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Feasibility Study on the Solar PV-B20 hybrid Powered Water Pumping System (A case study in Robit Village)

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Abstract— **With the experience of the global energy crisis attempts are being made throughout the world to harness alternate sources of energy. In this respect solar and bio fuel energy technologies stands out as the potential alternatives. Though initially photovoltaic technology was restricted to some special purposes, in recent times with the reduction in price of PV modules it has expanded to variety of common uses. In Ethiopia some PV systems have been installed for rural electrification and for pumping drinking water. Initial investment for this technology is very high, while operation and maintenance cost is very low so the reduction in the initial cost by combining with the bio fuel energy source which have equivalent energy per gallon and lower pollution emission than the conventional petroleum fuel is studied. In this paper several attempts are done to analyze the feasibility of PV-Diesel-Biodiesel hybrid system in comparison with PV-Diesel, Diesel-Biodiesel (B20), and Diesel powered systems. Thus this study provides some guidelines in evaluating the present situation in the context of economic viability and future scopes of PV-Diesel-Biodiesel hybrid technology by performing a case study in Robit Village.**

Index Terms—**Submersible pump, Hybrid, Homer,PV.**

I. INTRODUCTION

Ethiopia is a landlocked country situated in the Horn of Africa with a population estimated at over 83 million by 2007. Its annual population growth rate of 2.5% ranks it 28th fastest growing of 229 countries in the world. In terms of gross domestic product (GDP) per capita Ethiopia is rated 174th of 179 and in terms of human development index it is rated 169th of 177. Ethiopia as one of the poorest countries in the world. More country specific data can be found elsewhere. Most Ethiopians live in rural areas (84%) and only 1% of those have access to electricity.[1]

Due to its conditions, Ethiopia is an excellent example for most of the least developed countries in the sunbelt, hence several results achieved for Ethiopia might be transferred to countries comprising more than 500 million people around the world.

At present, a number of diversified and multipurpose national as well as international efforts have been exerted to ensure an improved provision of potable water supply service in both rural and urban areas of the developing countries.

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In spite of this recognition and effort, however, the gap between the standard requirement and the actual delivery of the service is getting wider and wider, consequently, an overwhelming majority of the rural poor are suffering from the lack of adequate and quality potable water supply. In short, the world wide recognition given to the importance of potable water supply.

In Ethiopia, both governmental and non-governmental development agents have been involved in order to enhance the coverage of potable water supply in different parts of the country. But, the coverage of the service in the country still lags behind and remains only less than 18 %. Even this low figure is not reliable as it presupposes a situation in which schemes that had been constructed so far are 100% functional, a presupposition that doesn’t reflect the reality on the ground. The existing poor coverage of potable water supply has been mostly attributed to and/or aggravated by the lack of sustainability of the water supply systems. Meanwhile, only a few of the water supply systems in rural Ethiopia have currently attained their financial status needed to run the schemes effectively through the collection of service charges from community members. This, however, is in contrary to the claim of the current water policy of the country that requires communities to cover the operation and maintenance costs.

Sustainability of a rural water system is a function of a number of factors. It depends not only on factors controlled by the project such as training, technology, the cost of the system, and construction quality, but also on factors beyond the control of the project such as the community’s poverty level and their access to technical assistance and spare parts.

Moreover, Ethiopia exhibits excellent prerequisites for a nearly 100% renewable energy supply. hydropower and solar resources offer the chance of renewable energy supply in an economically, ecologically and socially sustainable way. PV-hydro potentials have been already analyzed for Ethiopia and might lead to utility-scale PV power plants.

Ethiopia, even if, it is endowed with diverse energy sources it hasn’t make use of them because of lack of skilled personnel and absence of effective policy and implementation strategy. The majority of its population depends on traditional energy source, only very few portion of its population use modern energy sources. About 93 % of the country’s energy comes from fireweed and also other biomass. This traditional and unsustainable utilization of energy coupled with an increase in population has triggered the deforestation rate of the country that in turn leads to prevalence of drought and environmental degradation and also the rise in the price of fire wood.[9]

Therefore, on one hand it is important to increase the forest cover and forest product supply of the country and also expand the use of energy efficient technologies. On the other hand, it is vital to ensure sustainable economic development of the country and its national security by developing extensive bio-fuel plantations in a way that it doesn't compute with the agricultural production. Thus, the state gave due attention for this national development theme/ agenda/ as a result it had formulated and ratified different energy policy that will help its implementation including bio-fuel development and utilization strategy. [9]

Water is the primary source of life for mankind and one of the most basic necessities for rural development the rural demand of water for domestic use is increasing. At the same time, rainfall is decreasing so surface water is becoming scarce. Ground water seems to be the only alternative to this dilemma but the ground water table is also decreasing which makes traditional hand pumping and bucketing difficult.

The present day world, especially the developing countries, is experiencing a rapid growth in demand for energy use in order to improve the standard of living. For sustaining this growth, the fossil energy sources are not considered adequate. Realization of this situation has led the whole world to harness energy from other sources especially new and renewable sources of energy and to take measures of conservation due to this reason and the higher solar energy potential (Daily average monthly solar radiation on the horizontal surface is 6Kwh/m^2/day) in Robit Village which is higher than the recommended feasible solar energy potential of 5.2 Kwh/m^2/day for the generation of electrical energy.[10]

Robit village is located 27km from the capital of Amhara region BahirDar, with a total population of 15,946.The inhabitants in the village use hand pumps and diesel pumps for their water need. As a result of the raise in the price of fuel and the increase in the cost of maintenance the peoples in the village are suffering this huge problems. Hence the project deals with studying the feasibility of solar pv-diesel-biodiesel powered water pumping system in comparison with the existing diesel pumping system for a specific life time.

The relatively higher quantity of underground water in the village facilitates the implementation of additional pumping techniques for improving the water supply.

As it has been mentioned earlier currently the peoples in the village use diesel and hand pumps. because of the increase in the price of fuel for the diesel pumps and the decrease in the water level as well as lack of maintenance personnel's the difficulty in operation occurs. In addition, environmental pollution effects of fuels are the main issues of our world so in this study the feasibility of pumping systems with less pollution effects would be investigated.

Different organizations which are working on pure water supply in rural villages of Ethiopia are implementing diesel pumps which require frequent maintenance and fuel supply due to the shortage of maintenance personnel's the peoples should better be supported with systems which require an easy and less frequent maintenance.

In addition, the motivation behind this paper is also the recently revived interest in renewable technology.

II. SITE DESCRIPTION, DATA COLLECTION AND ANALYSIS

1) Site Description

Robit is a small village near the capital of Amhara Region with 1478 inhabitants. The Village is located 27km North of BahirDar The geographical location of the village is at latitude and longitude of 11°36′N 37°23′E11.6°N 37.383°E Coordinates: and an elevation of 1840 meters above sea level. the village have 4464 hectares of land out of this 1955 hectares is used for farming, 520hectar for animal grazing, 51.5hectar for flower plantation. The village community is having nearly 6138 people. In the village there are 24 wells, 1 spring and 2 seasonal rivers, for this wells the peoples use different water pumping systems most of the farmers were using pulley systems for pumping water from the wells but currently about 18 diesel pumps for irrigation.

The site is selected due to the scarcity of drinking water, the availability of data, water resource and different energy resources, the requirement of water pumping technologies for pumping drinking water. The renewable energy technologies which can save the environment are combined with the non renewable systems in a hybrid form for minimizing the effect of high PV-cell cost. The unexploited high potential of Bio-diesel which can be blended in an appropriate form with petroleum diesel and used with conventional diesel engines which results in reduced cost of fuels and reduces the pollution effect of the fuel are used in this work. Due to the missing values of the metrological data the data which is read from direct satellites by NASA is used in this thesis.

2) Pumping Test

Following the agreement made between AWWCE and Amhara water resource development bureau for the development of sustainable pure water supply for the village the pumping test which helps to determine, the safe yield (safe water flow rate), appropriate pump type, pump position, and the aquifer characteristics is performed. the test equipments like the deep meter, test pump(submersible pump with power output 10kw), generator and flow measuring device(cylindrical barrel was used.)

Testing procedure

Pre test

The test is performed continuously for 48hrs. but for this work the testing data for only 10 hours of the day time is taken due to the reason that the maximum sun shine hour of the region is less than 10hrs. which helps to choose the optimal discharge for the next step-test, to determine the no of steps and their discharges for the next step-test, to know whether the pump is proper or not for the well, and to check all the equipments are functioning.

