4	7.1	9.3
2003	9.4	10.2	8.5	6.3	6.9	4.9	3.9	4.6	7.2	6.7	7.2	9
2002	-	10.8	7.4	6.8	6	4.6	6.3	5.1	6.9	5.3	6.9	6.8
2001	9.2	9.4	7.2	6.3	6.5	5.4	-	-	6.6	6.1	7.6	-
2000	10.7	10.6	10	7.4	6.8	4.5	3.9	4.9	6.3	4.7	7.9	9.7
1999	-	10.5	5.8	7.6	6.6	5.3	3	5.9	7	4.8	9	9.5
1998	7.7	8.4	8.2	6.7	5.6	2.9	2.4	3.6	5.5	4.4	8.7	10.3
1997	9.5	10.9	8.1	4.9	7.6	5.1	4.8	6.9		4.4	6.6	7.9
1996	9.1	10.1	6.8	5.9	6.5	2	3.1	5.6	6.6	5	8	9.8
1995	10.7	9.4	6	5.2	7.8	5	4.4	3.7	5.7	5.2	7.6	8.3
Ave.sun shine hour	**9.2**	**9.9**	**7.8**	**6.3**	**6.7**	**4.9**	**4.3**	**5.2**	**6.4**	**5.3**	**7.8**	**9.2**

Table 6.5 Monthly average sunshine hours [6]

The missing line show that the sunshine hour is not measured for the site.

Calculation of solar radiation based on the data given in monthly average solar sun shine hour

Extraterrestrial Radiation

The extraterrestrial radiation for each day of the year and for different latitudes is estimated from the solar constant, the solar declination and the time of the year by: [7]

$$R_a = \frac{24(60)}{\pi} G_{Sc} d_r [\omega_s \sin(\varphi) \sin(\delta) + \cos(\varphi) \cos(\delta) \sin(\omega_s)] \quad \text{.......6.1}$$

Where,

R_a =is extraterrestrial radiation [$MJm^{-2}day^{-1}$],

G_{Sc} =is solar constant = 0.082 $MJm^{-2}min^{-1}$,

d_r =is inverse relative distance Earth-Sun,

ω_s = is sunset hour angle [rad],

φ = is latitude [rad],

δ = is solar declination [rad].

The latitude, φ , expressed in radians is positive for the northern hemisphere and negative for the southern hemisphere.

The conversion from decimal degrees to radians is given by:

$$[\text{Radians}] = [Radians] = \frac{\pi}{180}[decimal\ degrees] \quad \text{.......6.2}$$

The inverse relative distance Earth-Sun, d_r, and the solar declination, δ, are given by:

$$d_r = 1 + 0.033 \cos\left(\frac{2\pi}{365} J\right) \quad \text{.......6.3}$$

$$\delta = 0.409 \sin\left(\frac{2\pi}{365} J - 1.39\right) \quad \text{.......6.4}$$

Where J is the number of the day in the year and given as follow;

Months	J for i^{th} day of the month	date	day of year J
Jan	I	17	17
Feb	31+i	16	47
Mar	59+i	16	75
Apr	90+i	15	105
May	120+i	15	135
Jun	151+i	17	162
Jul	181+i	17	198
Aug	212+i	16	228
Sep	243+i	15	258
Oct	273+i	15	288
Nov	304+i	14	318
Dec	334+i	10	334

Table 6.6.The representative date of the month [5]

The sunset hour angle, ω_s, is given by:

$\omega_s = \arccos[-ta(\varphi)\, tan(\delta)]$ ……………………………………………………………….6.5

Daylight hours

The daylight hours are given by:

$N = \frac{24}{\pi}\omega_s$ .. ……………………………………………………..……………………...……. 6.6

Where:

N= the daylight hours

ω_s = the sunset hour angle calculated by the above formula

Solar radiation

If the solar radiation is not measured, it can be calculated with the Angstrom formula, which relates solar radiation to extraterrestrial radiation and relative sunshine duration:

$R_s = \left(a_s + b_s \frac{n}{N}\right) R_a$ ……………………………………………..………………………. 6.7

Where;

R_s =solar or shortwave radiation [MJ m^{-2} day^{-1}],

n =actual duration of sunshine [hour],

N =maximum possible duration of sunshine or daylight hours [hour],

$\frac{n}{N}$ =relative sunshine duration [-],

a_s =regression constant, expressing the fraction of extraterrestrial radiation reaching the earth on overcast days (n = 0),

$(a_s + b_s)$ = fraction of extraterrestrial radiation reaching the earth on clear days (n = N).

The default values for a_s and $b_s$are 0.25 and 0.50 respectively.

By using the above formula the solar radiation of the site is calculated and given in the following table.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	-	9.6	9.1	6.8	6.9	5.6	5.6	5.4	5.5	5.5	8.5	10.5
2006	-	8.5	8.1	6.6	7.1	6.8	3.6	5.7	5.9	4.4	7.7	8.9
2005	9	9.9	7.8	6.4	5.9	5.6	4.4	-	-	6.5	8.3	10.7
2004	7.9	9.9	8.7	5.5	7.4	5.8	5.9	6.3	7.3	6.4	7.1	9.3
2003	9.4	10.2	8.5	6.3	6.9	4.9	3.9	4.6	7.2	6.7	7.2	9
2002		10.8	7.4	6.8	6	4.6	6.3	5.1	6.9	5.3	6.9	6.8
2001	9.2	9.4	7.2	6.3	6.5	5.4	-	-	6.6	6.1	7.6	-
2000	10.7	10.6	10	7.4	6.8	4.5	3.9	4.9	6.3	4.7	7.9	9.7
1999	-	10.5	5.8	7.6	6.6	5.3	3	5.9	7	4.8	9	9.5
1998	7.7	8.4	8.2	6.7	5.6	2.9	2.4	3.6	5.5	4.4	8.7	10.3
1997	9.5	10.9	8.1	4.9	7.6	5.1	4.8	6.9	-	4.4	6.6	7.9
1996	9.1	10.1	6.8	5.9	6.5	2	3.1	5.6	6.6	5	8	9.8
1995	10.7	9.4	6	5.2	7.8	5	4.4	3.7	5.7	5.2	7.6	8.3
Average	**9.2**	**9.9**	**7.8**	**6.3**	**6.7**	**4.9**	**4.3**	**5.2**	**6.4**	**5.3**	**7.8**	**9.2**
Rad[MJm^{-2}day^{-1}]	**25.4**	**26.7**	**22**	**17.6**	**15.6**	**12.4**	**12.3**	**15.1**	**18.9**	**18.3**	**22.7**	**25.2**
Rad[kWh/m^{2}day]	**7.05**	**7.4**	**6.12**	**4.89**	**4.35**	**3.44**	**3.41**	**4.2**	**5.25**	**5.07**	**6.32**	**7.0**

Table 6.7 Monthly average solar sun shine hour and calculated solar radiation in kwh/m^{2}day for the Semento Kebele.

The last result of the solar radiation in $kwh/_{m^2day}$ is the input data for the average daily radiation of the site to analysis the system by the software.

In order to maximize the solar-powered system's energy production, the panels should be south facing with no significant shading in their vicinity in order to achieve full sun exposure. In case of our country the inclination of the PV panel should be to the southern part that is to the equator.

The solar array should be placed as close to the pump as possible to minimize the electric wire length (and thus any energy loss), as well as installation costs.

Step 6: Design Flow Rate for the Pump

There are two issues involved in providing adequate water for animals and people. First, the total water requirement, $1.1*10^6$ l/d, must be met. But there is another issue—the water must be available when the animals and the people want to drink it. If an adequate flow rate is available, then water can be supplied on demand. If, however, the flow rate is low, then storage capacity must be provided. In other words, providing a trickle of water over a 24-hour period requires storage capacity so that the water is available when the animal and people wants to drink. But during the scarcity of water for the site there is sufficient solar energy and wind energy. To minimize this let we multiply the water requirement by two and the reservoir can store water for one day. As calculated previously, the solar wind hybrid system work effectively for 6 hrs and the flow rate is $51 l/_s$

Step 7: Total Dynamic Head (TDH) for the Pump

To determine the pump's TDH, use the following equation:

TDH = Vertical Lift + Pressure Head + Friction Losses

Vertical Lift: is the vertical distance between the water surface at the intake point (well) and the water surface at the delivery point (the tank's water surface and the reservoir). According to the data that available for site, the water exists at 180m depth and 20m is added for the depth may vary during the dry season and the friction head and other losses. So the total vertical lift will be 180+20=200m

Friction loss: is the loss of pressure due to the friction of the water as it flows through the pipe. Friction loss is determined by four factors: the pipe size (inside diameter), the flow rate, the length of the pipe, and the pipe's roughness.

Change 3055.6lpm to gallon and then find from the table. That is 806.2GPM, and almost negligible when compared to the depth we added at the beginning. So the TDH is 200m

Step 8: Pump Selection and Associated Power Requirement

The pump that should be selected must be handle the flow rate required and the power required for the pump is also known by dividing to the efficiency of the selected pump.

$$P_{mech} = \frac{\rho * g * Q * h}{\eta}$$

Where $P_{mech}$the power from the motor, ρ is is density of water which is 1000kg/m^3, g is acceleration due to gravity which is assumed as 10m/s^2, Q is volume flow rate of water which is:

$$3055.6\text{lpm} = 51\text{lps} = 0.051\,{}^{\text{m}^3}/_{\text{s}} = 183.3\,{}^{\text{m}^3}/_{\text{h}}$$

h is depth of water available to the storage of water which is 200m, η is efficiency of the centrifugal pump which is approximately 78%.

$$P_{mech} = \frac{1000\frac{kg}{m^3} * 10\frac{m}{s^2} * 0.051\frac{m^3}{s} * 200m}{0.78} = 102000w = 102kw$$

Small electric motor efficiency is given as &75%-85 and the centrifugal pump efficiency are given as 75%-82%. [9]

By considering the efficiency of the motor as 80%, then we can calculate the motor power as follow.

$$\text{P}_{\text{elect}} = \frac{102\text{kw}}{0.8} = 127.5\text{kw} = 127.5\text{kw}$$

The overall efficiency of the$\eta_{overall} = \eta_{mech}\eta_{elect} = 0.78x0.8 = 0.624 = 62.4\%$

Depending on the power required, head, and flow rate the price of pump and motor differs. http://www.envisupply.com/environmental/Grundfos/home_water_pump.htm

So, for our system the estimated price of pump and motor is $9,000 including the tax, transportation and others.

