Feasibility Study of Entrepreneurship in Small Scale Power Generation:

The Case of North Wollo

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Abstract: Though Engineering being vast and of tremendous application we still not utilized it towards satisfying societal needs, especially in the case of our country. Renewable energy generation using renewable sources is one area in which one could professionally participate for income generation and satisfying societal energy demand. Renewable energy generation, except the initial investment costs, run with small operating cost. The sources are available anywhere in different forms. They are also ideal for rural electrification which is demographically characterized by dispersed population and isolated from main grid supply for which installing new grid connection is uneconomical. Our country totally, North Wollo being part, endowed with potential renewable energy sources. This work intended to assess the potential of renewable energy sources, particularly solar and hydro potential at North Wollo, for rural electrification through entrepreneurship. For investigating the feasibility, two potential sites Belbala at Lasta Lalibela Wereda for solar energy availability and Hult Adel Mikael at Gubalafto Wereda was taken to study the hydro potential. The investigation has analyzed the potential and designed a system and also made financial analysis finding that hydro potential is more attractive for income generation. Solar potential is found to be installed only for social power service without expecting gains.

***IndexTerms* - Renewable energy, Feasibility analysis, System design, Economic analysis.**

I. INTRODUCTION

Ethiopia is marking a great advancement at the expansion of higher education which is manifested in the increased number of its universities. Even if this is a great leap in the process of development, it is presenting fear of increasing the unemployed as the economic development of the country cannot support the big educated man power that is going to be produced in the next 5 years from these universities.

On the other hand, engineering production even if being indispensible solution for a sustainable and remarkable economic growth, our country has not sufficiently utilized it towards fulfilling its growth need. Many engineers graduated from higher education organizations are waiting employment from few saturated governmental organizations where redundant and ritual office works are prevalent. This makes them not to bring out their engineering skills and makes them to get apart from the engineering discipline.

Entrepreneurship in the engineering field is common in the developed countries. As an example, Billgetes the owner of the Microsoft Company started his career as an entrepreneur in software engineering. Germen is marking a big economic advancement in European countries preceding France and Britain having based its economy on small engineering enterprises. Many big private industries in these countries made their base on engineering researches so that they remain leaders on the world market.

In our country there is huge capacity and resource to establish entrepreneurship in engineering. Power generation from renewable energy sources is one of the areas among the many possible alternatives. The power generating sites can be realized in short times and the project complexity is less. Regarding to the resource our country is endowed with plenty of renewable energy sources which are suitable for realizing such projects.

North Wollo on the other hand has a topology suitable for generating small scale hydro power, abundant solar energy and wind energy.

I.1 STATEMENT OF THE PROBLEM

In recent years many first degree holders are coming to be the scenes around bulletin boards in search of job vacancies. Many of them are spending years of their precious times waiting until miracles open the doors of organizations. They do have no self-employment ideas. This is more serious being heard from graduated engineers.

Entrepreneurship in the area of power generation is the untouched area in our country even if other countries have achieved higher expertise in the field.

In the case of our country energy demand is doubling in every three year [1].This increasing energy demand is requiring alternative energy source solutions to be investigated.

Regarding to these two core problems this research intended at investigating the technical and economic feasibility of establishing energy generation sites as a solution to generate income and provide alternative energy source for the increasing energy demand, taking some North Wollo sites for the study.

I.2 OBJECTIVES

1.2.1. General Objective

The general objective of this research is showing the feasibility of entrepreneurship in small scale power generation.

1.2.2. Specific Objectives

The specific objectives include:

- Assessing potential energy sources sites in North Wollo.
- Mini power generation system design for selected sites.
- Making economic analysis of the designed system..

II. SITE MAPPING AND POTENTIAL ASSESSMENT OF THE SELECTED SITES

2.1. Socio-Economic and Physical Features of North Wollo Zone.

The North Wollo Administrative Zone is one of the eleven zones of the Amhara National Regional State. The administrative Zone has eight Woredas, namely Gubalafto, Habru, Kobo, Meket, Wadla, Bugna and Gidan .

The North Wollo Zone is geographically located between 110^0N-130^0N longitude and 38^0E To 40^0 E latitude and has an estimated area of 1,902, 200 hectares, which is about 20 percent of the region. The altitude of the zone varies from 600 to 4284meter above sea level. The estimated total population of the zone in 2000 was 1.4 million of who 721,002 are males and 669,328 are females. The rural population of the zone is about 94.6 per cent. The total rural households are estimated to be 334,044 with an average family size of 4.3 people [10].

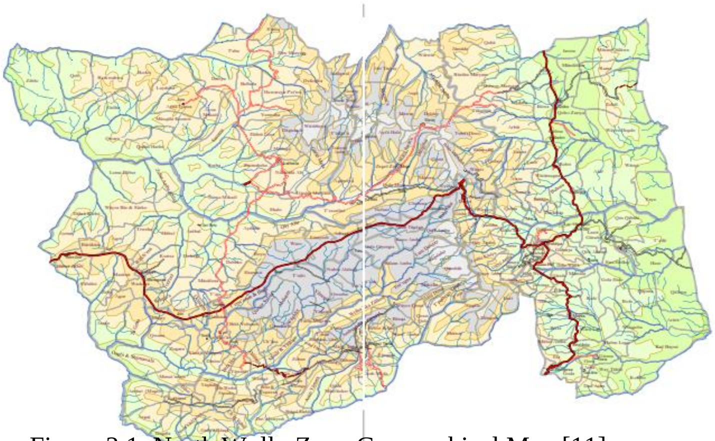

Figure 2.1 North Wollo Zone Geographical Map [11]

2.2. Solar Radiation Data of the Selected Site

Most part of the North Wollo zone is characterized by long duration of sunshine and an arid area. Among the wordas Lasta Lalibela, Kobo, Mersa-Habru weredas are characterized by arid environment having large sunshine duration and higher temperature.

The solar radiation data that was gathered from Sirinka , Lalibela and Kobo measurement stations prove this. This is due to its nearness to the desert Afar and arid Tigray region. The figure below shows the regional sun shine energy capacity.

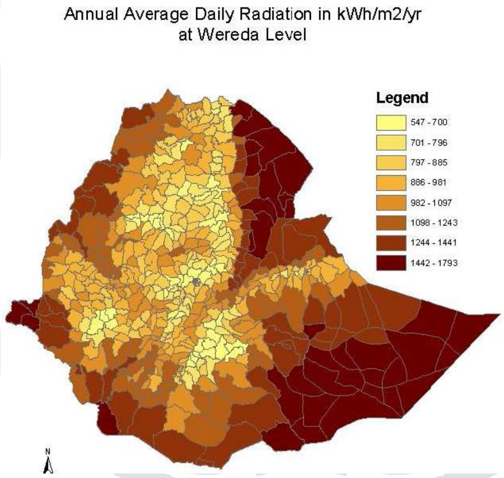

Figure 2.2 Average solar radiation at worda level (courtesy SWERA)

For this study we have selected the Last-Lalibela wereda among the potential woredas for the feasibility analysis of solar energy. The selection is based on the scarcity of other potential energy sources. The specific location is the Belbala kebele which is characterized by high tourist traffic area.