During the test for a fixed water flow rate of 5.5lt/sec. water was pumped for 1 hour from the well with the pump position 45m below datum, the corresponding water level was lowered from 32.2m below datum (at 0 min since pumping started) to 32.55m below datum (at 60min since pumping started).

Step draw dawn test

Based on the result from the pre-test performing the step draw dawn test was decided with three steps each step having a duration of 1.5hrs and successively higher discharging rates of 3.5lt/sec.,4lt/sec.5.5lt/sec.

Table 1 Summarized table on the step draw down test

steps	Discharging Rate(lt/sec.)	Pumping duration(hr)	Draw dawn(m)
1	3.5	1.5	2.45
2	4	1.5	0.78
3	5.5	1.5	1.79

Constant rate test

The reason to choose the constant rate test was the step test conducted previously. The result of step drawdown test indicates pumping the well with 5.5lt/sec. for 48hrs causes a draw down that might not fully exploit the whole water column.

The aquifer parameters can be calculated from the constant yield draw down test data. Many scientists have put forward theories and formulas which are used to compute the aquifer by performing a field test. The choice of equations and theories developed for steady and unsteady state flows relies on the type of aquifer. Before choosing well flow equation, the aquifer type should be identified, in this case

i) The logging of sub surface geologic formation shows that the water bearing formations are highly weathered basalt (47-50m), highly fractured and slightly weathered basalt with vesicles (50-52m), weathered basalt with green alteration materials (52-56m), weathered basalt with mineral grain (56-61m), slightly weathered and highly fractured basalt with fine vesicles (61-67m) bounded above (30m to 42m) and below (67m to 70m) by massive basalt which can be treated as a confining unit.
ii) The static water level (32.20m) is above the top of the aquifer (47m).

Based on the above two reasons the aquifer is semi-confined to confined type. Therefore, Copper and Jacob analysis method is selected to compute the aquifer characteristics.

Flow Equations

In working with these equations, when u is sufficiently small (less than 0.05), the non equilibrium equation can be modified to the following form without significant error.

$$s = \left[Q/4\pi T \right] \times W(u) \qquad (1)$$

Where

$$u = \frac{r^2 s}{4T_1}$$

$$s = \left[(0.183Q)/T \right] \times \log\left[(2.25 \times T \times t)/(r^2 S) \right]$$

For a particular situation where the pumping rate is held constant, Q,T and S are all constants. The draw dawn, s, varies with $\log(t/r^2)$ when u is less than 0.05. From this relationship, two important relationships can be stated: one of the relationships, for a particular aquifer at any specific point (where r is constant), the terms s and t are the only variables in the equation. Thus, s varies as $\log C_1 t$, where C_1 represents all the constant terms in the equation.

From this simplified equation the hydraulic characteristics of the aquifer is derived using the data collected from the pumping test. The transmissivity of the aquifer for the region is,

Table 2 Aquifer parameters .

Analysis Method	Transmissivity (m^2/min)
Cooper and Jacob	8.45×10^{-2}

a) 3.2.3 Maximum Yield

From Thiem's equilibrium well equation, we know that

$$Q = \left[(2.73 \times K \times b \times (H-h)/\log(R/r)) \right] \qquad (2)$$

Relationship of drawdown to yield

In the above equation, keeping K, R, r, b (as long as the draw down does not exceed the distance from the static photometric surface to the top of the aquifer) constant, the whole equation would be reduced to,

$$Q = C(H-h)$$

Where C is the constant term, theoretically, this means that if the draw down is doubled, the yield is doubled. Q and H-h has linear relationship. For the well in this case, The bottom of the aquifer is 67m and pizometric level is 32.20m from datum, Hence for the specified maximum testing flow rate of 5.5

H =67m-32.20m=34.8m.

h =67-40.6=26.4m. this implies for

$$Q = 5.5\,{}^{lt}\!/_{sec.} \quad H - h = 8.4m$$

$$h_{max} = 67 - 47 = 20m$$

where 47m is top of aquifer

$$H - h_{max} = 34.8 - 20 = 14.8m$$

Therefore

$$Q_{max} = (Q) \times (H - h_{max})/(H-h)$$
$$= (5.5 \times 14.8)/8.4 = 9.69\,lt/\text{sec.}$$

Thus, the well is expected to give up to 9.69 $lt/\text{sec.}$ for of 8.4m draw dawn

Safe Yield

Up to (70%-80%) of the yield of the well can be used as a safe yield by considering different constraints to minimize ground water depletion. Taking 70% of the maximum yield, $9.69\,lt/\text{sec} \times 0.7 = 6.78\,lt/\text{sec}$ so 6.5 lt/sec is the safest yield,

III. WATER PUMPING SYSTEM DESIGN

1) *Introduction*

Water pumping technology developed in parallel with the sources of power available at the time. Indeed one can say that our first ancestors who cupped their hands and lifted water from a stream chose the 'pumping' technique appropriate to them. Modern devices such as centrifugal pumps have reached a high state of development and are widely used, particularly in developed countries, only because suitable power sources such as diesel engines and electric motors became available.

A wide range of pump types is available on the market. Prevailing local conditions and management capacities determine the type that is most suitable and sustainable. While it may seem obvious that effective involvement of users, the private sector and support organizations is important in the choice of pumping technology, the fact remains that it is frequently disregarded. Too often technical capacities of users and local support are over-estimated, resulting in pumps not being properly operated and maintained, and eventually to their breakdown.

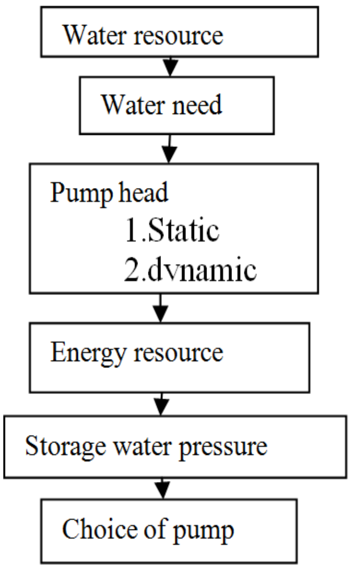
Participation by representatives of the different user groups, in selecting and trying out the pumps, helps to ensure that a type is chosen that is suitable and acceptable to them. Productive use of the pumped water generally has a very positive effect on the upkeep and lifetime of the pump. It also helps when users learn about the proper way of operating a specific type of pump and the underlying reasons, and set up and implement a system for proper operation as part of local participatory planning and management of the service. When local interest is not generated, lack of local funds or incentives to invest in O&M and replacement of pumps means that their condition degenerates quickly.

2) System lay-out

The hybrid pump system consists of solar panels on a mounting structure, diesel generator, pump controller, an electric pump and a storage tank for water. The big advantage of the hybrid pump is that there is no battery necessary to back-up the solar power. The pump is connected to solar panels and diesel generator so water is pumped from low to high level in case the sun shines. The water is buffered in the tank that is mounted at a higher level. In this way there is pressure on the taps and there is water available if the sun is not shining. The function of the water tank is comparable to the function of the battery.

To obtain a good match between solar panels and the pump, the pump controller is connected in between. This controller makes the solar pump a unique product. Not any other pump can be used, on the contrary! The controller converts the direct current from the solar panels and DC generator into alternating current with a frequency that depends to the irradiation. At low irradiation, eg. in the morning at sunrise, the pump will be driven by a slowly rotating engine.

3) Design Scheme



Total dynamic head and flow rate based on the water resource the well can safely deliver, 6.5lt/sec with a maximum use of water for 24hrs each day the other time of the day is left for recovery of the well, due to the result during the testing operation the maximum water depth after continuously pumping at the flow rate of 5.5lt/sec for 48hrs, is 40.60m and the static water level (32.20m).

4) Water resource

The flow rate of water the pump can deliver every day can be calculated based on the well capacity and the sunshine hour of the day, so the daily water flow rate that the pump can deliver is tabulated as,

Table 3 Daily water supply by the well for the respective month, and demand by the population in Robit village.