8.1 Piping

Galvanized steel, copper, and plastic are common pipe materials. Plastic pipe is made in flexible, semi-rigid, and rigid form. Flexible plastic pipe is commonly used in outdoor underground installations because of its ease and economy of installation. Also, for small diameters, flexible plastic pipe is the least expensive option.

The most important consideration in designing a piping system is proper pipe sizing. In general, the right pipe size is a trade-off between a diameter that is small enough to minimize pipe cost and large enough to not result in excessive friction losses, which will increase the pumping energy and therefore pumping costs. In other words, selecting a larger pipe size will result in greater pipe cost, but may allow for a smaller, and perhaps less expensive pump and will reduce the annual energy consumption[15].

To select a pipe size, the following information is needed:

- Distance that the water will travel,
- Flow rate required,
- Vertical distance between the water source and the outlet of the stock tank, and
- Required pressure at the outlet

From the standard table which taken from [11] based on 1.5m/s velocity, inside diameter is and the friction head loss (meter of head per meter of pipe) for the pipe is determined.

From the calculated value the volume given is 51l/s, the nearest value from the standard table is pipe with inside diameter 125mm and friction head loss (meter of head per meter of pipe) for the pipe is 0.017. The stored water is 5m away horizontally from the pumped water. So the total pipe length is 205m and the friction loss is calculated as follow:

$0.017x205 = 0.0035m$

The price of the pipe with inside diameter 125mm is \$8 per feet or \$ 26 per meter [1].

But, since there is pipe factories that can produce the pipe in our country the price will be calculated as follow:

The price of pipe for 125mm, 10bar and 6m length (with effective length is 5.85m) is:

$610 + 610x0.15 = 610 + 91.5(vat) = 701.5birr$

The total length is 205m and the effective length can be calculated as:

$$\frac{205}{5.85} = 35\, piecse$$

So that 35 pieces of pipes are required. The total price is

$$701.5birrx35pieces = 24552.5birr$$

When we change birr to dollar;

$$\frac{24552.5}{18.4} = \$1334.4$$

The total price is

$$15{,}184 + 9{,}000 + 1{,}334.4 = \$25{,}518.4$$

CHAPTER 7

Micro-power System Modeling With HOMER

The HOMER (Hybrid Optimization Model for Electric Renewable) Micro-power Optimization Model is a computer model developed by the U.S. National Renewable Energy Laboratory (NREL) to assist in the design of micro-power systems and to facilitate the comparison of power generation technologies across a wide range of applications. [31]

HOMER can model grid-connected and off-grid micro-power systems serving electric and thermal loads, and comprising any combination of photovoltaic (PV) modules, wind turbines, small hydro, biomass power, reciprocating engine generators, micro-turbines, fuel cells, batteries, and hydrogen storage.

The analysis and design of micro-power systems can be challenging, due to the large number of design options and the uncertainty in key parameters, such as load size and future fuel price. Renewable power sources add further complexity because their power output may be intermittent, seasonal, and non dispatch able and the availability of renewable resources may be uncertain. HOMER was designed to overcome these challenges.

HOMER performs three principal tasks: simulation, optimization, and sensitivity analysis. In the simulation process, HOMER models the performance of a particular Micro-power system configuration each hour of the year to determine its technical feasibility and life-cycle cost.

In the optimization process, HOMER simulates many different system configurations in search of the one that satisfies the technical constraints at the lowest life-cycle cost. In the sensitivity analysis process, HOMER performs multiple optimizations under a range of input assumptions to gauge 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 wind speed or the future fuel price.

Figure below illustrates the relationship between simulation, optimization, and sensitivity analysis. The optimization oval encloses the simulation oval to represent the fact that a single optimization consists of multiple simulations. Similarly, the sensitivity analysis oval encompasses the optimization oval because a single sensitivity analysis consists of multiple optimizations. [31]

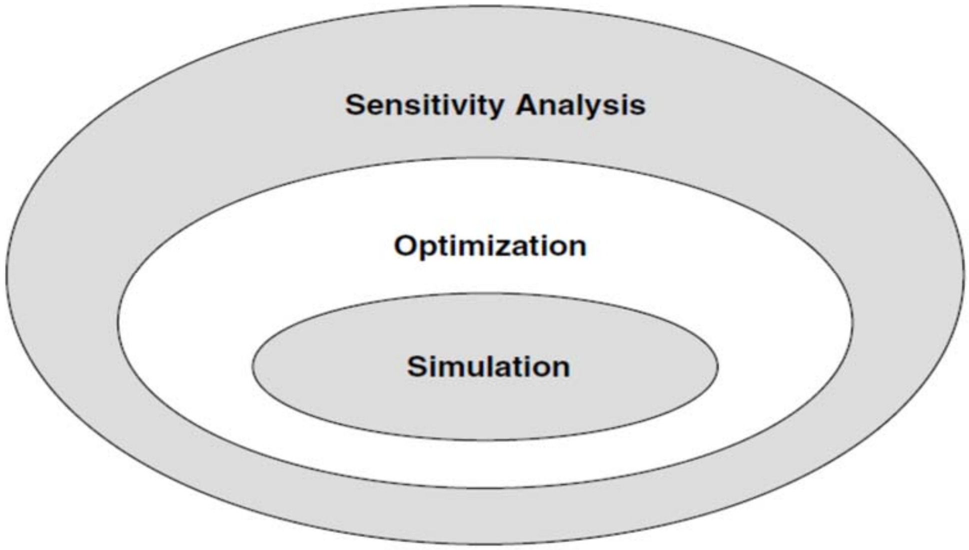

Figure 7.1 Conceptual relationships between simulation, optimization, and sensitivity analysis. [31]

To limit input complexity, and to permit fast enough computation to make optimization and sensitivity analysis practical;

- HOMER's simulation logic is less detailed than that of several other time-series simulation models for micro-power systems, such as:
  - Hybrid2,
  - PV-Design Pro, and
  - PV*SOL.
- But, HOMER is more detailed than statistical models such as RET Screen, which does not perform time-series simulations.
- From all Micro-power modeling, HOMER is the most flexible in terms of the diversity of systems it can simulate.[31]

7.1 Simulation

HOMER's basic capability is simulating the long-period operation of a micro-power system. Optimization and sensitivity analysis rely on the simulation capability.

The simulation process determines how a particular system arrangement, a combination of system components of specific sizes, and an operating strategy that defines how those components work together, would behave in a given setting over a long period of time.

The simulation process serves two purposes.

1. Determines whether the system is feasible.
2. Estimates the life-cycle cost of the system, which is the total cost of installing and operating the system over its lifetime.

HOMER considers the system to be feasible if it can adequately serve the electric and thermal loads and satisfy any other constraints imposed by the user. The life-cycle cost is a convenient measurement for comparing the economics of various system configurations which is the base for the optimization process.

The quantity HOMER uses to represent the life-cycle cost of the system is the total net present cost (NPC). This single value includes all costs and revenues that occur within the project lifetime, with future cash flows discounted to the present.

The total net present cost includes:

- The initial capital cost of the system components
- The cost of any component replacements that occur within the project lifetime
- The cost of maintenance and

Any revenue from the sale of power to the grid reduces the total NPC.

HOMER simulates how the system operates over one year and assumes that the key simulation results for that year (surplus power production) are representative of every other year in the project lifetime. It does not consider changes over time, such as load growth or the deterioration of battery performance with aging. The modeler can, however, analyze many of these effects using sensitivity analysis.

For our analysis of our thesis the input data for the simulation is:

1. Deferrable load
2. The detailed components
    - The wind turbine
    - The PV
    - Converter

3. Resource detail
    - Solar resource
    - Wind resource

7.2 Optimization

The simulation process models a particular system configuration; whereas the optimization process determines the best possible system configuration. In HOMER, the best possible, or optimal, system configuration is the one that satisfies the user-specified constraints at the lowest total net present cost. Finding the optimal system configuration may involve deciding on the mix of components that the system should contain, the size or quantity of each component, and the dispatch strategy the system should use. In the optimization process, HOMER simulates many different system configurations, discards the infeasible ones (those that do not satisfy the user-specified constraints), ranks the feasible ones according to total net present cost, and presents the feasible one with the lowest total net present cost as the optimal system configuration.

The goal of the optimization process is to determine the optimal value of each decision variable that interests the modeler. A decision variable is a variable over which the system designer has control and for which HOMER can consider multiple possible values in its optimization process. Possible decision variables in HOMER for the analysis of the hybrid system for pumping water include:

- The size of the PV array
- The number of wind turbines
- The size of the dc-ac converter

So during the optimization of the system different type in size of PV array, different selected number of wind turbine, and different type in size of dc-ac converter is feed to the software and then the software will optimize depending on the NPC of the system.

7.3 Sensitivity Analysis

In the optimization process, HOMER finds the system configuration that is optimal under a particular set of input assumptions. In the sensitivity analysis process, HOMER performs multiple optimizations, each using a different set of input assumptions. A sensitivity analysis reveals how sensitive the outputs are to changes in the inputs.

In a sensitivity analysis, the HOMER user enters a range of values for a single input variable. A variable for which the user has entered multiple values (numerical input) is called a sensitivity variable. The basic sensitivity variables that we have used in our software analysis are:

- Deferrable load
- Solar resource
- Wind resource

The primary uses of sensitivity analysis are in dealing with uncertainty. If a system designer is unsure of the value of a particular variable, they can enter several values covering the likely range and see how the results vary across that range. Beyond uncertainty, sensitivity analysis has another application. A system designer can use sensitivity analysis to evaluate trade-offs and answer such questions as:

- How much additional capital investment is required to achieve 50% or 100% renewable energy production?
- An energy planner can determine which technologies, or combinations of technologies, are optimal under different conditions.
- A market analyst can determine at what price, or under what conditions, a product competes with the alternatives.
- A policy analyst can determine what level of incentive is needed to stimulate the market for a particular technology, or what level of emissions penalty would tilt the economics toward cleaner technologies

7.4 Physical Modeling

In HOMER, a micro-power system must comprise;

- At least one source of electrical or thermal energy (in our case wind turbine and PV)
- At least one destination for that energy (in our case water pumping for rural area).
- Comprise conversion devices such as an dc-ac converter and
- Energy storage devices (in our case reservoir, and water tank).