This site is located at 12^0 lattitude. Among the three meteorological stations in North Wollo the Lalibela station has complete sun shine duration data. The region is drier getting extended climate from the arid Tigray Region. Previously an NGO called Plan International has been trying some solar projects for rural clinics supplying solar panels for electrification.

Figure 2.3 The selected area of study

The average monthly sunshine duration for the site is taken from Lalibela station of the Ethiopian meteorology Agency. The averaged data is measured for 4 years from 2007- 2011 G.C. This data is averaged for the years and averaged for the months as well. This result is shown in Figure 2.3. below.

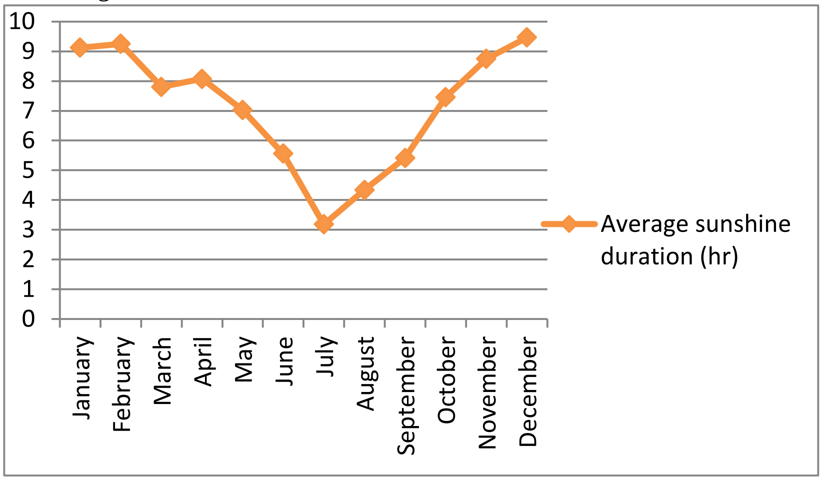

Figure 2.4 Average sunshine duration for the Lalibela area

As shown from the graph above the lowest sunshine duration is obtained during the summer season the lowest being measured at July about 3.3 hrs average duration. It is known that this time is of high rainfall and windy days hence it is possible to use hydro and wind power generation schemes to compensate the decline of sun shine.

2.2.1. Analysis of Photovoltaic (PV) Power for the Site

2.2.2. Declination angle

The declination is the angular position of the sun at solar noon, with respect to the plane of the equator. As the sun tracks beyond and below the equator depending of the time of the year the declination angle is dependent on the day of the year as shown below. Its value in degrees is given by Cooper's equation [4]:

$$\delta = 23.45 \sin\left(\frac{360}{365}(284 + N)\right) \quad (2\text{-}1)$$

Where N is the day of the year from January 1.

2.2.3. Solar hour angle and sunset hour angle

The solar hour angle is the angular displacement of the sun east or west of the local meridian; morning negative, afternoon positive. The solar hour angle is equal to zero at solar noon and varies by 15 degrees per hour from solar noon.

The sunset hour angle ω_s is the solar hour angle corresponding to the time when the sun sets and it is given by

$$\cos\omega_s = -\tan\emptyset \tan\delta \quad (2.2)$$

Where Ø is the latitude of the place.

The solar hour angel is important for calculating the average day light hoursusing the equation:

$$Ns = \frac{2}{15} cos^{-1}(-\tan\emptyset \tan\delta) \quad (2.3)$$

Taking the location of our site 12^0North we come across Average day light hours result that shown in Appendix 2. Summarizing the results for each month the trend is depicted in the following figure.

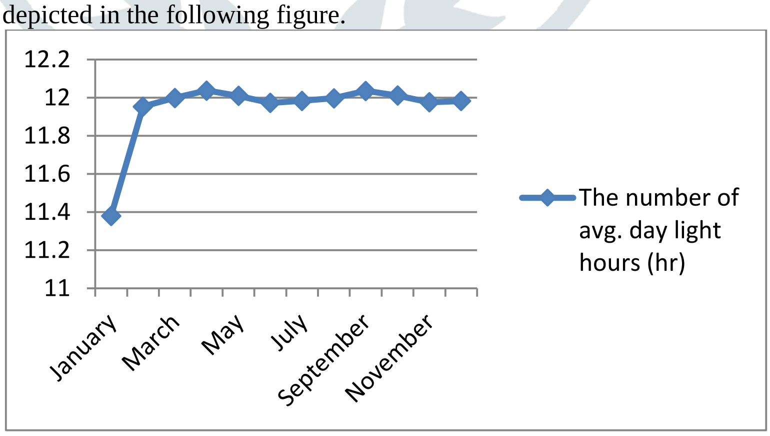

Figure 2.5 Average day light hours

Average daylight hour depend on the altitude of the site as well as the seasonal orientation of the sun. During January it is known in this area the day length is short being called " Yegena Junber". But since the measured sun shine hours is long there will be a balance between these counters.

2.2.4. Extraterrestrial radiation and clearness index

Solar radiation outside the earth's atmosphere is called extraterrestrial radiation. Daily extraterrestrial radiation on a horizontal surface is given by:

$$H_o = \left[\frac{24x3600}{\pi} x\, G_{sc}\right]\left[1.0 + 0.033\cos\left(\frac{360N}{365}\right)\right] x \left[\cos\emptyset\cos\delta\sin\omega_s + \frac{\pi}{180}\omega_s \sin\delta\sin\emptyset\right] \quad (2.4)$$

Where:

N = the day number,

G_{SC} = 1367 W/m2, the solar constant,

∅= the latitude of the location,

Using the geographical location of the place we got the following summarized results calculated using equation (4.3) over the year.

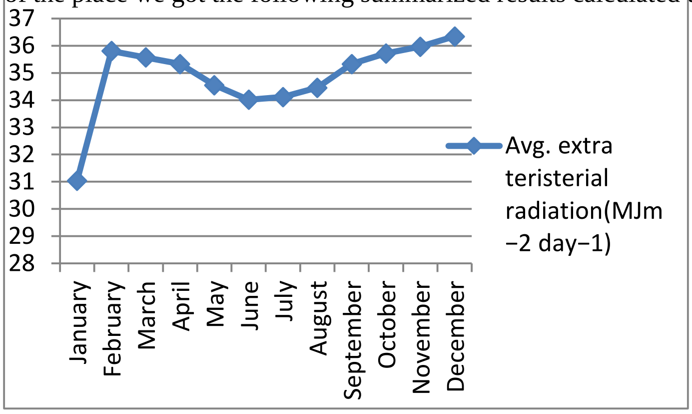

Figure 2.6 Average extraterrestrial radiation

2.2.5. Monthly average daily horizontal global radiation

In cases when solar radiation data are not available for a particular location, it is possible to use empirical relationships to estimate radiation values from hours of bright sunshine per day. Equation (4.4), called the Angstrom Page Model can be used to determine the monthly average daily radiation on a horizontal surface. [11][12]

$$\overline{K}_T = \frac{\overline{H}}{H_o} = a + b\frac{\overline{n}_s}{\overline{N}_s} \quad (2.5)$$

Where : $\overline{H}$ is the monthly average daily radiation on a horizontal surface,

$\overline{H}_0$is the extraterrestrial radiation for the location of interest.