Month	Avg. Sun Shine hour of each month(hrs/day)	Well capacity Lt/sec	Daily water supply (m^3/sec)	Daily water demand	Excess water
Jan	9.7	6.5	227	154	73
Feb	9.5	6.5	222.3	154	68.3
Mar	9.2	6.5	215.3	154	61.3
Apr.	8.8	6.5	206	154	52
May	8.5	6.5	199	154	52
Jun.	6.7	6.5	156.8	154	2.8
July	5.0	6.5	117	154	-37
Aug.	5.0	6.5	117	154	-37
Sep.	5.9	6.5	138.1	154	-15.9
Oct.	8.9	6.5	208.3	154	54.3
Nov.	9.5	6.5	222.3	154	68.3
Dec.	10	6.5	234	154	80

5) Water need (m^3/day)

The water need by a person from the standard Index number of World health organization is: 40 liter per person per day may be lower than this in the real need [11], This is including water for bathroom, shower, dishes, cloth washing. Assuming the maximum amount of water needed by a person in the village is 30 liter per person per day then the total water requirement by a total of 10350 peoples in the village is 310500 liters per day but the pump should satisfy the water demand on the month of June, which the peoples in the village suffer higher shortage of water but during this season the maximum water the solar pump with no battery system can supply is 156800 liters per day which is around half of the requirement so a similar pumping system is required 100m on the other side of the storage tank around the selected location.

6) Storage system

Storage is necessary for good water management. Water can easily be distributed fairly and stored for critical times when the system fails or during bad weather. Water storage design is different for village water supplies, livestock watering, and irrigation,

Designing water storage for domestic water supply requires an understanding of end users and the power resource. The available power resource must be considered when determining storage size. For example, the storage tank should be larger for PV water pumping systems. Unlike conventional systems, PV/wind systems depend on daily weather conditions. Poor solar radiation or calm days create problems for meeting the daily water demand, so water tanks should be larger for such systems.

Unlike conventional water pumping systems, estimating the proper size of a PV pumping system, including the water tank, requires detailed consideration of each component, and of the entire system.

So, As a rule of thumb, for Robit village the storage capacity should be the double of the estimated daily water demand, which is 621,000 liters, Based on the specified value the storage tank have a cylindrical geometry with 6m diameter and 12m height.

Vertical cylindrical tanks, with flat bases and conical roofs, are universally used for the bulk storage of liquids at atmospheric pressure. The main load to be considered in the design of these tanks is the hydrostatic pressure of the liquid, but the tanks must also be designed to withstand wind loading on the tank roof.

The minimum wall thickness required to resist the hydrostatic pressure can be calculated from the equations for the membrane stresses in thin cylinders,

$$e_s = \frac{\rho_L H_{Lg}}{2 f_t J} \frac{D_t}{10^8} \quad (3)$$

Where

e_s : tank thickness required at depth H_L, mm,

H_L .: liquid depth, m,

ρ_L : liquid density, kg/m^3,

J: joint factor (if applicable),

g:gravitational acceleration, 9.81 m/s^2,

f_t : design stress for tank material (concrete 3MPa), N/mm^2,

D_t: tank diameter, m.

Then at the depth of 12m from the top water level and since there is no joint in the construction the joint factor is taken to be 1 then the thickness becomes

$$e_s = \frac{\rho_L H_{Lg}}{2 f_t J} \frac{D_t}{10^8} = \frac{10 \times 12 \times 6}{2 \times 3 \times 10^8} = 0.059m$$

or small tanks a constant wall thickness would normally be used, calculated at the maximum liquid depth. With large tanks, it is economical to take account of the variation in hydrostatic pressure with depth, by increasing the plate thickness progressively from the top to bottom of the tank.[13]

7) Pump Head

"Head" is a term commonly used with pumps. Head refers to the height of a vertical column of water. The total head of a pump is composed of several types of head that help define the pump's operating characteristics.

Total dynamic head (TDH).

The total dynamic head is the sum of,

- Total static head.
- The friction head.
- The velocity head.
- The pressure head.

Total Static Head (TSH).

The total static head is the total vertical distance the pump must lift the water. When pumping from a well, it would be the distance from the pumping water level in the well to the ground surface plus the vertical distance the water is lifted from the ground surface to the discharge point. When pumping from an open water surface it would be the total vertical distance from the water surface to the discharge point.

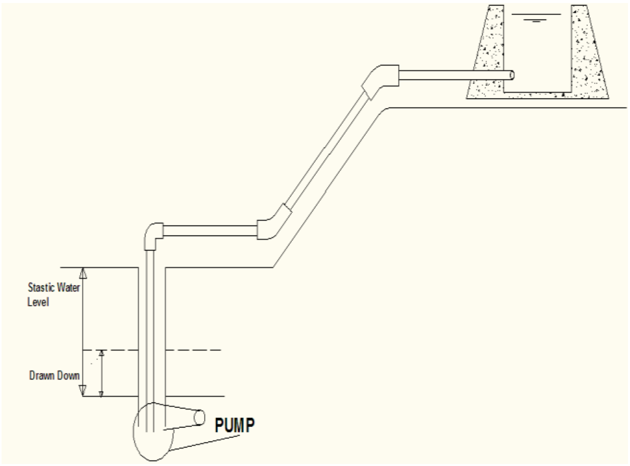


Figure 1 Well 1 characteristics

In the case of the well considered in this paper is,

TSH = lift + drawdown

Where**: lift** is the height from the static water level to the discharge point

For the discharge point of 12m from the ground level and since the water level before pumping starts is 32.2m,

lift =12m+32.2m=44.2m.

And the maximum drawdown for the 48hr. pumping test operation is 8.4m, then

TSH = 44.2m+8.4m=52.6m$\cong$53m=174ft

The total static head for the two wells is equal due to the assumption that **well no2** have an equal static water level, draw down, and delivery with the tested well called **well no1.**

Pressure Head (PH).

Center pivot systems require a certain pressure at the pivot point to distribute the water properly. The pressure head at any point where a pressure gage is located can be converted from pounds per square inch (PSI) to feet of head by multiplying by 2.31. Most busting water pump systems operate at 50 to 60 PSI,[12]

The Friction Head(FH).

Friction head is the energy loss or pressure decrease due to friction when water flows through pipe networks. The velocity of the water has a significant effect on friction loss. Loss of head due to friction occurs when water flows through straight pipe sections, fittings, valves, around corners, and where pipes increase or decrease in size. Values for these losses can be calculated or obtained from friction loss tables. The friction head for a piping system is the sum of all the friction losses.[13]

As shown in the proposed pump system arrangement. For the recommended pump position of 10% below the maximum drawdown position from the ground level which is at $44.66m \cong 45m$ so the pump is located at 45m below the ground level for both wells.

Selecting a 2inch (0.0508m) inside diameter plastic pipe for the two wells,

Then,

$$A = \pi \frac{d^2}{4} = 2.03 \times 10^{-3} m^2$$

The velocity of the fluid in the pipe becomes,

$$u = \frac{Q}{A} = \frac{6.5\times10^{-3}\ m^3/\text{sec.}}{2.03\times10^{-3}\ m^2}$$

Table 4 Physical properties of water at an ambient temperature of 25°.

Physical property.	Spec. weight γ (kN/m^3)	Density (kg/m^3)	Viscosity $\mu\times10^{-3}$ $N.s/m^2$	Vap. Press. P_v kN/m^2	Vap. Press. head P_v/γ, am.
Value	9.777	997.0	0.890	3.17	0.33

The Reynold number is calculated by,

$$R_e = \frac{\rho u d}{\mu} = 1.83\times10^5$$

For the smooth plastic pipe from [13] the friction factor is read as, $f = 0.00175$

Table 5 Pressure loss in pipe fittings and valves

Fitting or valve	K: number of velocity heads	Number of equivalent pipe diameter
45°	0.35	15
45°	0.20	10
90°	0.6-0.8	30-40
90°	0.45	23
90°	1.50	75
Tee-entry from leg	1.20	60
Tee-entry into leg	1.80	90
Union and coupling	0.04	2
Sharp reduction (tank outlet)	0.50	25
Sudden expansion (tank inlet)	1.00	50

Considering the Table 4.3 the losses for each well with the total pipe lengths of 82m and 184m for well no1 and well no2 respectively is tabulated as,

Table 6 Pressure losses for each system in well no1 and well no2.

Fitting type	No of fitting in		K, number of velocity heads		Number of equivalent pipe diameters.	
	well no1	well no2	well no1	well no2	well no1	well no2
45°standard elbow	2	1	0.70	0.35	30	15
90° standard radius elbow	1	2	0.80	1.60	40	80
Union and coupling	14	31	0.56	1.24	28	62
Sudden expansion (tank inlet)	1	1	1.00	1.00	50	50
Total			**3.06**	**4.19**	**148**	**207**

The pressure loss due to friction is given by,

$$\Delta P_f = 8f(L/d)\frac{\rho u^2}{2} \qquad (5)$$

Well no1

Friction loss in pipe, with 82m total pipe length is,

$$\Delta P_f = 116 kN/m^2$$

The extra length of pipe to allow for miscellaneous losses,

=0.0508m × 148=7.5m

So, total length for ΔP calculation=82+7.5=89.5m.