7.5 Loads

In HOMER, the term load refers to a demand for electric or thermal energy. Serving loads is the reason for the existence of micro-power systems, so the modeling of micro power system begins with the modeling of the load or loads that the system must serve [31].

HOMER models three types of loads.

1. **Primary Load:** is electrical demand that the power system must meet at a specific time. Electrical demand associated with lights, radio, TV, household appliances, computers, and industrial processes is typically modeled as primary load.
2. **Deferrable Load**: is electrical demand that can be met anytime within a defined time interval. Water pumps, ice makers, and battery-charging stations are examples of deferrable loads. This is because the storage inherent to each of those loads allows some flexibility as to when the system can serve them. The ability to defer serving a load is often advantageous for systems comprising intermittent renewable power sources, because it reduces the need for precise control of the timing of power production. This type of load is selected for our software analysis, because of the electric output is used for pumping water, rather than using it directly for the light purpose.
3. **Thermal Load**: HOMER models thermal load in the same way that it models primary electric load, except that the concept of operating reserve does not apply to the thermal load. The system supplies the thermal load with either the boiler, waste heat recovered from a generator, or resistive heating using excess electricity.

7.6 Economic Modeling

Economics play an integral role both to minimize total net present cost and in optimization process. It searches for the system configuration with the lowest total net present cost.

Renewable and nonrenewable energy sources typically have dramatically different cost characteristics. Renewable sources tend to have high initial capital costs and low operating costs, whereas conventional nonrenewable sources tend to have low capital and high operating costs. In its optimization process, HOMER must often compare the economics of a wide range of system configurations comprising varying amounts of renewable and nonrenewable energy sources. To be equitable, such comparisons must account for both capital and operating costs.

Life-cycle cost analysis does so by including all costs that occur within the life span of the system.

HOMER uses the total net present cost (NPC) to represent the life-cycle cost of a system. The total NPC condenses all the costs and revenues that occur within the project lifetime into one lump sum in today's dollars, with future cash flows discounted back to the present using the discount rate. The modeler specifies the discount rate and the project lifetime. The NPC includes the costs of initial construction, component replacements, maintenance, fuel, plus the cost of buying power from the grid and miscellaneous costs such as penalties resulting from pollutant emissions. Revenues include income from selling power to the grid, plus any salvage value that occurs at the end of the project lifetime. With the NPC, costs are positive and revenues are negative. This is the opposite of the net present value. As a result, the net present cost is different from net present value only in sign.

HOMER assumes that all prices escalate at the same rate over the project lifetime.

With that assumption, inflation can be factored out of the analysis simply by using the real (inflation-adjusted) interest rate rather than the nominal interest rate when discounting future cash flows to the present. The HOMER user therefore enters the real interest rate, which is roughly equal to the nominal interest rate minus the inflation rate. All costs in HOMER are real costs, meaning that they are defined in terms of constant dollars.

For each component of the system, the modeler specifies the initial capital cost, which occurs in year zero, the replacement cost, which occurs each time the component needs replacement at the end of its lifetime, and the O&M cost, which occurs each year of the project lifetime. The user specifies the lifetime of most components in years, but HOMER calculates the lifetime of the battery and generators.

A component's replacement cost may differ from its initial capital cost for several reasons. For example, a modeler might assume that a wind turbine nacelle will need replacement after 15 years, but the tower and foundation will last for the life of the project. In that case, the replacement cost would be considerably less than the initial capital cost. Donor agencies or buy-down programs might cover some or all of the initial capital cost of a PV array but none of the replacement cost. In that case, the replacement cost may be greater than the initial capital cost. When analyzing a retrofit of an existing diesel system, the initial capital cost of the diesel engine would be zero, but the replacement cost would not.

To calculate the salvage value of each component at the end of the project lifetime, HOMER uses the equation

$$s = c_{rep}\frac{R_{rem}}{R_{comp}} \quad \text{......} \quad 7.1$$

Where; S is the salvage value, C_{rep} the replacement cost of the component, R_{rem} the remaining life of the component, and R_{comp} the lifetime of the component.

For each component, HOMER combines the capital, replacement, maintenance, and fuel costs, along with the salvage value and any other costs or revenues, to find the component's annualized cost. This is the hypothetical annual cost that if it occurred each year of the project lifetime would yield a net present cost equivalent to that of all the individual costs and revenues associated with that component over the project lifetime. HOMER sums the annualized costs of each component, along with any miscellaneous costs, such as penalties for pollutant emissions, to find the total annualized cost of the system. This value is an important one because HOMER uses it to calculate the two principal economic figures of merit for the system: the total net present cost and the levelized cost of energy.

HOMER uses the following equation to calculate the total net present cost:

$$C_{NPC} = \frac{C_{ann;tot}}{C_{RF}(i; R_{proj})} \quad \text{......} \quad 7.2$$

Where $C_{ann;tot}$ is the total annualized cost, i the annual real interest rate (the discount rate), R_{proj} the project lifetime, and $C_{RF}(i; R_{proj})$ is the capital recovery factor, given by the equation

$$C_{RF}(i; N) = \frac{i(1+N)^N}{(1+N)^N - 1} \quad \text{......} \quad 7.3$$

Where N is the number of years [31]

7.7 The procedures to work with the HOMER software

The procedures to do with HOMER are explained here with eleven steps below. We start by providing HOMER with information, or inputs, about power system designs that you want to consider. HOMER will simulate system configurations; create a list of feasible system designs, and sort the list by cost-effectiveness. In the final step, you will use HOMER to perform a sensitivity analysis. The general steps are given as follow:

1. **Formulate a question that HOMER can help answer**

HOMER can answer a wide range of questions about the design of small power systems. It is useful to have a clear idea of a question that you want HOMER to help answer before you begin working with HOMER. This thesis done for the livestock and people that have the lack of accessibility of water especially, during the dry season they move to other place to fetch water and some of them die. For this reason, the question that is raised for the software to analyze is "Will my design meets a growing water demand of the site with the least possible cost effective?"

2. **Create a new HOMER file**

A HOMER file contains all of the information about the technology options, component costs and resource availability required to analyze power system designs.

3. **Build the schematic**

HOMER compares multiple technology options for a power system design. The schematic represents all of the technology options that you want HOMER to consider: it is not a schematic of a particular system's configuration. We build the schematic to give HOMER information about the components to consider, answering your question. The schematic may include components that are not in the optimal design.

For this thesis, to build the schematic, the equipment to be considered are shown graphically on the software by containing the deferrable load, selected wind turbine, PV and converter. The other diagram that is shown is the wind resource and the solar resource and other. With this schematic HOMER simulate to answer the question "Will my design meet a growing water demand of the site with the list cost effective? "

HOMER displays buttons on the schematic that represent the load and components (wind turbine, PV, and converter).

In the Resources section (directly below the schematic) HOMER displays buttons for the resources that each component will use. In this case, buttons for the wind and PV resources appear in the resources section of the schematic. In front of the resource section, there is section under other (Economics, system control, Emissions, constraints).

4. **Enter load details**

The load details are inputs to the HOMER simulations. The load inputs describe the electric demand that the system must serve. The type of load that we use is the deferrable load and the average load that we fill the table manually is calculated as follow: The average water required daily is $1100\, {m^3}/{d}$ and the pump can deliver $183.3\, {m^3}/{h}$.

The hours required to fulfill $1100\, {m^3}/{d}$ with pump that can deliver $183.3\, {m^3}/{h}$ is:

$$\frac{1100 \, {}^{m^3}/_{d}}{183.3 \, {}^{m^3}/_{h}} = 6hrs$$

It would take the pump 6 hours at full power to meet the daily requirement of water, so the average deferrable load is 6hours per day times 127.5 kW, which is:

$$102kwx6 \, {}^{h}/_{d} = 612 \, {}^{kwh}/_{d}$$

The livestock and the people averagely drink and fetch the water in a day 6 hours. And the mechanical power required to pump water is 102kw. So that depending on the above calculated value we can fill the table below depending on what month is more load is needed and on what month it decrease.

Month	Average load (kwh/d)
January	660.000
February	650.000
March	640.000
April	620.000
May	600.000
June	560.000
July	550.000
August	570.000
September	610.000
October	620.000

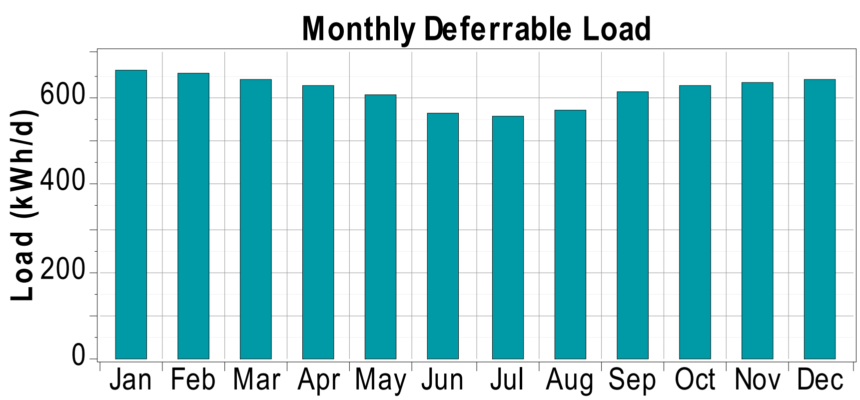

Figure 7.2 Average monthly deferrable loads

Table 7.1 Average monthly deferrable loads of the Semento kebele

Let we describe the graph and table above and define some words as follow: [10]

1. Baseline data

The baseline data is the set of 12 values representing the average deferrable load, in kWh, for each month of the year. The average deferrable load is the rate at which energy leaves the deferrable load storage tank or reservoir. So it is the amount of power required to keep the level in the storage tank constant.

Enter the average deferrable load for each month of the year in the table on the left. HOMER assumes that the deferrable load is constant throughout each month. HOMER calculates the resulting annual average deferrable load and displays it below the table. The monthly average values are displayed in the deferrable load graph as you enter them.

2. Scaled data for simulation

HOMER scales the baseline deferrable load data for use in its calculations. To scale the baseline data, HOMER multiplies each of the 12 baseline values by a common factor that results in an annual average value equal to the value that you specify in Scaled annual average. To determine the value of this factor, HOMER divides the scaled annual average by the baseline annual average. The scaled data retains the seasonal shape of the baseline data, but may differ in magnitude. The default value for the scaled annual average is the baseline annual average. When the two values are equal, the scaled data and baseline are identical. HOMER interprets a scaled annual average of zero to mean that there is no deferrable load.