'a' and 'b' are constants that depend on location,

$\overline{n}_s$is the monthly average daily hours of bright sunshine and

$\overline{N}_s$is the monthly average number of daylight hours.

$$a = -0.11 + 0.235\cos\emptyset + 0.323\,\frac{\overline{n}_s}{\overline{N}_s} \quad (2.6)$$

$$b = 1.449 - 0.553\cos\emptyset - 0.694\,\frac{\overline{n}_s}{\overline{N}_s} \quad (2.7)$$

For our case at Lalibela substation we got the regression constants from our data as, a =0.378842 and b= 0.401644.Hence the Angstrom –Page Model will get:

$$\overline{K}_T = \frac{\overline{H}}{H_o} = 0.3788 + 0.4016\frac{\overline{n}_s}{\overline{N}_s} \quad (2.8)$$

Combining the above results now we come across calculating monthly average daily radiation on a horizontal surface shown in **appendix 2**: This result is summarized in figure 2.6 for each month of the year.

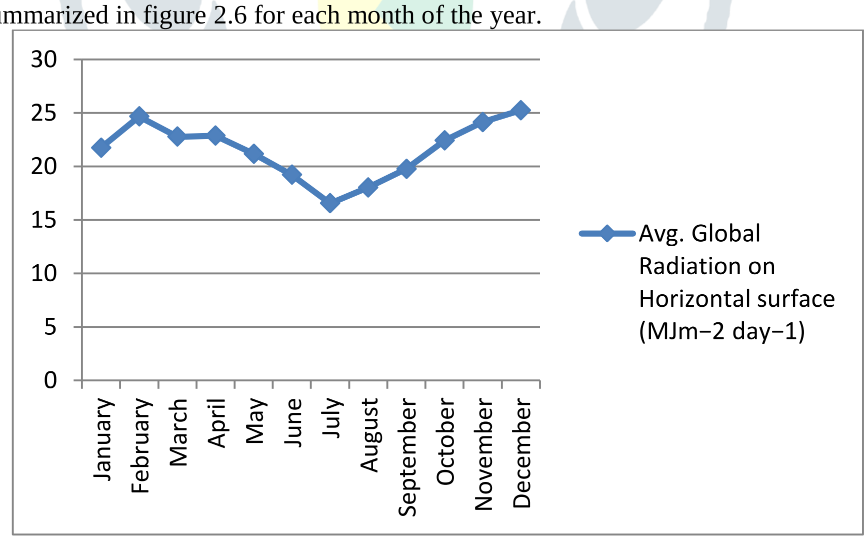

Figure 2.7 Average global radiation on horizontal surface

As shown in figures 2.5 and 2.6 both extraterrestrial radiation and Global radiation declines in the summer season as expected due to the increment of the cloud covers. This trend is best expressed by the ratio called the clearness index (K̅T), which indirectly indicate the cloud cover.

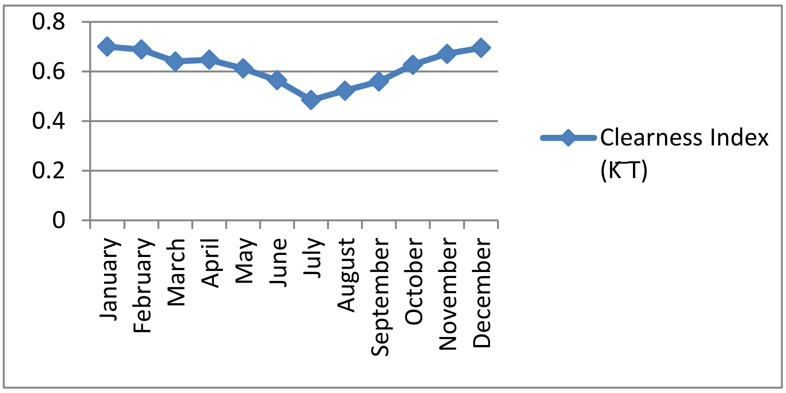

Figure 2.8 Clearness index

2.2.6. Hourly global and diffuse irradiance

Radiation received at the earth's surface can be split into diffuse and beam radiation. Knowledge of these components is important for calculating the incident radiation on surfaces that have an orientation that differs from those surfaces for which data is available. It is also important to know the beam component of the total radiation to determine the long-term performance of concentrating solar collectors.

a) ***Beam radiation***, which the solar radiation propagating along the line joining the receiving surface and the sun, and
b) ***Diffuse radiation***, the solar radiation scattered by aerosols, dust, and molecules.

The monthly average daily diffuse radiation $\bar{H}_d$is calculated from the monthly average daily global radiation using the Erbs et al. correlation [13][14].

$$\frac{\bar{H}_d}{\bar{H}} = 1.391 - 3.560\bar{K}_T + 4.189\,\bar{K}_T^2 - 2.137\bar{K}_T^3 \qquad (2.9)$$

Equation (3.9) is functional when the sunset hour angle for the average day of the month is less than 81.4^0. If the sunset hour angle is greater than 81.4^o then equation (3.9) can be written as:

$$\frac{\bar{H}_d}{\bar{H}} = 1.311 - 3.022\bar{K}_T + 3.42\,\bar{K}_T^2 - 1.82\bar{K}_T^3 \qquad (2.10)$$

The monthly average hourly global radiation for the representative days of the month on a horizontal surface can be calculated from the monthly average daily global radiation on a horizontal surface by using formulae from Collares-Pereira and Rabl for global irradiance**[15]**

$$\frac{\bar{I}}{\bar{H}} = r_t = \frac{\pi}{24}(a + b\cos\omega)\frac{\cos\omega - \cos\omega_s}{\sin\omega_s - \frac{\pi}{180}\omega_s\cos\omega_s} \qquad (2.11)$$

Where :- $a = 0.409 + 0.5016\,sin(\omega_s - 60)$

$$b = 0.6609 + 0.4767sin(\omega_s - 60)$$
$$\omega = (ST - 12)x15^0$$

$$\frac{\bar{I}_d}{\bar{H}_d} = r_d = \frac{\pi}{24}\frac{\cos\omega - \cos\omega_s}{\sin\omega_s - \omega_s\cos\omega_s} \qquad (2.12)$$