$\Delta P_f = 127\ kN/m^2$.

The total energy required can be calculated from the equation:

$$E = \lfloor \rho g (TSH + P_f) \rfloor \times Q \qquad (6)$$

E=4.2kw=5.63Hp

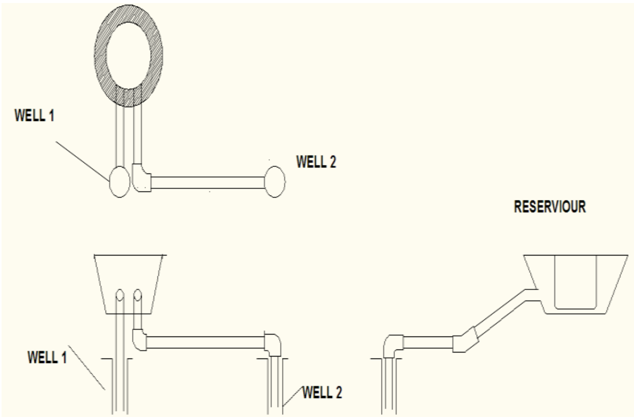


Figure 2 Characteristics of Well 1 and Well 2

Well no2

For the arrangement of Well no2 shown in fig 4-2 which have a total tube length of 184m the friction loss in the pipe which accounts the loss in the pipe, bends and couplings as well as at the entrance to the storage tank is,

$\Delta P_f = 261 kN/m^2$.

The extra length of pipe to allow for miscellaneous losses,

=0.0508m × 207=10.5m.

So, total length for ΔP_f calculation=184+10.5=194.5m.

ΔP_f =276 kN/m^2.

The total energy required for the pump in well no2 can be calculated using equation 4.7:

E = 5.2kw=6.97Hp.

8) Pump Selection

A chart showing the most desirable pump types to use for a given range of flow rates and total dynamic heads.

Then from the known pump manufacturer a Franklin submersible pump having the capacity of 7.5Hp based on the selection criteria shown in the table below is selected

For both wells.

The pump has the following features

- Heavy-duty stainless steel discharge head and motor bracket.
- Stainless steel shaft, shell, intake screen and cable guard provides corrosion resistance and longer pump life.
- Glass-filled impeller stage assemblies provide exceptional strength and durability.
- Ceramic shaft sleeve and rubber discharge bearing minimize bearing wear and shaft misalignment.
- Modular motor bracket enabling 4" or 6" motor mount for 5-10 horsepower units.
- The maximum efficiency of the pump is 65%.

Table 7 Pump selection criteria

liters per second	TDH (meter)		
	15 or less	**15 to 150**	**150 or more**
0 to 20	Propeller centrifugal.	Centrifugal vertical turbine submersible.	Centrifugal vertical turbine submersible.
20 to 315	Propeller.	Centrifugal vertical turbine submersible.	Centrifugal vertical turbine submersible.
315 or more	Propeller.	Centrifugal vertical turbine propeller submersible.	Centrifugal vertical turbine.

So, for the pumping system design in the Robit village from the known pump and motor manufacturer Frankline a 7.5 hp 6" Franklin Submersible Motor is selected, with the following additional features in the table below,

Table 8 Specifications of Frankline motor.

Hp	Voltage	wiring	phase	price
7.5	230V	3 wire	3	$1449.00

Franklin Electric super stainless submersible 6" well water pump motor 230 volts, 3 phase. Hermetically sealed windings, water lubrication, 48" removable leads, UL 778 recognized, CSA certified, ANSI/NSF certified with NEMA mounted dimensions.

IV. HYBRID SYSTEM OPTIMIZATION

The HOMER software, NREL's micro power optimization model, can evaluate a range of equipment options over varying constraints and sensitivities to optimize power systems. HOMER's flexibility makes it useful in the evaluation of design issues in the planning and early decision-making phase of rural electrification and water pumping projects.
Whereas the simulation process models a particular system configuration, the optimization process determines the best possible system configuration. In HOMER, the best possible, or optimal, system configuration is the one that satisfies the 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 which HOMER can consider multiple possible values in its optimization process. Decision variables in this work are:

- The size of the PV array
- The size of each generator
- The size of the ac–dc converter
- The set of rules governing how the system operates

1) 6.2 Equipment Considered

In this work the equipments considered to compare both the PV diesel hybrid system and the PV-Diesel-Biodiesel hybrid (PV-B20) system are PV, Converter, Generator and the primary load (primary load is the pump load which should be satisfied based on the requirement i.e the main load) as shown in fig 6.1 below.

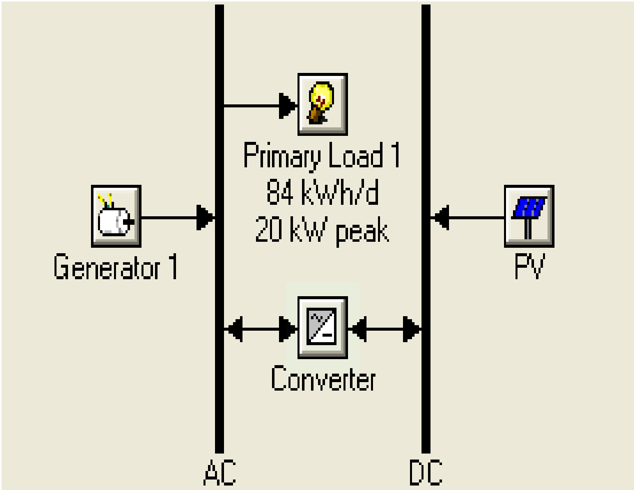


Figure 3 Equipments Considered in Homer Simulation

2) Sensitivity Analysis

For a particular input variable sensitivity analysis is performed by entering multiple values HOMER repeats its optimization process for each value of that variable and lets to see how the results are affected.
An input variable which have multiple values is called a sensitivity variable, and it can be defined as many sensitivity variables as required. A sensitivity analysis can be referred to as one-dimensional if there is a single sensitivity variable. If there are two sensitivity variables, it is a two-dimensional sensitivity analysis, and so on. HOMER's most powerful graphical capabilities were developed to help examine the results of sensitivity analyses of two or more dimensions.

Assumptions and model inputs.

Solar Resource

To model a system containing a PV array, we must provide HOMER the solar resource data for the location of interest. Solar resource data indicate the amount of global solar radiation (beam radiation coming directly from the sun, plus diffuse radiation coming from all parts of the sky) that strikes Earth's surface in a typical year. The data can be in one of three forms: hourly average global solar radiation on the horizontal surface (kW/m^2), monthly average global solar radiation on the horizontal surface ($kWh/m^2/day$), or monthly average clearness index shown its results in fig below
The solar resource and the time zone are specified in the solar resources input window. Solar radiation data on the monthly average bases from NASA Surface Meteorology is used the software then develops an automatic output of the clearness index, and the results are plotted in bar chart form as shown in fig below

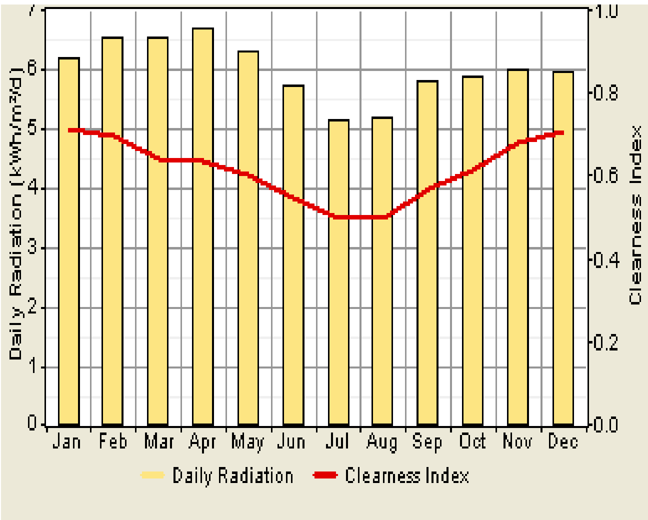


Figure 4 Global Horizontal Radiation and Clearness Index

Extraterrestrial Radiation $\left(\overline{H_o}\right)$

The extraterrestrial Radiation $\left(\overline{H_o}\right)$ in the HOMER analysis for Robit village is tabulated on the monthly bases when the location data latitude and longitude of 11°36′N 37°23′E11.6°N 37.383°E Coordinates is provided.