3. Peak load

The peak load is the maximum amount of power, in kW, that can serve the deferrable load. In a water pumping application, it is equal to the rated electrical consumption of the pump. In our case the peak load is 127.5kw as calculated in the previous chapter.

4. Storage capacity

The storage capacity is the size of the storage tank, expressed in kWh of energy needed to fill the tank. In our case there are two storages that are for the livestock (reservoir) and for the people (tank). So the total volume of the storage is:

$V_{total} = V_{tank} + V_{reservoir} = 235.357\mathrm{m}^3 + 1964.6\mathrm{m}^3 = 2200m^3$

The time hourly required filling the reservoir and the tank is:

$$\frac{2200m^3}{183.3\, {m^3}/{h}} = 12h$$

From this it take 12h to fill the reservoir and the tank. So the storage capacity is:

$$12hx102kw = 1224kwh$$

So for the software analysis scaled annual average is 612kwh/d, storage capacity is 1224kwh, and peak load of 127.5kw is given as an input.

5. Enter component details

The component inputs describe technology options, component costs, and the sizes and numbers of each component that HOMER will use for the simulations. This section describes how to enter cost data for PV, wind turbines, and Inverters. The costs in this exercise may not reflect real market conditions.

5.1.PV details

Here we define the cost curve of photovoltaic (PV) panels, choose the sizes you want HOMER to consider as it searches for the optimal system, and specify the orientation of the array.

In the cost table, enter the PV cost curve*,* meaning the way the cost varies with size. Typically this requires only a single row since PV costs are often assumed to be linear with size.

When specifying the capital and replacement costs, it includes all costs associated with the PV subsystem, which may include:

- PV panels
- mounting hardware
- control system (maximum power point tracker)
- wiring
- installation

The capital cost is the initial purchase price, and the replacement cost is the cost of replacing the PV panels at the end of their lifetime (relevant only if the project lifetime exceeds the PV array lifetime), and the operating and maintenance cost is the annual cost of operating and maintaining the PV array (often assumed to be zero). The cost of PV per kw is given in the following table [17]. The cost of the selected size of PV is done depending on the cost given in the following table.

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
1.000	1800	0	150

Table 7.2The cost of the PV per kw [17]

We enter the PV array sizes that HOMER to consider as it searches for the optimal system. We should include a zero size if the systems want to consider systems without PV. HOMER will use the information we entered in the cost table to calculate the costs of each PV array size, interpolating and extrapolating as necessary. The size that is given in the table below is depending on the demand of the power.

Size (kw)	0	80	90	100	110	120	130	140	150	160	170	180	190	200

Table 7.3The size of PV array to be considered during the simulation of the systems

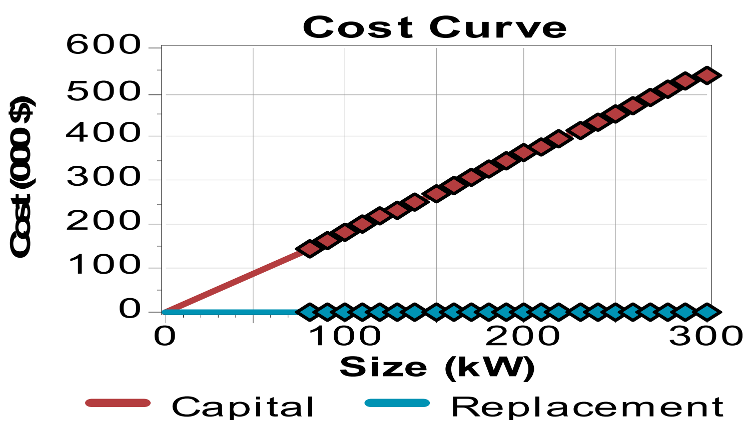

Figure 7.3The graph of the PV size (kw) with respect to cost.

5.2.Wind details

In this section we give input and decide the type of wind turbine we want to model, specify its costs, and tell HOMER how many to consider as it searches for the optimal system.

From the turbine exist in the HOMER software or from the internet the type of the wind turbine selected key properties should be explained. The most significant property is the power curve, which specifies the turbine's power output over a range of wind speeds. We use this graph to verify that the wind turbine we have selected is an appropriate size for our system.

In the cost table, we enter the wind turbines cost curve in as much detail as we would like. In the simplest case, where each wind turbine costs the same regardless of how many are purchased, we only need to enter one row of data in the cost table. We would enter a quantity of one, along with the per-turbine capital, replacement, and operating and maintenance costs. HOMER extrapolates these costs as needed, so if we modeled a system with three wind turbines, the associated capital, replacement, and O&M costs would be three times the values entered in the cost table. We can see from table 7.4

Note that the capital cost is the initial purchase price, the replacement cost is the cost of replacing the wind turbine at the end of its lifetime (relevant only if the project lifetime exceeds the wind turbine lifetime), and the operating and maintenance cost is the annual cost of operating and maintaining the turbine (typically about 2% percent of the capital cost).

The number of wind turbines entered should decide by us that we want HOMER to consider as it searches for the optimal system. We should include a zero, because the software should consider systems without wind turbines. HOMER will use the information we entered in the cost table to calculate the corresponding costs, interpolating and extrapolating as necessary. We can see the results in the cost curve graph below

Bergey Wind power Co. (BWC) Excel

The **BWC EXCEL** is a modern 7 meter diameter, 10kW wind turbine designed for high reliability, low maintenance, and automatic operation in adverse weather conditions. It is available in three configurations: battery charging, water pumping, and grid-connected. The BWC Excel is a ruggedly built turbine that comes with the longest warranty (5years) in the industry.

Battery charging BWC EXCEL's can be supplied with outputs of 24, 48, 120 or 240 VDC. They are well suited for large rural homes, remote villages and facilities, eco-tourism resorts, and larger telecommunications sites.

As a water pumper, the BWC EXCEL can be located as much as 600 m from the well to take advantage of improved wind conditions.

Connected to the grid, the BWC EXCEL can provide most of the electricity for an average total electric home at moderate wind sites. The all new GridTek 10 power processor (inverter) is the most advanced in the industry and it carries a full certification to the latest utility standards.

Prices, which include a voltage regulator, pump controller, or a line-commutated inverter, range from $17,000 to $19,500. For severe sites, an Extra-Stiff blade option is available for an additional $395**.**

The BWC EXCEL is most often installed on a guyed lattice tower, which is available in heights of 18 m to 37 m. Prices range from $5,000 to $7,500. Tilt-up versions of these towers are available for sites without crane access. A list of requirements for customer supplied towers is available.

Excel-S 10.0 kW with GridTek Specifications:

Start-up Wind Speed: 3.4 m/s

Cut-in Wind Speed: 3.1 m/s

Rated Wind Speed: 13.8 m/s

Rated Power: 10 kW (grid & pumping), 7.5 kW for battery-charging

Cut-Out Wind Speed: None

Furling Wind Speed: 15.6 m/s

Max. Design Wind Speed: 54 m/s

Type: 3 blades upwind

Rotor Diameter: 7 m

Blade Pitch Control: POWERFLEX®

Over speeds Protection: AUTOFURL

Gearbox: None, Direct Drive

Temperature Range: -40 to +60 c^o

Generator: Permanent Magnet Alternator

Output Form: 3 Phases AC, Variable Frequency (Regulated 48 - 240 VDC after VCS-10 or 240 VAC, 1Ø, 60 Hz with GridTek® inverter)

For our system I have decided to select this type of turbine depending on the following factors

- Since the infrastructure of the site is not suitable for the transportation, it is impossible to use the large wind turbines which decrease the cost of the system.
- The Bergey Wind power Co. (BWC) Excel is used for many years for the water pumping purpose
- The cost of the Bergey Wind power Co. (BWC) Excel is cheap relative to the other wind turbine of sizes the same.

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	18,000	0	250

Table 7.4The cost of the wind turbine per 10 kw

Depending on the demand of power required for our system the size of the wind turbine is given as follow.

Size (kw)	0	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Table 7.5The size of wind turbine to be considered during the simulation of the systems

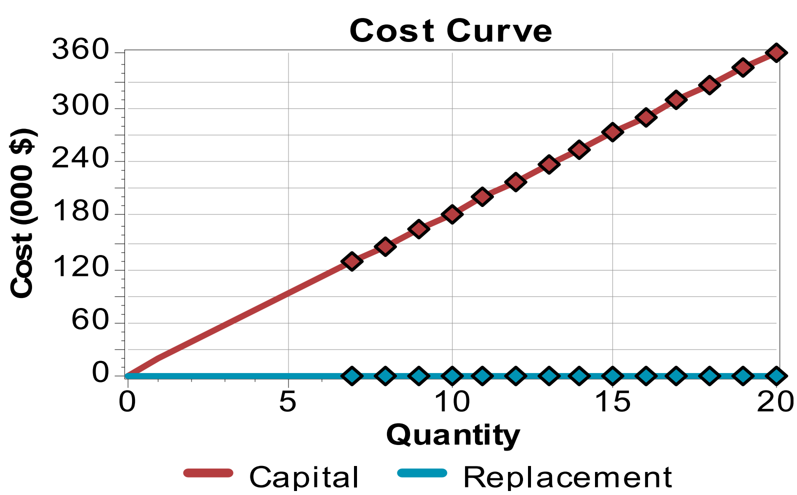

Figure 7.4The graph of the cost of wind turbine as the quantity increase.

The table and graph which is shown below is the power production of the selected wind turbine at the available wind speed. It shows the property of the wind turbine that we have selected.