For each hour of the "average day", global horizontal irradiance *I* and it's diffuse and beam components *Id* and *Ib* are therefore given by:

$$I = r_t\bar{H}$$
$$I_d = r_d H_d$$
$$I_b = I - I_d \qquad (2.13)$$

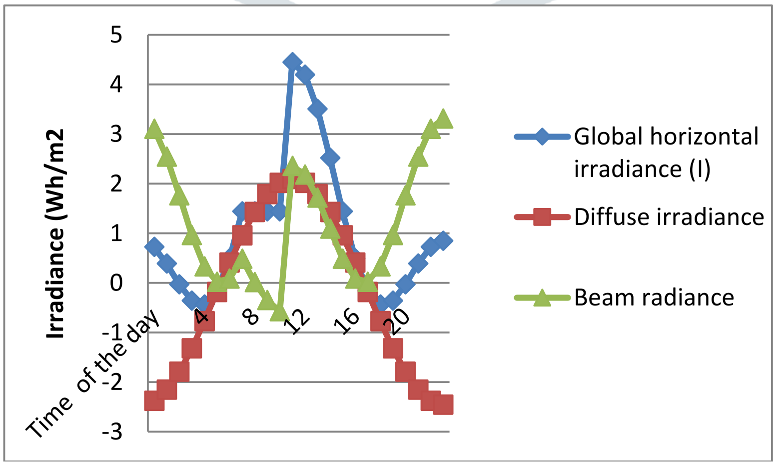

Figure 2.9 Irradiance components for the site

2.3. Hydro Power Potential of the Region

North Wollo, despite the known frequent draught affected areas it also encompasses major drainages that feed the known national rivers. According to North Wollo water resource bureau there are 42 all year round rivers as shown in the table below.All the rivers in North wollo feed three main drainage systems. Accordingly, the rivers can be classified into:

The Awash drainage system riversThe Abbay drainage system rivers andThe Tekeze drainage system riversMost rivers are tributaries of Awash and Tekezie Due to the location of the zone. Among the largest ethiopian rivers Tekazie river originate from the highlands of North wollo the possible head that can be generated is High Due to the most Hilly areas. The Average discharge rate of most rivers is higher which is together the highland heads able to produce hydro potential.or this study Alawuha is selected among the rivers for the study due to its nearness and relatively larger discharge rate.

Table 2.1 All year flowing water resources of North Wollo (Courtesy North Wollo Water resource Bureau)

No	River Name	Wereda	Kebele	River Basin	Termination River	Average discharge m3/s
1	Gunaguna	Meket	15	Tekezie	Tekezie	0.0068
2	Koga	Meket	26	Tekezie	Tekezie	0.0216
3	Dermo	Meket	020/023	Tekezie	Tekezie	0.016375
4	Tota Bahir	Meket	21	Tekezie	Tekezie	0.4532
5	Weyen Arta	Meket	4	Tekezie	Tekezie	0.0036
6	Bege Matebiya	Meket	30	Tekezie	Tekezie	0.0124
7	Tilkit	Meket	24	Tekezie	Tekezie	0.020075
8	Telef	Meket	26	Tekezie	Tekezie	0.01825
9	Dirfa	Meket	28	Abay	Abay	0.03695
10	Deba Wenze	Meket	26	Abay	Abay	0.0203
11	Lay Wuha	Meket	18	Abay	Abay	0.00337
12	**Birakua**	Meket	**13**	Abay	Abay	0.00595
13	Gulo Wenze	Habru	wurgesa	Awash	Awash	0.1256
14	Eba	Habru	Werelalie	Awash	Awash	0.13055
15	Megenagna Wenze	Habru	1	Awash	Awash	0.125115
16	Abare Wenze	Habru	4	Awash	Awash	0.456
17	Sirinka Wenze	Habru	Sirinka	Awash	Awash	0.09936
18	Senbo Wenze	Habru	Gosh Wuha	Awash	Awash	0.5236
19	Dehala	Gidan	3	Tekezie	Tekezie	NA
20	Tirarie	Gidan	20	Tekezie	Tekezie	0.0785
21	Guba	Gidan	17	Tekezie	Awash	NA
22	Golima	Gidan	27	Tekezie	Awash	NA
23	Gimbora	Gubalafto	Debot	Awash	Awash	0.2236
24	Tikur Wuha	Gubalafto	Geter Amba	Awash	Awash	0.47622
25	Aba klisha	Gubalafto	Jarsa	Awash	Awash	0.2131
26	Melka Demo	Gubalafto	Amaye Micha	Awash	Awash	0.11277
27	Cherti	Gubalafto	Kubil	Awash	Awash	NA
28	Shelie Wenze	Gubalafto	Dero Giibr	Awash	Awash	NA
29	Chira Wenze	Gubalafto	Diha Wedih	Awash	Awash	0.305
30	Golina Wenze	Raya Kobo		Awash	Awash	0.43
31	Amid Wuha	Raya Kobo	12	Awash	Awash	0.18465
32	Hormat	Raya Kobo		Awash	Awash	0.247
33	Ala wuha	Raya Kobo		Awash	Awash	1.284
34	Enchikie Wenze	Wadla	1	Abay	Abay	0.0035
35	Gazo Wenze	Wadla	21	Abay	Abay	0.0159
36	Zhita Wenze	Wadla	4	Abay	Abay	0.0266
37	Tekezie	Lasta	9	Tekezie	Tekezie	0.645
38	Kechin Wenze	Lasta	9	Tekezie	Tekezie	0.714
39	Zora	Lasta	Belbala	Tekezie	Tekezie	0.81515
40	Zeziya	Lasta	Belbala	Tekezie	Tekezie	0.063
41	Tawunt	Lasta	Yimreha	Tekezie	Tekezie	0
42	Simeno	Lasta	Segno Gebeya	Tekezie	Tekezie	0.9088

III. POWER GENERATION SYSTEM DESIGN

As previously we have explained in the previous chapter the area of interest being wide we have selected three sites for system design one from each alternative energy source, based on the availability of data.

3.1. Photovoltaic System Design For Lalibela Region

3.1.1. Calculation of average efficiency of PV module

The array is characterized by its average efficiency, η_p which is a function of average module temperature Tc.

$$\eta_p = \eta_r \left(1 - \beta_p (T_c - T_r)\right) \quad (3.1)$$

The average module temperature (Tc) can be obtained from the mean monthly ambient temperature (Ta) through Evans' formula.

$$T_c - T_a = (219 + 832\bar{K}_T)\frac{NOCT-20}{800} \quad (3.2)$$

This Equation is valid when the array's tilt is optimal which is latitude minus declination. If the angle differs from the optimum, the right side of this equation has to be multiplied by a correction factor Cf defined by:

$$C_f = 1 - 1.17x10^{-4}(Z_m - \beta)^2 \quad (3.3)$$

$$Z_m = \emptyset - \delta \quad (3.4)$$

3.1.2. Energy of the PV array

The power delivered by the PV array (E_p) can be calculated as:

$$E_p = A_p \eta_p \bar{H}_t \quad (3.5)$$

The array energy available to the load and the battery (E_A) can be obtained by the following relations:

$$E_A = E_p(1 - \lambda_p)(1 - \lambda_c) \quad (3.6)$$

λ_p Miscellaneous loss like dust cover on the PV array commonly taken as 4%.