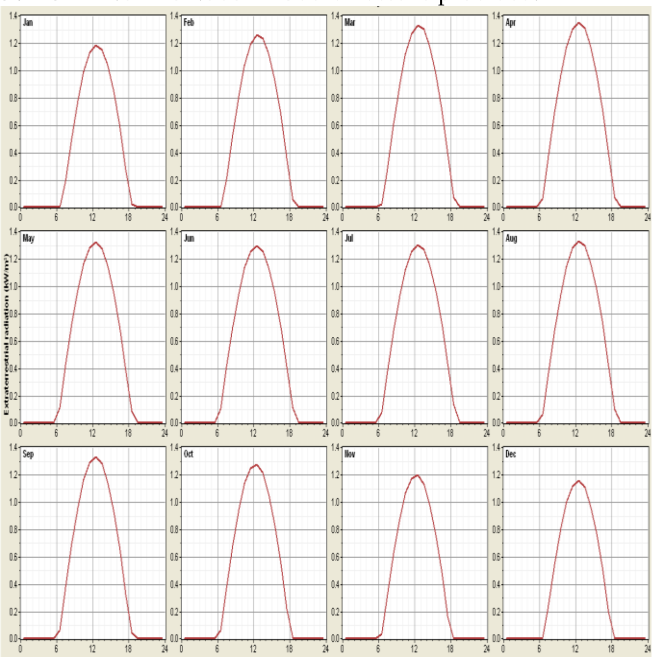


Figure 5 Extraterrestrial Horizontal Radiation Daily profile

Load inputs

HOMER models the PV array as a device that produces dc electricity in direct proportion to the global solar radiation incident upon it, independent of its temperature and the voltage to which it is exposed and the loads to be served are AC and DC, AC primary load served is the total amount of energy that went towards serving the AC primary load during the year and the DC primary load served is the total amount of energy that went towards serving the DC primary load during the year.

Loads are demand requirements that the power system must supply. HOMER can model electric, thermal, and hydrogen loads. Electric loads can be primary, meaning they must be served on demand, or deferrable, meaning there is some flexibility in when they can be served. So the primary load 1 is selected in the equipments to consider window of HOMER and the power requirement by the pumps in well no1 and well no2 which is 15Hp (11.2Kw) is entered based on the sunshine hours of each month.

Reliability Constraint

The economic performance of a renewable energy system can be significantly improved if a small portion of the annual load is allowed to go unserved. a solar array that do not have to meet an occasional large load may be significantly smaller than those that must meet the load at all times. This is especially true for those extreme cases with a peak load that occurs after several cloudy days. If it is acceptable for the system to be down for a small fraction of the year, or if unnecessary loads can be shed when the storage is low, significant capital cost may be saved. HOMER models this scenario with the maximum annual capacity shortage constraint. Set to 0% by default (in which the system must meet all of the load all of the time) a sensitivity analysis on this variable shows that the optimal system type might change if a small amount of the annual load (1/2% to 5%) is allowed to go unserved.

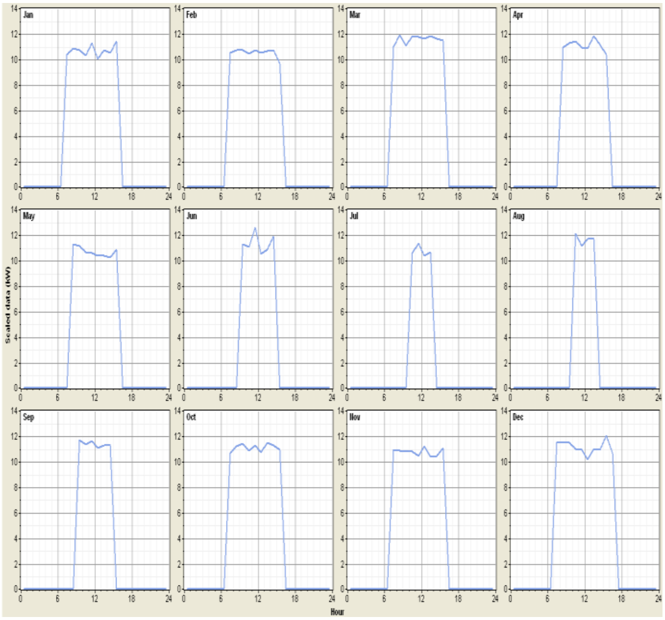


Figure 6 Scaled Data Daily Profile.

The load profile is based on the pump power requirement in each day of a year due to this load inputs HOMER can perform a sensitivity analysis by accepting multiple values for a particular input variable such as the average load. By scaling the annual average value of kWh/d, HOMER models the impact of increasing loads. This analysis determines how changes in the input variable affect the performance of the system and the relative ranking of different systems.

The scaled data seasonal profile of the load after the inputs on each hour of the day is provided on the loads input window the seasonal average value is shown in fig 6.6.

PV inputs

Photovoltaic panels were specified with capital and replacement costs of $ 4.21/Wp on May 2010. Very little maintenance is necessary for the panels themselves. A derating factor of 90% was applied to the electric production from each panel.

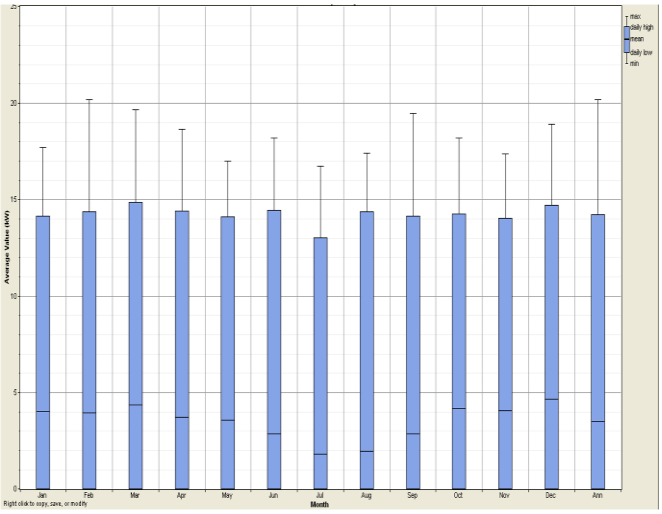


Figure 8 Scaled data seasonal profile

This factor reduces the PV production by 10% to approximate the varying effects of temperature and dust on the panels. The panels were modeled as fixed and tilted south at an angle equal to the latitude of the site.

In the PV input window the cost curve of photovoltaic (PV) panels, the sizes that we want HOMER to optimize are provided, since PV costs are often assumed to be linear with size, a single input generates the cost curve for the different sizes to be considered.

The cost in the cost inputs window of the PV system, the cost per kilowatt peak of the PV taken from Solar Buzz, which is the known distributer of PV modules above 125Wp, inverters, Batteries and Charge controllers, on May 2010 $4.21 per watt peak is taken, so for 1Kw $4210 is set as capital and replacement costs the operation and maintenance costs are considered zero. In addition the costs of PV modules of higher capacities have costs which have linear relation is considered for the different PV sizes considered which ranges from 0Kw to the maximum of 45Kw for best optimization results.