	Wind speed (m/s)	Power output (kw)
1	0.00	0.000

2	1.00	0.000
3	2.00	0.000
4	3.00	0.046
5	4.00	0.247
6	5.00	0.587
7	6.00	1.028
8	7.00	1.678
9	8.00	2.620
10	9.00	3.690
11	10.00	4.750
12	11.00	6.150
13	12.00	7.330
14	13.00	8.680
15	14.00	10.130
16	15.00	11.300
17	16.00	12.000
18	17.00	11.940
19	18.00	11.600
20	19.00	11.040
21	20.00	10.480
22	21.00	9.800
23	22.00	9.120
24	23.00	8.440
25	24.00	7.760
26	25.00	7.080

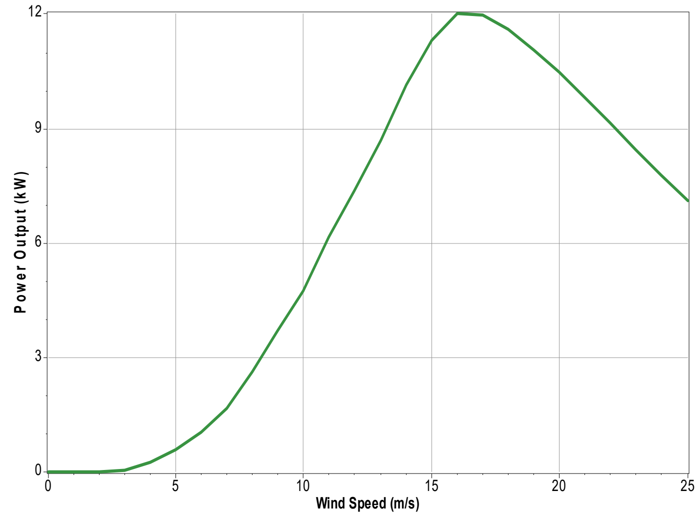

Figure 7.5The power curve of the selected wind turbine.

Table 7.6The power extracted from selected wind turbine.

5.3.Converter details

Any system that contains both AC and DC elements requires a converter. So we have to define the cost curve of the converter and choose the sizes we want HOMER to consider as it searches for the optimal system.

In the cost table, enter the converter's cost curve, meaning the way its cost varies with size. When specifying the capital and replacement costs, remember to account for all costs associated with the converter, including installation.

Note that the capital cost is the initial purchase price, the replacement cost is the cost of replacing the converter at the end of its lifetime (relevant only if the project lifetime exceeds the converter lifetime, but in our case it is not), and the operating and maintenance cost is the annual cost of operating and maintaining the converter.

We have to enter the converter sizes we want HOMER to consider as it searches for the optimal system. We have included zero size since we want to consider systems without converters. HOMER will use the information we entered in the cost table to calculate the costs of each converter size, interpolating and extrapolating as necessary.

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
7.000	1200	0	250

Table 7.7.The cost of the converter per 7kw

Depending on the demand of the system that is converted to the ac the size of the converter is given to the software as follow to optimize by using it.

Size (kw)	0	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200

Table 7.8.The size of the converter to be considered to optimize the systems

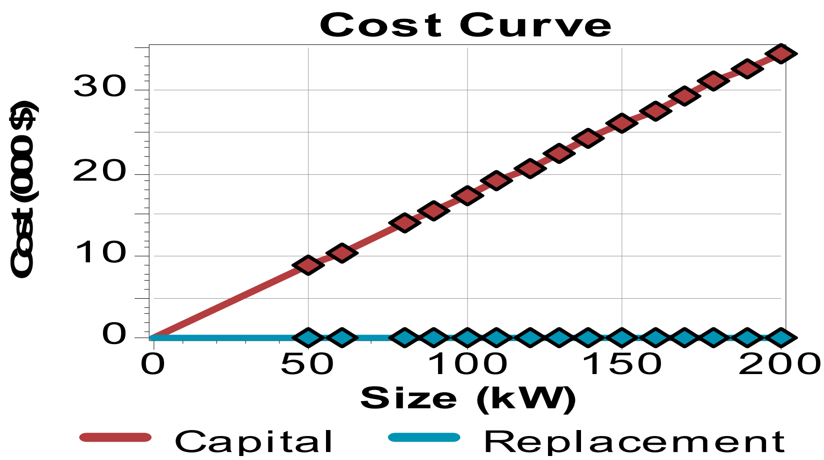

Figure 7.6The cost curve of the converter with respect to size

6. Enter resource details

6.1.Solar Resource

Here we specify the latitude and the amount of solar radiation available to the photovoltaic (PV) array throughout the year. HOMER uses this data to calculate the output of the PV array each hour of the year.

The latitude specifies your location on the Earth's surface. It is an important variable in solar calculations. It is used when calculating radiation values from clearness indices, and vice versa. It is also used to calculate the radiation incident on a tilted surface.

The baseline data is the set of 8,760 values representing the average global solar radiation on the horizontal surface, expressed in kWh/m^2, for each hour of the year. HOMER displays the monthly average radiation and clearness index of the baseline data in the solar resource table and graph.

There are two ways to create baseline data: we can use HOMER to synthesize data, or we can import hourly radiation data from a file. For our case we use HOMER to synthesize data.

To synthesize data, we enter twelve average monthly values of either solar radiation or clearness index and in our case we have average monthly solar radiation. We do not have to enter both; HOMER calculates one from the other using the latitude. Enter each monthly value in the appropriate row and column of the solar resource table. As we enter values in the table, HOMER builds a set of 8,760 solar radiation values, or one for each hour of the year. HOMER creates the synthesized values using the Graham algorithm which results in a data sequence that has realistic day-to-day and hour-to-hour variability and autocorrelation. [10]

HOMER uses scaled data for calculations. To create scaled data, HOMER multiplies each of the 8,760 baseline values by a common factor that results in an annual average value equal to the value that you specify in Scaled annual average. To determine the value of this factor, HOMER divides the scaled annual average by the baseline annual average solar radiation. The scaled data retains the shape and statistical characteristics of the baseline data, but may differ in magnitude. The default value for the scaled annual average is the baseline annual average solar radiation. When the two values are equal, the scaled data and baseline are identical. HOMER interprets a scaled annual average of zero to mean that there is no solar radiation.

Two reasons to use a scaled annual average that is different from the baseline annual average are for unit conversion or to perform a sensitivity analysis.

Latitude: 5 degrees 20 minutes North

Longitude: 39 degrees 36 minutes East

Time zone: GMT +3:00

Data source: Synthetic

Month	Clearness Index	daily Radiation
		(kWh/m^2/day)
Jan	0.745	7.050
Feb	0.741	7.400
Mar	0.589	6.120
Apr	0.470	4.890
May	0.429	4.334
Jun	0.349	3.440
Jul	0.343	3.410
Aug	0.411	4.203
Sep	0.508	5.253
Oct	0.504	5.070
Nov	0.662	6.320
Dec	0.756	7.000

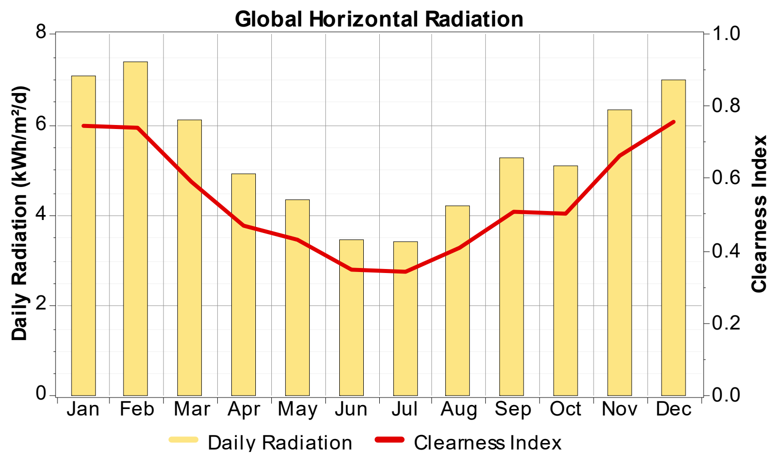

Figure 7.7.The graph of the average daily radiation with respect to clearness index of the site

Table 7.9.The average daily radiation for each of the 12 months

6.2.Wind Resource

Here we describe the available wind resource for the site that we are doing for. HOMER uses this data to calculate the output of the wind turbine each hour of the year.

The baseline data is the set of 8,760 values representing the average wind speed, expressed in meters per second, for each hour of the year. HOMER displays the monthly averages calculated from the baseline data in the wind resource table and graph.

There are two ways to create baseline data: Using HOMER to synthesize data, or importing hourly data from a file. In our case we have used the HOMER to synthesize data, because of the available data that we have is the monthly average wind velocity of the site.

To synthesize data, we must enter twelve average wind speed values: one for each month of the year. As we enter values in the table, HOMER builds a set of 8,760 values, or one wind speed value for each hour of the year. The synthesized data sequence has the specified seasonal and daily patterns, as well as the specified Weibull distribution and autocorrelation.

HOMER uses scaled data for calculations. To create scaled data, HOMER multiplies each of the 8,760 baseline values by a common factor that results in an annual average value equal to the value that we specify in Scaled annual average. To determine the value of this factor, HOMER divides the scaled annual average by the baseline annual average. The scaled data retains the shape and statistical characteristics of the baseline data, but may differ in magnitude. The default value for the scaled annual average is the baseline annual average. When the two values are equal, the scaled data and baseline are identical. HOMER interprets a scaled annual average of zero to mean that there is no wind resource.

Two reasons to use a scaled annual average that is different from the baseline annual average are for unit conversion or to perform a sensitivity analysis.

Data source: Synthetic

Month	Wind Speed (m/s)
Jan	2.68
Feb	2.78
Mar	2.40
Apr	2.06
May	2.34
Jun	2.97
Jul	3.33
Aug	3.28
Sep	2.66
Oct	1.99
Nov	2.18
Dec	2.52

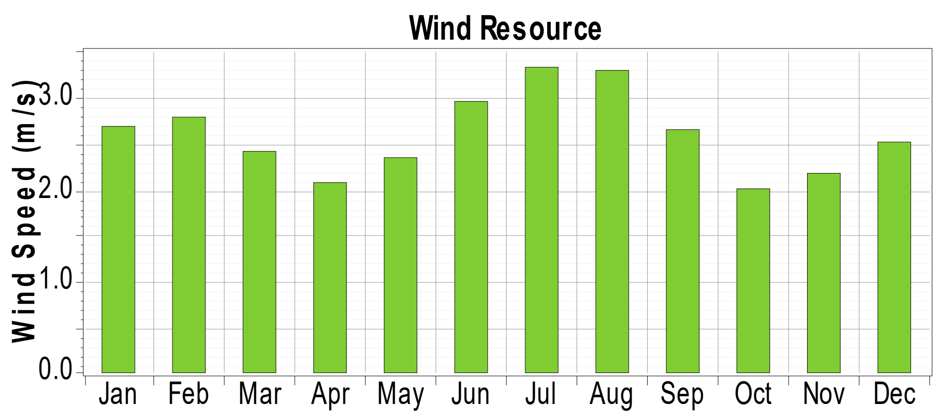

Figure 7.8.The graph of average wind speed

Table 7.10.The average wind velocity of the site at 10m

7. **Examine optimization results**

HOMER simulates system configurations with all of the combinations of components that you specified in the component inputs. HOMER discards from the results all infeasible system configurations, which are those that do not adequately meet the load given either the available resource or constraints that you have specified.