λ_c Power conditioning losses commonly taken as 10%

The overall array efficiency is defined as:

$$\eta_p = \frac{E_A}{A_p \bar{H}_t} \quad (3.7)$$

The off-grid model of the PV Array represents stand-alone systems with a battery backup, with or without an additional power generation. Energy from the PV array is either used directly by the load, or goes through the battery before being delivered to the load.

The flow chart is as follows:

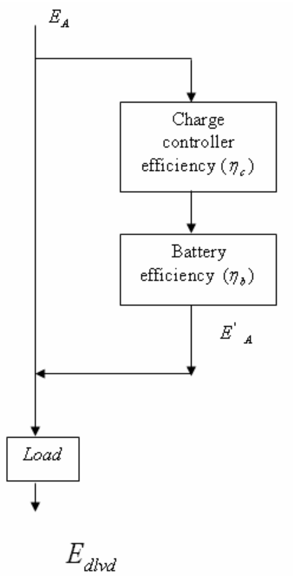

Figure 3.1 Flow chart for off grid model of PV power generation

3.1.3. Household energy demand for the site

For determining the average energy demand of a house hold we model the demand using three CF lamps a radio and 21" tv as shown in the table below.

Table 3.1 Household Average Daily Energy Demand

No	Appliance	Watt (W)	Daily use/hour	Daily Energy
1	Lamp 1 (Salon)	11	3	33
2	Lamp 2 (Kitchen room)	11	2	22
3	Lamp 3 (Bed room)	11	2	22
4	Radio / Caste player	8	3	24
5	21'' color Television	60	2	120
Total		101		221 Wh/day

3.1.4. Sizing of PV system

a) Battery

The minimum energy that can be stored by the battery is given by:

$$E_b = \frac{E_u}{\eta_b} = 245.56\ Wh/day \quad (3.8)$$

(Assuming efficiency of battery to be 90%)

Assuming that the working voltage for direct current is 12V, then, the net capacity that the battery can store in Ah/day will be:

$C_{bn} = \frac{E_b}{V_{cc}} = 20.46 \frac{Ah}{day}$ (3.9)

The net capacity of the battery depends on the depth of the discharge of the battery (DDP), and the depth of discharge determines the life cycle of the battery. Deep cycle lead acid battery can store 30% to 80% depth taking an assumption of DDP = 30% then the total commercial capacity of the battery is calculated as:

$C_b = \frac{C_{bn}}{DDP} = 68.2Ah$ (3.10)

This value is correct, if only if there aren't cloudy days. Considering cloudy days, let us assume the battery have energy demand of two days.

$C_b = 68.2\ Ah\ x\ 2 = 136.42\ Ah$ (3.11)

Hence, the capacity of the battery is taken as 140Ah.

b) Charge controller

The power output required per household if all appliances are functional at the same time is 101W and the voltage required for the solar home system is usually 12V. So, the charge controller must work at a maximum current of

$I_T = \frac{power\ out\ put}{V_{cc}} = 8.4A$ (3.12)

c) Area of the solar panel

The PV panel of the solar home system must be sized with the annual minimum of daily available PV electric energy (E h). In Belbala village, it occurs in month of July (with a value of 503.99Wh/m2) as determined in table (A. 7).

Thus, the net energy to the load from the battery per unit area is:

$E_{net} = E_h \eta_b \eta_c = 408.23\ Wh/day$ (3.13)

The maximum daily energy consumption per household if all the appliances operate at the same time is 221Wh/day. Hence the required PV panel area will be:

$A_p = \frac{daily\ energy\ demand}{E_{net}} = \frac{221}{408.23} = 0.541m^2$ (3 .14)

From this, the energy available to the load and battery from the PV panel can be determined by:

$E_p = E_h x A_p = 503.99x0.541 = 272.66\ Wh/day$ (4.15)

In order to select PV panel in the market, the panel has to be specified in peak watts, which is the power obtained with irradiation of 1000W/m2 at the cell temperature of 25ºC. The monthly global irradiance ranges from 4.84 KWh/day in July to 6.72 KWh/day in April. Hence, the effective hours with peak radiation (1000W/m2) for the minimum case is 4.84 hours that gives the same energy per day.

As the temperature of the PV panel is not constant, a given correction factor (ft) is taken as 0.89 [14]. From this, the peak power for a given PV panel from the daily available electrical energy of the panel can be obtained as follows:

$P_p = \frac{E_p}{EEHxf_t} = 63.3\ W_p$ (4.16)

The standard size of solar module which fits this size is 65Wp Solar PV Module.

d) Electrical Accessories

Installation of PV panel requires the following accessory parts:

- Wire from solar panel to charge controller;
- Wire from charge controller to battery;
- Wire from charge regulator to charges: Lights, radio, etc;
- Key of charges control;
- Switches and Radio connections.

3.2 Micro-hydro power generation

The other alternative energy source covered in this study is the micro hydro option. Among the 34 all year round flowing rivers of north wollo the Alwuha river and a near by village called Mito Giyorgis with a population of 45 households is selected for the study.

Figure 3.1 The Arial image of the village Mito Giyorgis at Qalim Kebele

3.2.1 Typical scheme layout of micro hydro power generation [3]

Micro-hydro power generation is a very site-specific technology and scheme configurations that varies from site to site. The flow of water in a river may be regulated by means of a small dam or weir. The weir also slightly raises the water level of the river and diverts sufficient water into the conveyance system. The water is channeled to a fore bay tank where it is stored until required and it forms the connection between the channel and the penstock. The penstock carries the water under pressure from fore bay to the turbine. The penstock is a very important part of a hydro project as it can affect the overall cost and capacity of a scheme. The penstock connects to the hydraulic turbine, which is located within the powerhouse.

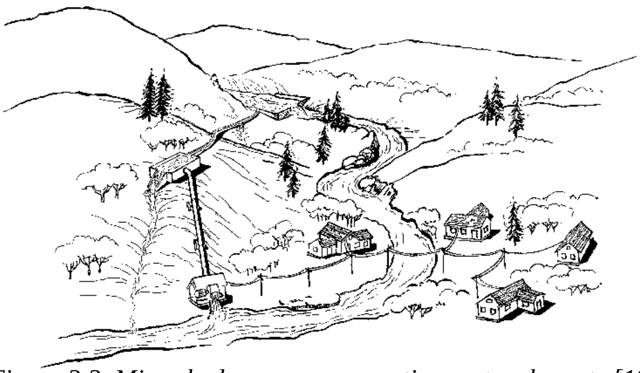

Figure 3.3 Micro hydro power generation system layouts [18]

3.2.2 Turbine Selection

A turbine converts energy in the form of falling water in a rotating shaft power. The selection of best turbine for a particular micro hydro site depends on the site characteristics, the dominant factor is the head available and the power required.