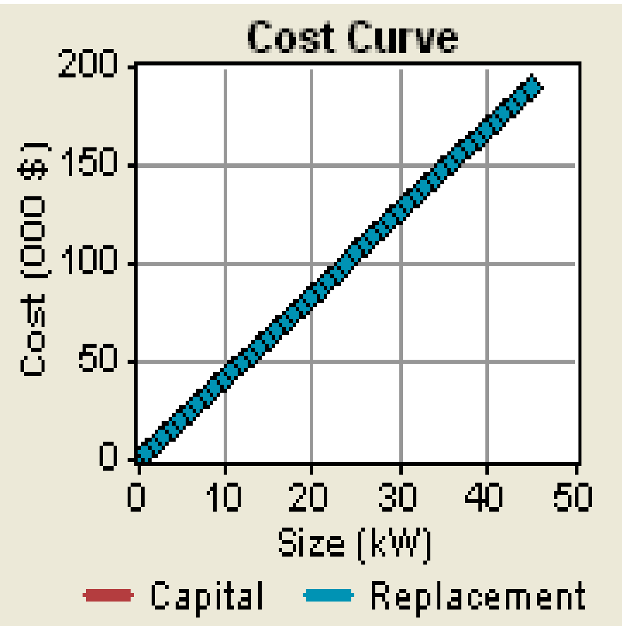


Figure 9 Cost Curve for PV Inputs

Converter inputs

A converter is a device that converts electric power from dc to ac in a process called inversion, and/or from ac to dc in a process called rectification. HOMER can model the two common types of converters: solid-state and rotary. The converter size, which is a decision variable, refers to the inverter capacity, meaning the maximum amount of ac power that the device can produce by inverting dc power. The rectifier capacities which are specified in the converter inputs window, which is the maximum amount of dc power that the device can produce by rectifying ac power, as a percentage of the inverter capacity. The rectifier capacity is therefore not a separate decision variable. HOMER assumes that the inverter and rectifier capacities are not surge capacities that the device can withstand for only short periods of time, but rather, continuous capacities that the device can withstand for as long as necessary. The HOMER user indicates whether the inverter can operate in parallel with another ac power source such as a generator or the grid. Doing so requires the inverter to synchronize to the ac frequency, an ability that some inverters do not have. The final physical properties of the converter are its inversion and rectification efficiencies, which HOMER assumes to be constant. The economic properties of the converter are its capital and replacement cost in dollars, its annual O&M cost in dollars per year, and its expected lifetime in years. The converter window of HOMER allows to define the cost curve of the converter and choose the sizes that we need HOMER to consider as it searches for the optimal system. The inverter efficiencies were assumed to be 90% for all sizes considered and solar buzz provides inverter with 0.715$/Wp.

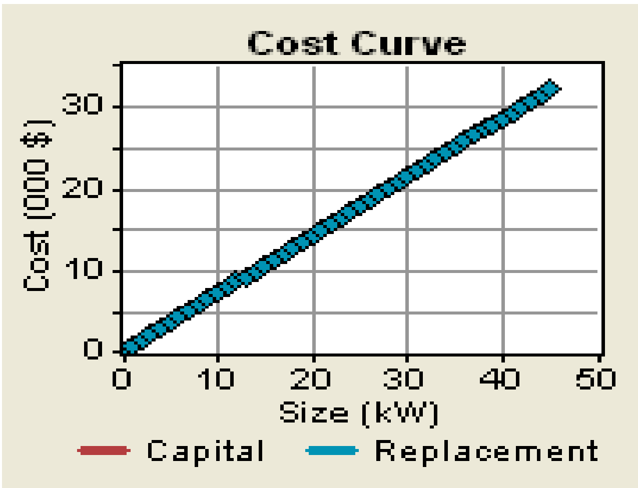


Figure 10 Cost Curve for Inverter Inputs

Generator inputs

A generator consumes fuel to produce electricity, and possibly heat as a by-product. HOMER's generator module is flexible enough to model a wide variety of generators, including internal combustion engine generators, micro turbines, fuel cells, Sterling engines, thermo photovoltaic generators, and thermoelectric generators. HOMER can model a power system comprising as many as three generators, each of which can be ac or dc, and each of which can consume a different fuel.

A vast range of diesel generators is available. The various manufacturers and distributors provide different information that can be difficult to compare. The partial load efficiency is an important parameter that HOMER requires when simulating this component. The generators were not allowed to operate at less than 30% capacity. Operation and maintenance costs for the generators are listed per hour of operation. HOMER determines the amount of time the generator must be used in a year and calculates the total operating costs from this value. The costs used for this study are very conservative and may be much higher in reality. Only one generator was allowed per system and that generator had to be large enough to meet the peak load. HOMER considered two different types of control strategies. Under the load-following strategy, the generator provides only the power necessary to meet the load at the time. The generator input window allows us to enter the cost and performance characteristics of a generator.

Cost input

In the cost window the generator cost curve is developed by entering the cost of different sized generators from the generator distributor Robin Subaru the costs and sizes considered are .

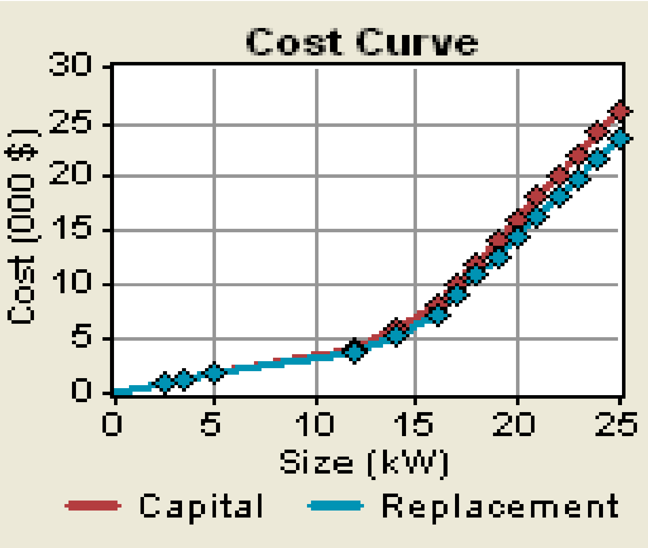


Figure 11 Cost Curve for Generator Inputs.

Fuel inputs

Using B20

Biodiesel refers to the pure fuel before blending with diesel fuel it is either directly extracted like jatropha curcas linn oil or extracted from oil plants e.g. coconut, soy bean, palm via chemical process (Transesterification or Alcoholysis), using alkaline as a catalyst to transform fatty acid into ester.[6]

Biodiesel is blended with the common diesel and every type of blend is known based on its percentage. The "B" factor is just a letter prefixed in the actual percentage of the blend. Biodiesel operates in conventional engines**.** Biodiesel blends operate in diesel engines, from light to heavy-duty, just like petroleum diesel. B20 or ,20%biodiesel and 80% petroleum diesel ,works in any diesel engine with no modifications to the engine or the fuel system, and provides similar horsepower, torque as diesel in addition it helps clean and lubricate the engine which results in reduction of spares and maintenance costs. So in the generators input window a new fuel B20 is introduced, it's properties Average Density and Heating Value of Biodiesel and blends for the inputs of the HOMER for the new fuel B20.

Using Diesel

For diesel fuel the properties of diesel are already provided under the generators input window so we need not require to create the new fuel in the fuels input column so the resulting efficiency curve is plotted as,

Table 9 Average Density and Lower Heating Value of Biodiesel and Biodiesel blends [8]

Fuel	**Density (gm/cm^3)**	**Lower heating value(MJ/kg)**
Biodiesel (B100)	0.880	37.42
B20 Blend (B20)	0.856	41.38
B2 Blend (B2)	0.851	42.29

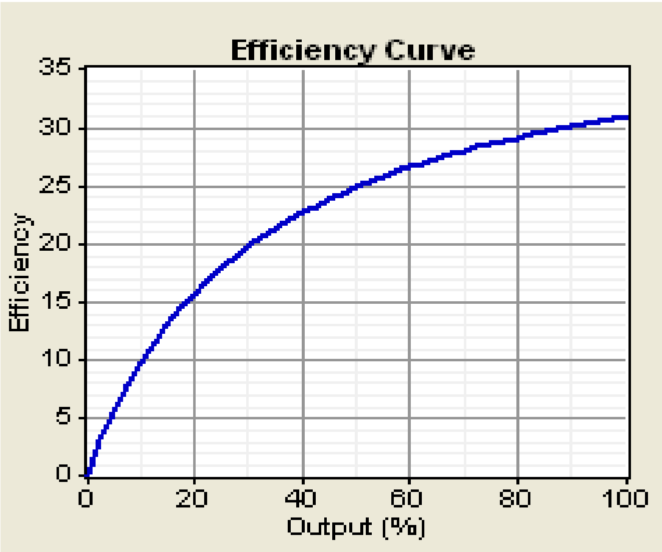


Figure 12 Fuel Efficiency Curve.