In the Overall Optimization Results table, HOMER displays a list of the solar-wind hybrid system configurations that it found to be feasible. They are listed in order (from top to bottom) of most cost-effective to least cost-effective. The cost-effectiveness of a system configuration is based on its net present cost, displayed under the heading "Total NPC" in the results tables. That is in this configuration Solar PV system is more feasible than that of hybrid PV- wind turbine and wind turbine alone is not feasible.

1. PV system

When the software compares PV alone, wind turbine alone, and PV-wind hybrid system, the PV system is the winner with system architecture of 210kw PV, 120kw inverter, Total NPC $856,033, levelized cost of energy (COE) $0.3/kwh, and operating cost $35,786/yr.

When we double click a row in the optimization result to open the simulation results window for that system, the top of the window displays the components of the system and three outputs: the total net present cost, levelized cost of energy, and operating cost.

This window contains the following tabs:

- The cost summary tab displays the total cash flow, categorized either by component or by cost type.

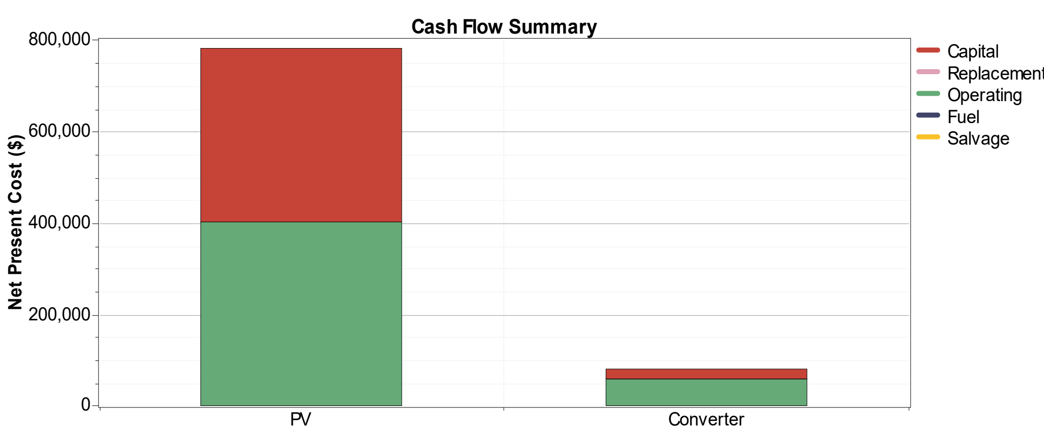

Fig.7.9 The cash flow summary of the PV system alone

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	378,000	0	402,676	0	0	780,676
Converter	20,571	0	54,786	0	0	75,357
System	398,571	0	457,462	0	0	856,033

Table7.11 The cash flow summary of the PV system alone

- The cash flow tab shows the year-by-year cash flows and provides access to the detailed cash flow table. The cash flow details window displays a table of cash flows and the cash flow graph in a format that can be resized. Cash inflows (income) appear as positive numbers, and cash outflows (expenditures) appear as negative numbers. There are several options for displaying the cash flow table:
  - Nominal cash flows display a table showing the actual cash flows that HOMER anticipates in each year of the project lifetime.
  - Discounted cash flows displays the cash flows discounted to year zero. HOMER calculates the discounted cash flows by multiplying the nominal cash flows by the discounted factor.

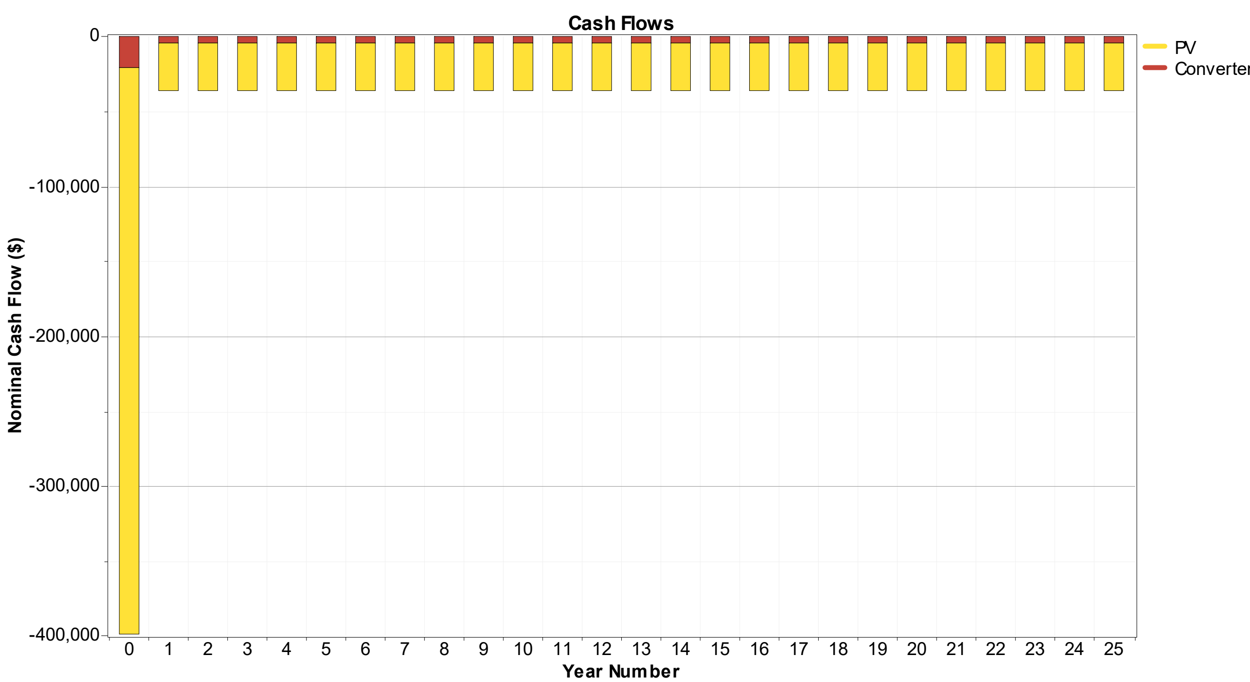

Fig.7.10.The cash flow analysis of the PV system

➢ The Electrical tab displays details about the production and consumption of electricity by the system. The total electrical production is the total amount of electrical energy produced by the power system in one year. It is the sum of the electrical energy produced by all components of the system. The renewable fraction is the portion of the system's total energy production originating from renewable power sources. HOMER calculates the renewable fraction by dividing the total annual renewable power production (the energy produced by the PV array, wind turbines, hydro turbine, and biogas-fueled generators) by the total energy production. Excess electricity is surplus electrical energy that must be dumped because it cannot be used to serve a load. Unmet load is electrical load that the power system is unable to serve. It occurs when the electrical demand exceeds the supply. Capacity shortage is a shortfall that occurs between the required operating capacity and the actual amount of operating capacity the system can provide. HOMER keeps track of such shortages and calculates the total amount that occurs over the year.

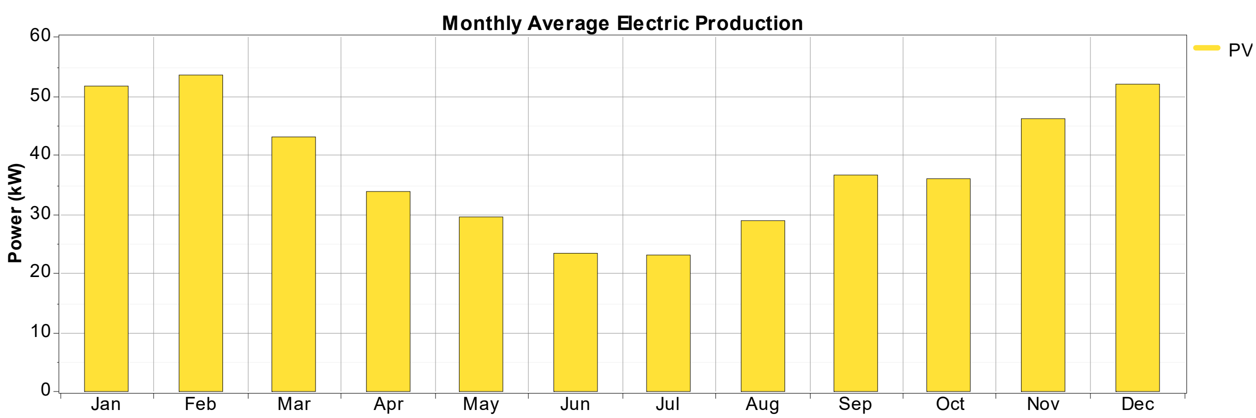

Fig.7.11.The monthly average electric production of the PV

The summary of the PV alone and the PV-wind turbine hybrid system is given in the following table.

	PV	xls	converter	Total capital cost	Total NPC	Tot.ann. cap. cost	Tot.ann. repl.cost	Tot.O&M. cost	Total fuel cost
No	kw		kw	$	$	$/yr	$/yr	$/yr	$/yr
1	210	0	120	398,571	856,033	31,179	0	35,786	0
2	190	7	100	485,143	917,494	37,951	0	33,821	0

Tot.ann. cost	Operating cost	COE	PV production	Wind production	Tot.electrical production	Deferrable load served	Ren. Fraction	Cap. shortage
$/yr	$/yr	$/kwh	Kwh/yr	Kwh/yr	Kwh/yr	Kwh/yr		Kwh/yr
66,965	35,786	0.300	333,540	0	333,540	223,129	1	0
71,773	33,821	0.322	301,774	12,756	314,530	222,945	1	186

Cap. Shortage fra.	Unmet load	Unmet load frac.	Excess electricity	Co_2 emissions	Co emissions	UHC emissions	Pm emissions	So_2 emissions	No_x emissions
	Kwh/yr		Kwh/yr	Kg/yr	Kg/yr	Kg/yr	Kg/yr	Kwh/yr	Kwh/yr
0	0	0	85,620	0	0	0	0	0	0
0	186	0	68,232	0	0	0	0	0	0

Table 7.12.The summary of the PV system alone and PV-wind hybrid system

The third option which is the wind turbine alone power generation is not feasible for this system and the software ignored it. Because wind turbine is feasible economically when we use large wind turbine and due to the site is not comfortable we cannot select the large one.