Selection also depends on the speed at which it is desired to run the generator or other devices loading the generator [18]. From table (4.2), a turbine type suitable for this site is impulse turbine typically cross flow type

Table 4.2 Classification of micro hydro turbines [19]

Classification	TurbineName	Head Range(m)	Flow Range (m^3/s)	Power output
Impulse	Pelton	50-1,000	0.2-3	50-15,000
	Turgo	30-200	0.2-5	20-5000
	CrossFlow	2-50	0.01-2	0.1-600
Reaction	Kaplan	3-40	3-20	50-5000
	Propeller	3-40	3-20	50-500
	FrancisRadial-	40-200	1-20	500-15000
	Francis-Mixed-	10-40	0.7-10	100-5000

3.2.3 Sizing of Cross Flow Turbine

For sizing of cross flow turbine, the dimension of interest is the runner length (Lrunner), diameter (Drunner) and jet thickness (tjet). Assuming gear ratio 2 and alternator speed 500rpm,

$$D_{runner} = \frac{42\sqrt{H_{net}}}{N_t} \qquad (3.17)$$

Where:-

Turbine speed (N_t)= $Alternator\ rpm\ gear\ ratio = \frac{500}{2} = 250rpm$

$H_{net} = H_g - h_{hydr}$ H_{hydr} is usually 2 to7% of Hg

$= H_g - 7\% of H_g = 9.3m$

$Drunner = \frac{41\sqrt{9.3}}{250}$=0.50m

The jet thickness is usually one tenth of the runner diameter

$$t_{jet} = 0.1xD_{runner} = 50mm \qquad (3.18)$$

Having tjet, the approximate runner length (Lrunner) can be obtained from the orifice discharge equation. The runner length will be equivalent to the jet width.

$$Q = A_{nozzle}\ 2gH_{net} = t_{jet}\ xL_{runner}\ x\ \sqrt{2gH_{net}} \qquad (3.19)$$

For Q=1.284m^3/s (Alwha river)

L_{runner} =1.902 m

3.2.4 Turbine efficiency

For this condition, it is assumed that the three parameters design flow(Q_d),flow at anytime(Q) and peak flow(Q_p)be equal[21].

$$e_t = 0.79 - 0.15\frac{(Q_d - Q)}{Q_p} - 1.37\left(\frac{Q_d - Q}{Q_p}\right)^{14} \qquad (3.20)$$

Hence, turbine efficiency will be 0.79 or it is possible to read from figures (3.4) approximately equal to the calculated value.

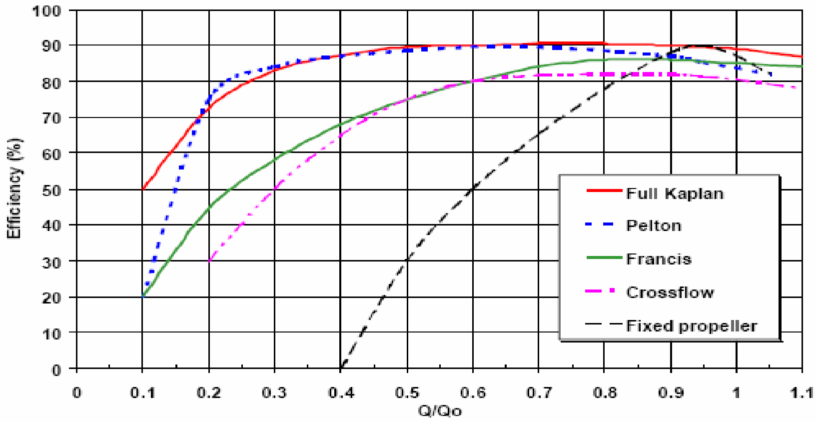

Figure 3.4 Relative efficiency of turbines for micro-hydro power generation [20]

3.2.5 The available power

Power input=power output + losses

The power input, or the total power absorbed by the hydro scheme is the gross power and the power usually delivered is the net power. The overall efficiency of the scheme is termed as e_o.

$$P_{net} = \rho g h_{gross} Q e_o \qquad (4.20)$$

Where:-

$$e_o = e_{chanal} x e_{penstock} x e_{turbine} x e_{generatore} x e_{line}$$

$$=0.95x0.9x0.79x0.85x0.9=0.52$$

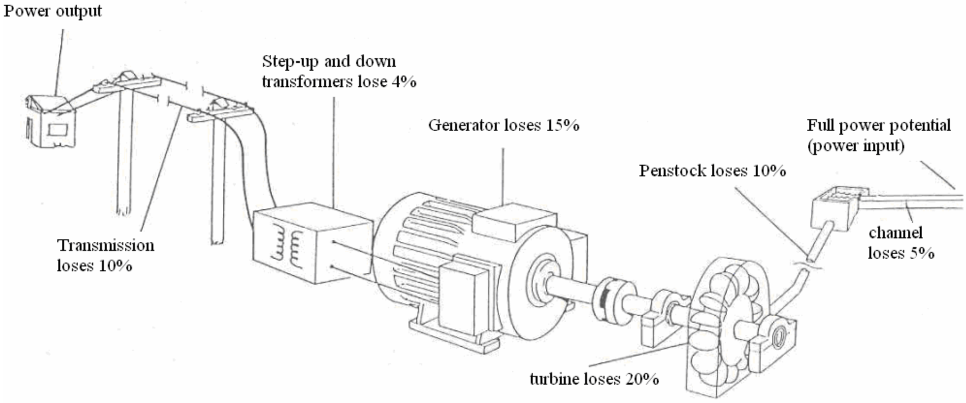

Figure 3.2 System Losses of micro-hydro power generation[20]

Hence, the actual power i.e. P_{net} available from Alawuha River micro-hydro power generation is

P_{net} = 1000 kg/m^3 X 9.8 m/s^2 X 10m X 1.284m3/s X 0.52 = 65.43 kw

3.2.6 Capacity factor or plant factor

The plant capacity factor can be calculated by :

$$Capacity_{orplantfactor} = \frac{energyused}{Energyavailable}$$

In our load of the village Mito there are three lamps taking 11W power and functional one for four hours and two lamps for two hours each, radio/tape recorder taking 8W power functional for ten hours, and 21" color television taking 60W power which is functional for eight hours. And there are 45 households.

$$C.F = \frac{[0.011x4 + 0.011x2 + 0.011x2 + 0.008x10 + 0.06x8]x45(kWhr)}{65.43x24(kWh)}$$
$$= 0.0186$$

Possible annual energy production becomes $64.43kWx8760hr/year = 564.5MWh/year$..

The annual energy consumption of the village can be calculated as:

$64.43kWx8760hr/yearx0.0186 = 10.5MWh/year$

Hence,554 MWh/year is extra energy and the residents may use this energy for other works such as flour mills and wood shops.

IV. FINANCIAL ANALYSIS OF THE PROPOSED DESIGNS

To study the economic feasibility of the business it is important to make the financial feasibility of the system. Here below the chosen options are subjected under the financial analysis.