Generator Schedule

The schedule diagram of HOMER shows the times of the day and year during which the generator must operate and must not operate, and HOMER decides based on economics.The generator is working during the sunshine hours of the day together with the solar PV and the maximum average sunshine hour of a day is for ten hours in December, so the generator should at list be switched off for 14 hours of a day and it should be switched on for at list 4 hours a day since the. minimum sun shine hour of a day is for 4.3hours on July for the rest cases optimized system is selected in the schedules window of HOMER

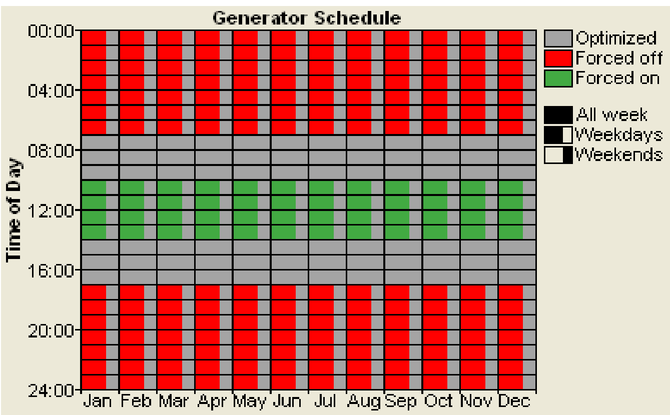


Figure 13 Generator Schedule

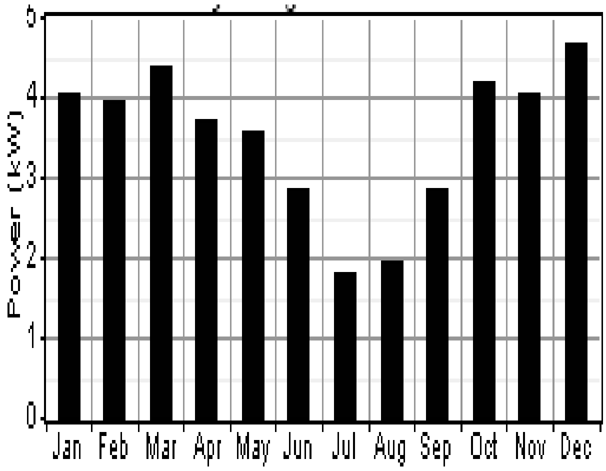
3) 6.5 Results of Homer Simulation.

Diesel Powered System

It is not always easy to obtain lifetime data for a particular generator, as it can depend on operating conditions, maintenance frequency, fuel quality, and other factors. But it is possible to estimate longevity based on the engine type. Reciprocating internal combustion engines are the most common engine type. Of these, compression-ignition (diesel) engines tend to last several times longer than spark-ignition engines (gasoline, propane, or natural gas) engines. For longevity, low speed (1800 RPM) is superior to high speed (3600 RPM), liquid cooling is superior to air cooling, and pressurized oil lubrication is superior to splash lubrication. The Robin Subaru diesel generator having a maximum capacity of 20Kw with 150000hr of life time is chosen.

Table 10 Yearly Energy Production

Diesel powered system	**Component**	**Production (kWh/yr)**	**Fraction**
	Generator 1	30,646	100%
	Total	**30,646**	**100%**



Generator.

The amount of energy delivered to the load by the system for the respective month and operating hours of the pump is shown as,

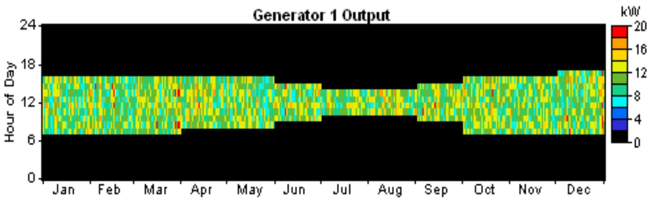


Figure 15 Generator Output During Sunshine Hours.

Diesel-Biodiesel Powered System.

The generators are not allowed to operate at less than 30% capacity. For the listed Operation and maintenance costs per hour of the generators HOMER determines the amount of time the generator must be used in a year and calculates the total operating costs from this value and finally Only one generator was allowed per system and that generator had to be large enough to meet the peak load. A 20Kw diesel Generator that consumes B20 is selected as a single power source for the study of diesel-Biodiesel hybrid system.

Table 11 Yearly Energy Production

Diesel-Biodiesel Powered System	**Component**	**Production (kWh/yr)**	**Fraction**
	Generator 1	30,646	100%
	Total	**30,646**	**100%**

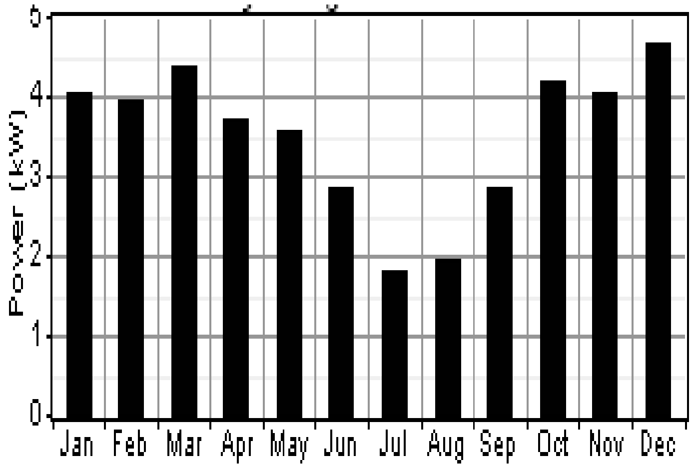


Figure 0-1 Monthly Power Production by Diesel Generator in B20 Powered System

The amount of energy delivered to the load by the system for the respective month and operating hours of the pump is shown as,

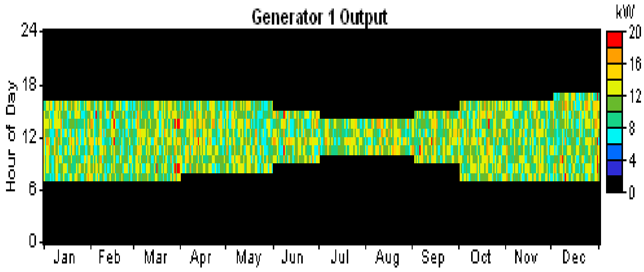


Figure 15 Generator Output During Sunshine Hours

a) 6.5.3 PV-Diesel Hybrid Powered System.

A solar PV diesel hybrid optimized system with renewable fraction of 0.514 is selected after simulation using HOMER software with the following combination of PV, generator and inverter for efficient supply of the load.

Table 12 Component Outputs for PV-Diesel Hybrid Powered System

PV Array	11 kW
Generator 1	16 kW
Inverter	7 kW

Table 13 Yearly Energy Production by PV-Diesel Hybrid System

Component	**Production** (kWh/yr)	**Fraction**
PV array	19,756	51%
Generator 1	18,703	49%
Total	**38,459**	**100%**

Annual Electric Energy Production

The total annual output of each electrical energy producing component of the power system, The amount of energy produced in each month of the year, the average value for the 24hr of each day is shown as.

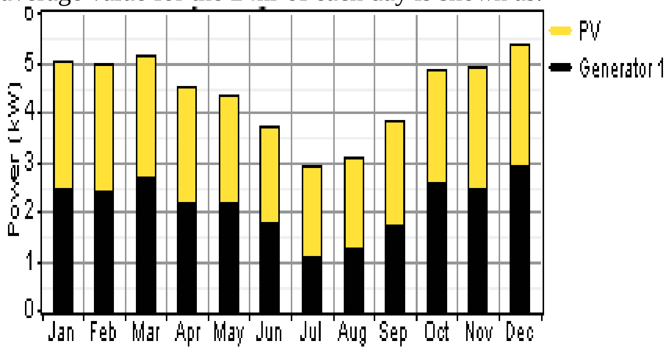


Figure 16 Monthly Average Electric Production by PV-Diesel Hybrid System.

The amount of energy delivered to the load by the system for the respective month and operating hours of the pump is shown as,

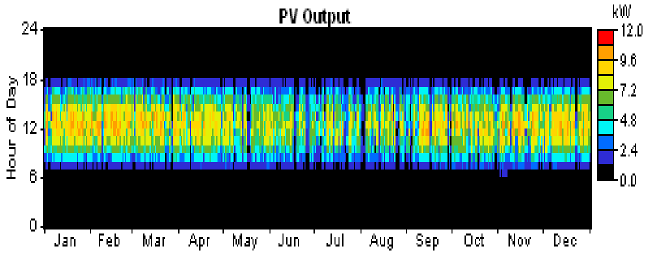


Figure 17 PV Output of PV-Diesel Hybrid System.

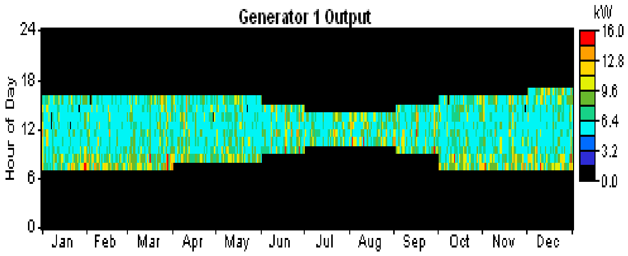


Figure 18 Generator Output of PV-Diesel Hybrid System.