8. **Add sensitivity variables**

From the above procedure HOMER uses scaled resource data for simulations. This section describes how to enter sensitivity values for both the wind speed scaled annual average and solar radiation scaled annual average to perform a sensitivity analysis on these variables. The sensitivity analysis will allow you to explore how variations in average annual wind speed and average annual solar radiation affect the optimal design of the system. Another way to say this is that the analysis will show you the range of average annual wind speeds and average annual solar radiation for which we have to take solar-wind hybrid, solar PV or wind turbine alone is more feasible to design the system.

1. Click Wind resource to open the Wind Resource Inputs window.
2. Click the Scaled annual average Sensitivities button to open the Sensitivity Inputs window.
3. Add the values 1.5m/s, 2m/s, 3.5m/s, and 4.5m/s to the Average Wind Speed sensitivities table. Notice that the base value of 2.6m/s is already hard-coded into row 1.
4. Click solar resource to open the solar Resource Inputs window.
5. Click the Scaled annual average Sensitivities button to open the Sensitivity Inputs window.
6. Add the values 3kwh/m^2/d, 4 kwh/m^2/d, 6 kwh/m^2/d, and 7 kwh/m^2/d to the Average solar radiation sensitivities table. Notice that the base value of 5.36 is already hard-coded into row 1.
7. Click the Scaled annual average Sensitivities button to open the Sensitivity Inputs window.
8. Add the values 400kwh/d, 500kwh/d, 700kwh/d, and 750kwh/d to the average deferrable load table. Notes that the base value of 612 is already hard-coded into row 1.

Step 9: Examine sensitivity analysis results

HOMER displays sensitivity results in graphs and tables. This section describes how to view and interpret the sensitivity results to determine under what conditions a solar-wind system is more cost-effective than a solar system alone or wind turbine system alone.

1. Click Calculate to start the simulation. The progress bar indicates an estimate of the time remaining until the simulation and optimization process is complete.

2. Click the Optimization Results tab, and click Categorized to display the table of sorted system designs.
3. Click the Sensitivity Results tab, and click Graphic to display the table of sorted system designs. Make or verify the following selections:

   Sensitivity variable

   a. Deferrable load (kwh/d)=x-axis, global solar (kwh/m^2/d) = y-axis, wind speed (m/s) = 2.6, 1.5, 2, 3.5, 4.5
   b. Under Variables to plot, select Optimal System Type in the Primary list. Select <none> in the superimposed list.

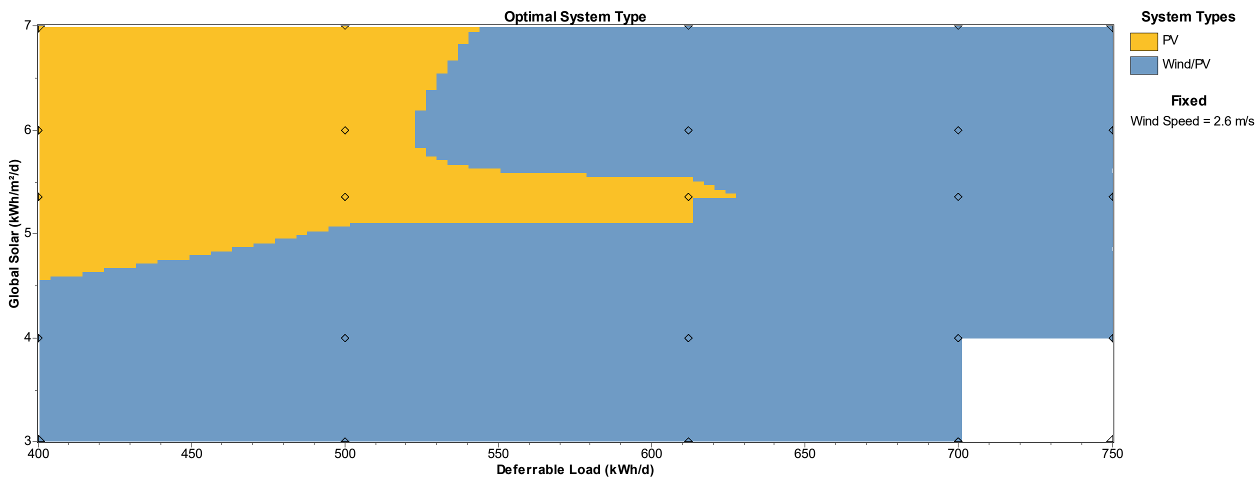

Figure 7.22 shows the optimal system type as the demand and global solar radiation increase

From this graph as the deferrable load increase, the using PV alone or wind turbine alone is not recommended rather using the hybrid system is recommended.

When we click on the optimization result, the leading one is the hybrid one and when we see the detailed of it as follow:

1. Cost summary

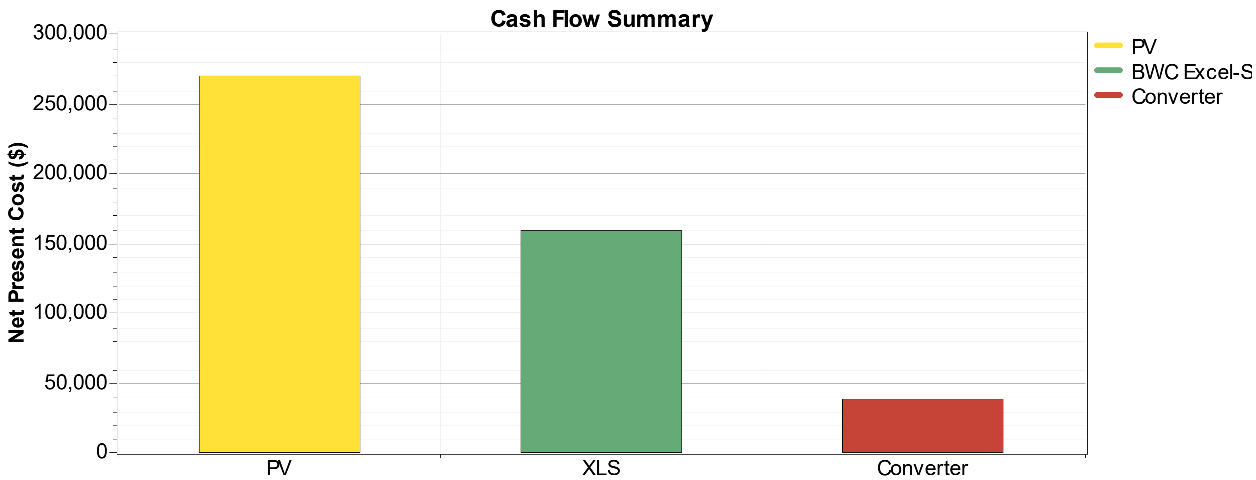

Figure 7.23 shows the summary of the cash flow as it is changed to net present cost

Component	Capital ($)	Replacement($)	O&M ($)	Fuel ($)	Salvage($)	Total ($)
PV	116,000	0	153,400	0	0	269,400
BWC Excel-S	144,000	0	15,340	0	0	159,340
Converter	10,286	0	27,393	0	0	37,679
System	270,286	0	196,133	0	0	466,419

Table 7.11 shows the total cost of the system which generate power

2. Cash flow

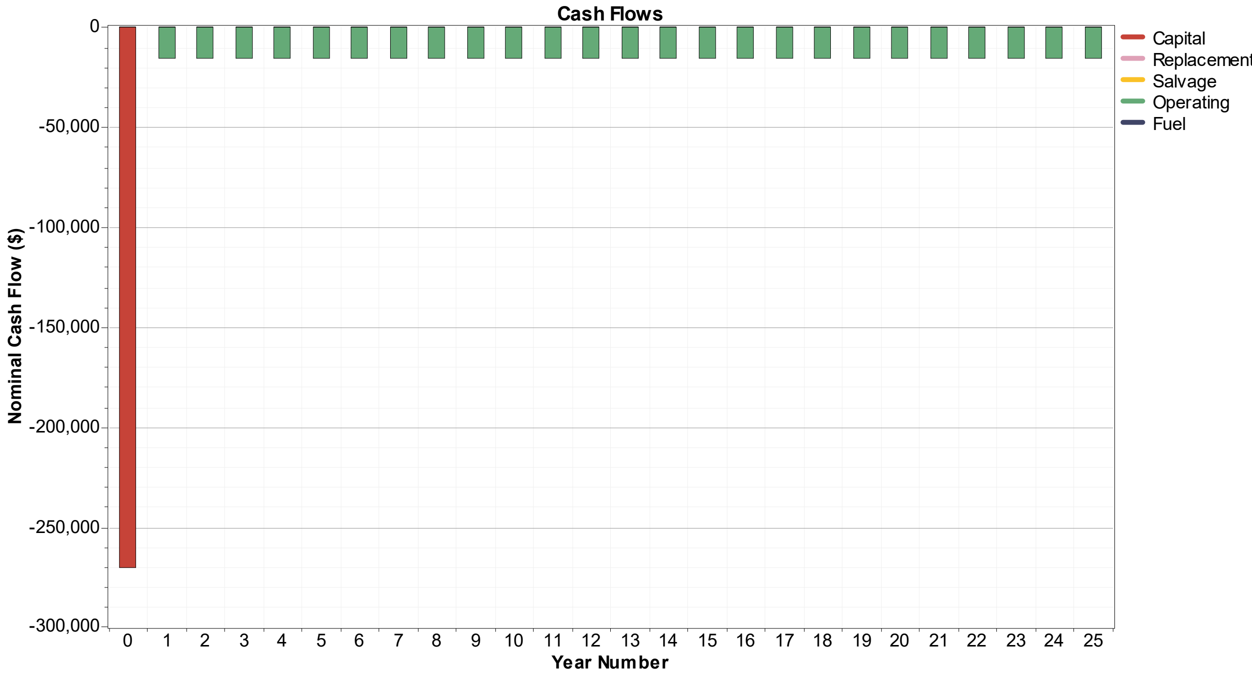

Figure 7.24 shows the cash flows of the system

3. Electrical

Production	kWh/yr	%
PV array	149,220	64
Wind turbines	83,271	36
Total	232,491	100

Consumption	kWh/yr	%
Deferrable load	211,266	100
Total	211,266	100

Table 7.12 shows the % of the PV and wind turbine for the consumption of the deferrable load.