4.1 Cost Evaluation of Solar Photovoltaic Power Generation

The cost data was collected from different importers of solar PV system in Addis Ababa and the average cost of the PV panel per peak watt was found to be Birr 63. The investment cost break down of solar PV system for our design for Belbala region is given by the following data table:

Table 5.1. Cost break down of solar PV system in birr

No.	Component	Quantity	Unit P rice	Total Price
1	Module (65Wp)	1	63.00/Wp	4095.00
2	Battery (140) deep cycle	1	1900.01	1900.01
3	Charge Regulator (8.4A)	1	700.00	700.00
4	DC-AC inverter	1	710.00	710.00
5	Cabling, Switch, Holder, plug, Divider and PV panel support structure cost			300.00
	Direct Equipment Cost			7705.01
7	Taxation			200.00
	Total			7905.01

Per each house hold a given entrepreneur can expend 7905.01.

4.1.1 Financial evaluation

The method used in this study the different option is using the electricity service cost either in monthly or unit energy basis. The monthly energy cost which has to be beard by the user is calculated from the annual cost of the investment and annual operating cost which is mainly maintenance cost and operator payment. The maintenance here except the material needed the professional fee is ignored because the entrepreneur has the necessary skill to carry out maintenance and installations. Similarly, the unit energy cost can be calculated by dividing the total annual cost by the energy generated per annum.

$$C_A = \frac{C_I}{\frac{(1+i)^n-1}{i(1+i)^n}} + C_m \qquad (4.1)$$

Where:-

CA = Annual payment

CI = Capital cost

CM = maintenance cost and operator (owner cost)

n = life span

i = interest rate

The unit energy cost (price) is determined by dividing the total annual cost by the total of electrical energy generated per year. For solar power generation system

$$pe = \frac{CA}{365\times Ed}) \qquad (4.2)$$

Where: -

Pe = unit energy cost

Ed = daily energy consumption

To evaluate the system, an assumption of 10% interest rate is taken in to consideration [22]. The initial capital cost (C) of the PV system is Birr 8320.29. Then, the annual payment will be [20]:

$$C_A = \frac{C_I}{\frac{(1+i)^n-1}{i(1+i)^n}} + C_m = \frac{7905.01}{\frac{(1+.1)^{25}-1}{.1(1+0.1)^{25}}} + 940.00 = 1270.87\ Birr$$

Monthly payment (MP)= $\frac{1810.92}{12} = 150.91\ Birr$

The unit energy cost will be: $pe = \frac{CA}{365\times Ed} = 15.75\ birr/kWh$

Here a single house hold as previously noted will use a total of 221wh/day. Since the village has 45 households in the Village a total of 45*221=9.945 kwh/day energy is utilized.

For a rural community for which doesn't have large energy need monthly payment of 150.91 birr is reasonable. This payment would include the taxation which will be paid to the government.

In a month an entrepreneur who install the panels can get a gross payment of 940.00*45=42,300 ETB per year assuming maintenance cost per month 1000 ETB per year can have a net income of 3425.00 ETB per month.

4.2. Cost Evaluation of Micro-Hydro Power Generation

4.2.1. Cost calculation of penstock [20]

In this research far from the customary usage of steel pipes it is recommended to use PVC pipes. The pen stock is estimated to be 8 meter totally PVC pipe is selected for Birr 800.00. In addition, pipe flanges and bolts are required. The standard length of penstock is 8m and 8 joints are required. Cost of flange sand bolts for each joint is Birr100.57.

Total Cost= 800+ 8*100.57= 1600.57 ETB

4.2.2. Turbine (cross flow) cost

The cost of various types of turbine is given in references[22] which are given in range with respect to the shaft power and the shaft power is calculated as 65.43 kW. Hence,it is possible toget the cost of turbine for shaft power which is (US$3,000). Considering the inflation rate, transportation cost and taxation, the total cost rises to US$ 5250.00.

4.2.3. Cost of synchronous generator

Rating for induction motors tend to cost less than synchronous generator upto 25kW capacity. Larger size of induction motor costs more than asynchronous generator of the same size[22]. Due to this reason we selected a synchronous generator of rating with rating 73.16kW , considering the losses is selected for birr of 5,000 USD. If the owner purchased used generators and winds it up the cost can be highly reduced to 2500 USD.

4.2.4. Civil work

The cost of civil works varies depending on the general layout of the scheme, and it includes channel work, fore bay tank, tailrace, and power house. The civil work is estimated to be Birr 17,000.

4.2.5. Transmission line

The best approximate cost of transmission line including poles and cables will be[22]:-

$$\text{Transmission line cost}=0.0011xDxPxl^{0.95}\ xVx10^{6} \qquad 1$$

Where:

D: Transmission line installation difficulty1to2;

P: Reflect cost of wood vs. steel tower construction 0.85 ifv<69,1.0ifv⩾69;

V: Transmission line voltage (kV)which is 380V(0.38kV);

lt: Length of transmission line in(km).

Transmission line cost= $0.0011x1x1x0.85x(5)^{0.95}\ x0.38x10^{6}$=US$1639.14 with considering inflation, transportation and taxation it becomes Birr 24,151.95or US$ 2704.59.

4.2.6. Installation cost

Installation cost of the micro hydro power generation is approximated as 20% of the total cost of the equipment [22]. Hence, it becomes Birr 32,053.62

Table 4.2 Summarized cost of micro hydro power generation

	Component	Unit Price	Total Price
1	Penstock	1600.57	1600.57
2	Turbine(crossflow)	53,672.5	53,672.5
3	Generator	7,514.6	7,514.6
	Frequency control	15,534.06	15,534.06
	Voltage Control	13,029.2	13,029.2
5	Transmission line	24,151.95	24,151.95
	Total cost of the equipment		115,501.71
6	Civil work		17,000.00
7	Miscellaneous cost (8%) of direct cost		9240.14
8	Installation cost (20% of total		23,100.342
	Total Cost of the System		164,842.19

The total costs for individual house hold will be Birr 3663.16 ETB . Here important to mention is since the entrepreneur himself is a professional most of the installation and maintenance costs are to be paid for himself.

4.2.7. Financial evaluation of the system

The initial capital cost of the micro hydro power generation for village system is Birr 164,842.19 according to this situation. The annual maintenance cost of micro hydro power generation is usually taken as 2% of the initial investment cost of the system. Together with the maintenance cost imposing the electricity service cost of 500 per house hold per year. Total payment by total households per year will be:

$$C_A = \frac{C_I}{\frac{(1+i)^n-1}{i(1+i)^n}} + C_m = \frac{164{,}842.19}{\frac{(1+.1)^{25}-1}{.1(1+0.1)^{25}}} + 62839.68 = 81000.00\ \text{Birr}$$

Monthly payment (MP)= $\frac{81000}{12} = 6750.00\ Birr$

The unit energy cost will be: $pe = \frac{CA}{365\times45\times Ed} = 22.31\ birr/kWh$

From these calculations it is evident that those villages around the Allawuha river will purchase power at reasonable cost which is 150.90 birr per month for their consumption. The excess power from the river can further be used for other power needs such as flour mill and wood making shops.

The entrepreneur on the other hand could claim a higher payment than a solar alternative. Together with taxation and maintenance related costs he would have monthly income of 5236 birr.