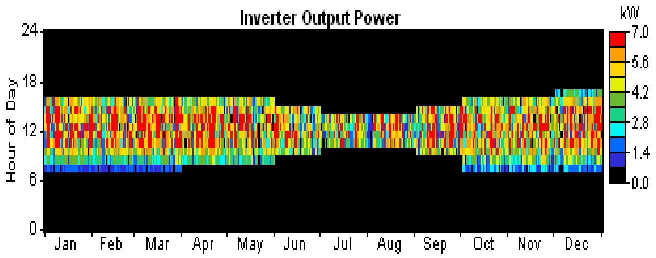


Figure 19 Inverter Output of PV-Diesel Hybrid System.

PV-Diesel-Biodiesel Hybrid Powered System.

HOMER simulates how those components work together as a system and produces the optimized result the result in the case of PV-B20 system is, a solar PV-Diesel-Biodiesel hybrid optimized system with renewable fraction of 0.514 is selected after simulation using HOMER software with the following combination of PV, generator and inverter sizes for efficient supply of the load.

Table 14 Energy Output by Each System.

PV Array	11 kW
Generator 1	16 kW
Inverter	7 kW

Annual Electric Energy Production

The total annual output of each electrical energy producing component of the power system,

Table 15 Yearly Energy Production by PV-Diesel-Biodiesel Hybrid System

Component	Production (kWh/yr)	Fraction
PV array	19,756	51%
Generator 1	18,703	49%
Total	38,459	100%

The amount of energy produced in each month of the year, the average value for the 24hr of each day is shown as.

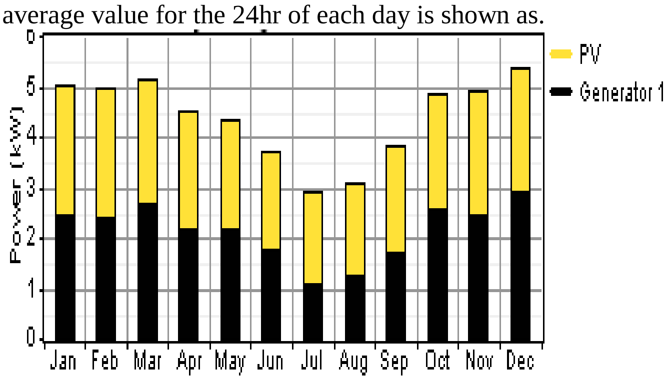


Figure 20 Monthly Average Electric Production.

The amount of energy delivered to the load by the PV-Diesel-Biodiesel Hybrid Powered System. for the respective month and operating hours (sunshine hours) of the pump with each component PV, Generator, and Converter out puts with colour map on the right side of the picture is shown in the following figures.

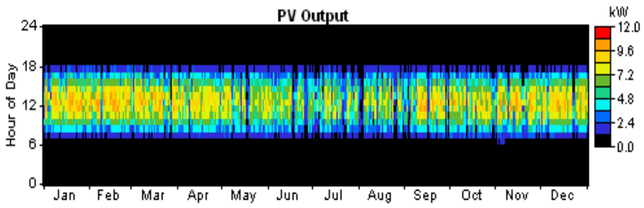


Figure 21 **PV Output of PV-Diesel-Biodiesel Hybrid System.**

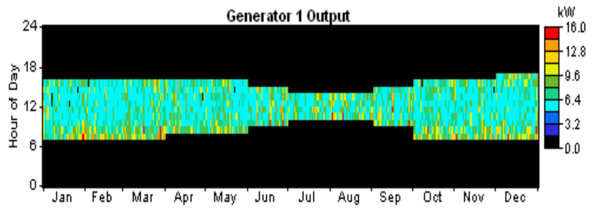


Figure 222 Generator Output of PV-Diesel-Biodiesel Hybrid System.

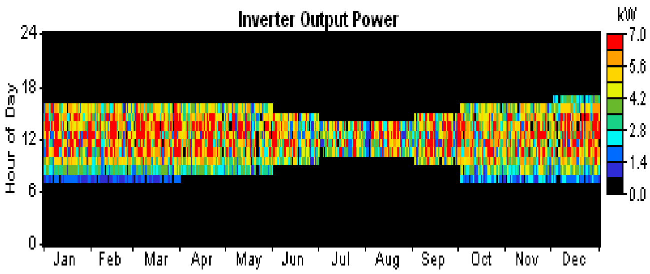


Figure 23 Inverter Output of PV-Diesel-Biodiesel Hybrid System

IV. CONCLUSION AND RECOMENDATION

Conclusion

For the considered Diesel-Biodiesel(B20), PV-B20, Diesel and PV-Diesel Hybrid systems the cash flow summary of each system details shown in Appendix A-1 For the initial cost of B20 and Diesel powered systems is lower than the other systems considered, but for B20 the operation, maintenance and replacement cost of the Generator after the generator life time of 5.42yr is 26997$ and similarly the operation, maintenance and replacement cost of diesel powered system after the generator life time of 5.42yr is 28629$, these components are replaced four times for the total system life time of 25yrs and the PV-B20 and PV-Diesel Hybrid systems have an initial cost of 64895$ both, inspite of having 8426 and 9575$/yr operation and maintenance cost respectively.

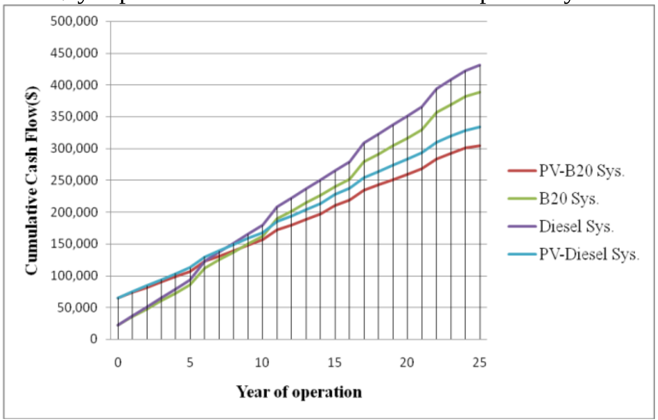


Figure 0-1 Cash Flow Summery

and finally as the Net Present Cost(NPC) is considered in the financial analysis as a measure of best system for the total life time of the system the result shows,

Table 16 Net Present Cost of Each System.

System	(NPC)Net Present Cost ($)
Diesel	230,721
B20	209,092
PV-Diesel	202,175
PV-B20	187,494

Hence, the result of both Net Present Cost and the Cash flow Summery in fig 8.1 shows that the PV-B20 system is the most feasible and PV-Diesel powered system is the second in the feasibility rank finally B20 system follows the PV-Diesel system and Diesel powered system is the lest feasible system.

Recommendation

Governmental and non governmental organizations working on water development if they install the PV-Diesel-Biodiesel powered pumping system rather than the diesel and manual pumping systems in the village they will result in a sustainable water supply with better quality to the inhabitants.

Researchers are recommended to participate in PV technologies which there efficiencies 12%-15% are available in the current market and laboratory tests show that about 47% efficient PV cells are manufactured and the solar energy potential of Ethiopia which is more than the recommended feasible solar energy potential for power generation is 5.2 Kwh/m^2/day in most parts of the country in addition the cost of PV cell is decreasing up to 30% each year so the future is bright to use these technologies

At a country level it was estimated that more that 23,305,890 hectares of land are suitable for bio fuel development and now the plantation of these crops across the country which requires different technologies for the utilization of the fuels so these research provides a way and additional developments can provide better technologies.

For the village in this study there exists the production of excess water on the months with

higher level of solar time as shown in table 4-1 these pumped water can be used for the flower plantation which consists about 51 hectare of land

V. APPENDIX

Nomenclature

e_s Tank thickness

f_t Design stress

H_L Liquid depth

ρ_L Liquid density

D_t Tank diameter

ΔP_f Pressure loss due to friction

E Total Energy Required

f Friction factor

g Gravitational acceleration

n Day Number

s Drawdown

T Transmissivity

δ Declination Angle

μ fluid viscosity

ω Hour Angle

ω_{ss} Sunset hour angle

Φ latitude angle

$\overline{H}_o$ Monthly average extraterrestrial daily solar radiation on a horizontal surface.

C_{NPC} Total net present cost

η_r PV module efficiency at reference temperature Tr

β_p The temperature coefficient for module efficiency

i Interest rate

VI. ACKNOWLEDGMENT

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