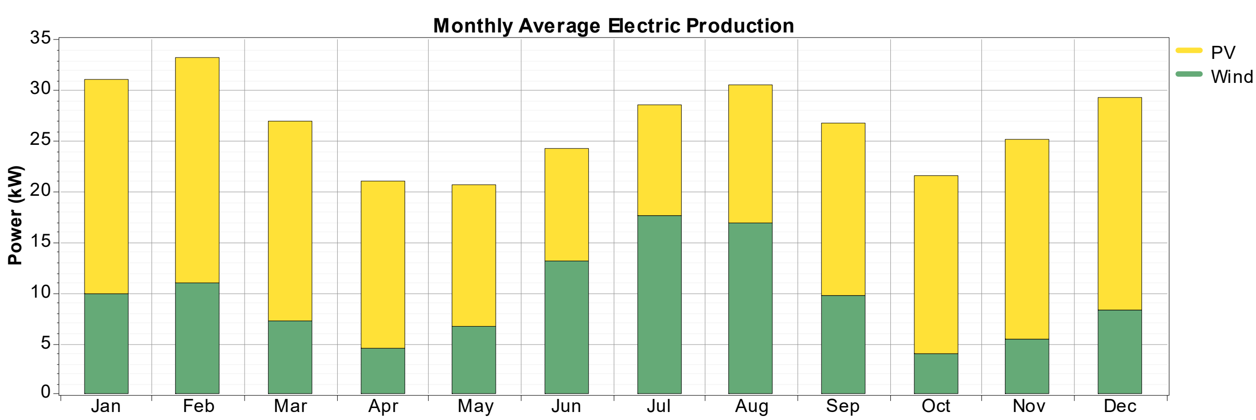

Figure 7.25 shows the monthly average electric production of the system

4. PV

Quantity	Value	Units
Rated capacity	80.0	kW
Mean output	17.0	kW
Mean output	409	kWh/d
Capacity factor	21.3	%
Total production	149,220	kWh/yr

Quantity	Value	Units
Minimum output	0.0	kW
Maximum output	86.6	kW
PV penetration	0.00	%
Hours of operation	4,398	hr/yr
Levelized cost	0.141	$/kWh

Table 7.13 shows the property of the selected PV

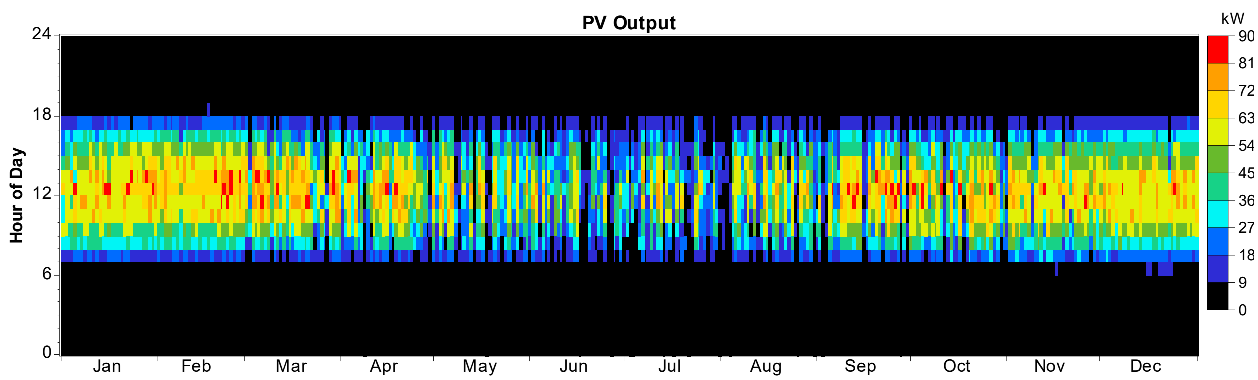

Figure 7.26 shows the PV output of the systems

5. XLS

Quantity	value	units
Minimum output	0.0	kW
Maximum output	95.7	kW
Wind penetration	0.00	%

Hours of operation	7,794	hr/yr
Levelized cost	0.150	$/kWh

Quantity	Value	Units
Total rated capacity	80.0	kW
Mean output	9.5	kW
Capacity factor	11.9	%
Total production	83,271	kWh/yr

Table 7.14 shows the property of the wind turbine selected

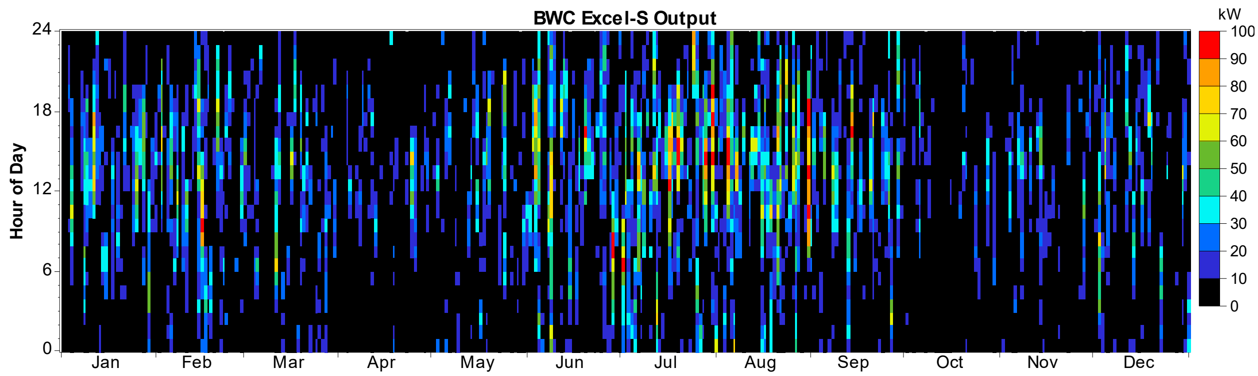

Figure 7.27 shows the BWC Excel-s output of the systems

6. Converter

Quantity	Inverter	Rectifier	Units
Capacity	60.0	60.0	kW
Mean output	14.7	0.0	kW
Minimum output	0.0	0.0	kW
Maximum output	60.0	0.0	kW
Capacity factor	24.5	0.0	%

Quantity	Inverter	Rectifier	Units
Hours of operation	4,362	0	hrs/yr
Energy in	143,341	0	kWh/yr
Energy out	129,006	0	kWh/yr
Losses	14,334	0	kWh/yr

Table 7.15 shows the property of the Converter selected

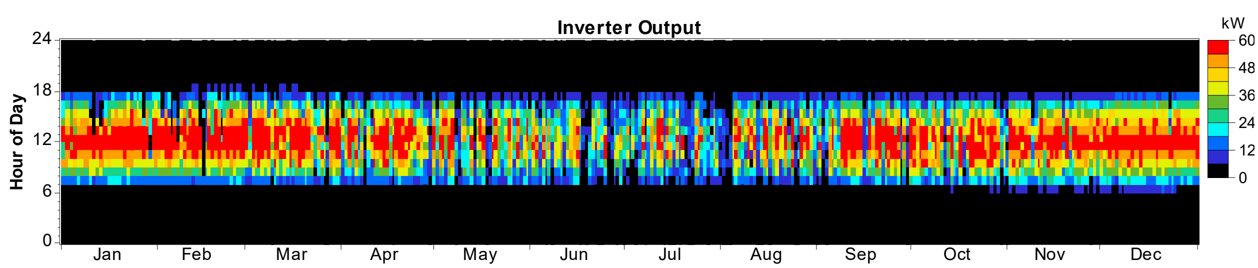

Figure 7.28 shows the inverter output for the systems

7. Emission

Pollutant	Emissions (kg/yr)
Carbon dioxide	0
Carbon monoxide	0
Unburned hydrocarbons	0
Particulate matter	0
Sulfur dioxide	0
Nitrogen oxides	0

Table 7.16 shows the Emission from the systems

7.9. Conclusion and Recommendation

7.9. 1. Conclusion

From this thesis we conclude that the problem of drinking water which faced the Liban woreda, specifically, the semento village which is found in the Borena Zone is solved easily by pumping water from the ground by the power of solar-wind hybrid systems.
Generally, the simulation of the hybrid system is;

- 80 kw PV
- 8 BWc Excel-s
- 60 kw inverter
- 60 kw rectifier
- Total NPC is: $ 466,419
- Levelized COE: $0.173/kwh

The total cost for the installation, operation and maintenance of the system is $93,674 + $ 466,419 = $560,093. By investing this amount of money for the system the people and the livestock living around the area will live without any fear for more than 15 years. The water which is pumped is excess and they can use for the irrigation purpose. Since the health problems comes to the society due to the lack of pure drinking water and the problem that face the livestock to die with luck of water is absent, the economy of the society will increase.

From the simulation system as the deferrable load increase, the feasibility of the system will divert to the hybrid system rather than the PV system alone or wind turbine alone. So as the demand of the power increase, using hybrid system is preferable. Since the power from the solar alone or from the wind turbine alone is seasonal we may not get the required power and we will expose to another cost for the power storage system. So the hybrid system will minimize this additional cost and almost we will get the constant power output.

7.9.2 Recommendation

The following recommendations are made out of this research; some of them are directed to the researchers while the others are directed to decision makers.

- Most of the people living in the drying area shift their home from place to place to the place where there is water. During this they cannot do the work that they can live with it and become dependent on the government help for food. But rather than displacing them from place to place and giving them the food for their eating, there is the easiest way to help them by installing for them the solar-wind hybrid system powered water pump for drinking, breeding the livestock and for irrigation purpose.
- The livestock and the people go the far place to fetch the drinking water and then become tired to do another work, and in addition to this they take the livestock to far place for drinking water and the livestock is uncomfortable and the people become tired to take them to the water. Rather than this once you invest on the resource exist around you, you will solve the problem by using the existing renewable energy.
- This thesis will change the living standard of the society around the liban woreda if it is changed to the work. So the responsible body living there, the government body, the researchers, or/and others should participate to change to ground.
- Since the road is difficult and it is impossible to install the wind turbine by using the crane. So If possible the road should be available and we replace the 10kw turbine by big turbine and the cost of the system will decrease.

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