V. RESULTS CONCULUSION AND FUTURE WORKS

5.1. Results

The study has covered two renewable sources the hydro potential and the solar potential. System was designed for selected sites and system feasibility in terms of economical points was analyzed. The results are indicating:

i) Solar energy assessment

Solar potential for Belbala was analyzed and corresponding system was designed the current market data was assessed.

- The selected Belbala site and Lalibela region has high solar duration throughout the year and suitable for solar panel installations.
- An average family consumed 221Wh/day.
- Total installation cost was 7905.01 ETB per house hold.
- The initial investment cost can be obtained from loan with annual interest of 10 % with long time period.
- For the selected site the entrepreneur can earn monthly 3425.00 ETB net amount.
- This is showing that the income generated is lower than the corresponding income obtained from hydro potential. But the study show that for the mere supply as a social service solar energy is viable source for the assessed area.

ii) Hydro potential case

- There are many potential sites. However the Alawaha river and a nearby village Mito Giyorgis is selected for the study and it is found from the river we could produce about 64.43 kW power.
- The total installation cost for 45 households is 164,842.19 ETB. With project age of 25 years the entrepreneur can earn a monthly income of 5236.00 ETB.
- If he could manufacture the turbine and use maintained motors for energy conversion he could minimize construction costs and maximize his monthly income further.

5.2. Conclusion

The results from this work are indicating that hydro potential is more promising than solar energy. One can maximize the generation potential for further maximization of his income. Solar energy is not attractive due to relatively larger initial investment cost and hence low monthly low income generation.

Producing locally imported equipment could further reduce the cost that has been previously explored and make further maximized feasibility of the potential sources.

5.3. Future works

The wind Potential which is the feature of the highland area could have been assessed. The feasibility of hybrid systems is also another area of research.

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APPENDIX I. METEOROLOGICAL DATA OF A SELECTED MONTH

year	day number	declination	Solar Hour Angle (rad)	deg	extra teristerial radiation (H0)	extra teristerial radiation (H0) (MJ)	Global Radiation on Horizontal surface (H)	The number of day light hours (Ns)	Sun shine Hours (n)
1-Jan	1	-23.0116	1.480397394	84.82052	30148679	30.14868	21.64443	11.3094	9.55
2-Jan	2	-22.9305	1.480753737	84.84094	30184726	30.18473	20.64982	11.31213	8.6
3-Jan	3	-22.8427	1.481139443	84.86304	30223479	30.22348	21.42482	11.31507	9.3
4-Jan	4	-22.748	1.481554283	84.88681	30264909	30.26491	21.88095	11.31824	9.7
5-Jan	5	-22.6466	1.48199801	84.91223	30308987	30.30899	22.20535	11.32163	9.975
6-Jan	6	-22.5385	1.482470364	84.9393	30355681	30.35568	22.09082	11.32524	9.84
7-Jan	7	-22.4237	1.482971068	84.96798	30404955	30.40495	22.38177	11.32906	10.08
8-Jan	8	-22.3023	1.483499833	84.99828	30456773	30.45677	22.32969	11.3331	10
9-Jan	9	-22.1742	1.484056352	85.03017	30511096	30.5111	22.17092	11.33736	9.82
10-Jan	10	-22.0396	1.48464031	85.06362	30567885	30.56788	21.84	11.34182	9.48
11-Jan	11	-21.8985	1.485251377	85.09864	30627096	30.6271	21.72631	11.34648	9.34
12-Jan	12	-21.7509	1.485889209	85.13518	30688686	30.68869	22.1348	11.35136	9.68
13-Jan	13	-21.5968	1.486553455	85.17324	30752608	30.75261	22.37195	11.35643	9.86
14-Jan	14	-21.4363	1.487243748	85.21279	30818813	30.81881	22.17547	11.36171	9.64
15-Jan	15	-21.2695	1.487959716	85.25381	30887253	30.88725	21.69585	11.36717	9.16
16-Jan	16	-21.0963	1.488700974	85.29628	30957875	30.95787	21.19388	11.37284	8.66
17-Jan	17	-20.917	1.489467128	85.34018	31030626	31.03063	20.45026	11.37869	7.94
18-Jan	18	-20.7314	1.490257778	85.38548	31105450	31.10545	21.87749	11.38473	9.2
19-Jan	19	-20.5397	1.491072515	85.43216	31182292	31.18229	21.26638	11.39095	8.6
20-Jan	20	-20.3419	1.491910922	85.4802	31261092	31.26109	20.78607	11.39736	8.12
21-Jan	21	-20.138	1.492772578	85.52957	31341791	31.34179	21.84998	11.40394	9.04
22-Jan	22	-19.9282	1.493657054	85.58025	31424328	31.42433	20.81774	11.4107	8.06
23-Jan	23	-19.7125	1.494563916	85.6322	31508640	31.50864	19.98155	11.41763	7.26
24-Jan	24	-19.491	1.495492728	85.68542	31594662	31.59466	20.87515	11.42472	8.02
25-Jan	25	-19.2636	1.496443046	85.73987	31682330	31.68233	21.10548	11.43198	8.18
26-Jan	26	-19.0306	1.497414427	85.79553	31771577	31.77158	22.78749	11.4394	9.64
27-Jan	27	-18.7919	1.498406421	85.85236	31862334	31.86233	22.33124	11.44698	9.18
28-Jan	28	-18.5477	1.499418579	85.91036	31954533	31.95453	21.9856	11.45471	8.82
29-Jan	29	-18.2979	1.500450449	85.96948	32048104	32.0481	23.25581	11.4626	9.9
30-Jan	30	-18.0428	1.501501577	86.0297	32142975	32.14298	22.46158	11.47063	9.14
31-Jan	31	-17.7823	1.502571509	86.09101	32239075	32.23908	22.45371	11.4788	9.08
Avg			1.4896929	85.35312	31042236	31.04224	21.74846	11.38042	9.124677

APPENDIX II. AVERAGED GLOBAL SOLAR RADIATION FOR BELBALA REGION

Month	Average sunshine duration (hr)	The number of avg. day light hours (hr)	Avg. extra teristerial radiation(MJm−2 day−1)	Avg. Global Radiation on Horizontal surface (MJm−2 day−1)	Clearness Index ($\bar{K}T$)
January	9.124677	11.38042	31.042236	21.7484628	0.700609
February	9.251034	11.95286	35.803409	24.6639143	0.688871
March	7.805968	11.99874	35.57089	22.7724471	0.640199
April	8.0715	12.03702	35.326856	22.8609175	0.647126
May	7.024355	12.00966	34.554007	21.1679954	0.612606
June	5.559167	11.97255	34.017244	19.2113725	0.564754
July	3.182258	11.98361	34.114863	16.5490238	0.485097
August	4.33871	11.99677	34.454553	18.029028	0.52327
September	5.414333	12.03552	35.326972	19.7642772	0.559467
October	7.460753	12.0114	35.714828	22.4140787	0.627585
November	8.7475	11.97566	35.963431	24.1377678	0.671175
December	9.465054	11.98251	36.339218	25.24987	0.694838