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Research Article

Feasibility Study of Solar Energy for Standalone Home system of Afar Region, Ethiopia: A Case Study of Dubti district

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Abstract

The study's objective is to determine whether the Dubti district in the Afar region might support a solar PV energy system. The National Meteorological Agency Ethiopia (NMAE) provided the sunshine hours data, which is analyzed by using Origin 8 software. We found that the study area has a high potential for solar radiation, with an estimated annual average 6.8 KWh/m^2.day, compared to NASA's estimate of annual average 6.4KWh/m^2.day. The estimated electricity need for the house hold essential utilities, such as television, radio, Air conditioner, and lighting. The solar PV system's energy cost is estimated to be around 11.28ETB/KWh based on the storage system.

Keywords: Solar Energy, Solar PV, Sunshine Hours, Load Estimation

1. INTRODUCTION

Ethiopia's distant rural areas are mostly still without electricity. It is challenging and expensive to electrify these isolated locations by extending the grid facilities to these remote communities. Utilizing renewable energy resources is the current global trend in rural electrification; solar, wind, biomass, and micro hydro power systems can be considered as options. Due to the abundance of solar radiation that is available close to the rural community in Ethiopia, solar energy systems are believed to be the best option for electrifying rural areas (Beckley, 2009; Oliver, 2002; AAU, 2001). Ethiopia is located in the sunshine belt, which spans northern latitudes 3^0 to 15^0.

As a result, there may be significant advantages to using renewable energy sources such as solar energy. As stated in the region receives approximately 200 million tons of oil equivalents of solar radiation annually, which is more than thirteen times the nation's annual energy consumption (Mulugeta, 1999). When it comes to geographical distribution, the amount of solar

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radiation that reaches the surface rises from west to east. In the west, there are roughly 2200 hours of brilliant sunshine annually, while in the semi-arid eastern parts, there are over 3300 hours (Mulugeta and Drake, 1996). Ethiopia has enormous solar energy resources that are still insufficiently utilized, primarily due to a lack of methodological and scientific know-how in planning, site selection, and technical implementation. Another obstacle impeding the efficient utilization of resources is the uncertainty surrounding actual potential of solar at specific location. This is partly because there aren't enough resource databases and there is not enough focus on research to create novel applications for solar energy (Tadesse, 2011). The Afar area extends over northeastern Ethiopia. The Afar depression, also known as the Danakil depression, is located in the northern half of the region and is primarily arid scrubland with shallow salty lakes and lengthy chains of volcanoes. The Awash River valley constitutes the southern section of the area, with the river emptying into the northern lakes rather than the sea. The Afar region is located in northeastern Ethiopia, between 8°49′ to 14°30′ N latitude and 39°34′ to 42°28′E longitude (Kassem *et al*., 2020). The research site Dubti is located in Afar Region; this town has a latitude and longitude of 11°44′N and 41°05′E with an elevation of 378 meters above sea level.

There are numerous attempts to identify global models that may be used anywhere in the globe (Degarege, 2015), and studies of the global distribution of solar radiation have been conducted by Lof *et al*. (1966), and Gueymard and Thevenard (2009). Aside from these studies, the Angstrom-Prescott relationship has been investigated in a wide range of nations across the globe, including Australia (Rietveld, 1978), Canada (Gueymard and Thevenard, 2009), the Caribbean (Guatemala, for example), the West Indies (Hutchinson *et al*.,, 1984) , South Asian nations like Sri Lanka (Haluoani *et al*., 993) , Pakistan (Orozco, 1987) , Nigeria (Muneer and Hawas, 1984), Sudan (Samuel, 1991), (Khogali, 1983) , and South East Asia ,for example Hong Kong.

The objective of this research is to investigate the viability of using solar energy to electrify Dubti Woreda Afar region's rural areas that aren't currently served by the national grid. In this community, inhabitants utilize firewood for cooking, diesel for pumping water and grinding machines, kerosene for lamps, and dry cells for tape recorders and radios. Deforestation and outdated farming practices are contributing to the increasing desertification of the area. Therefore, the feasibility of solar photovoltaic energy systems for electricity of a specified community located in the Dubti worda Afar Region is investigated in this research paper.

2. MATERIALS AND METHODS

2.1.Solar energy potential of Dubti

A feasibility study of solar PV power system which comprises of PV arrays with battery banks and power conditioning units has been discussed. Before the Study was conducted to assess feasibility of solar PV power system for Dubti Woreda of the Afar regional (Figure 1). Residential area energy consumption and solar energy potentials of the area under study had been studied.

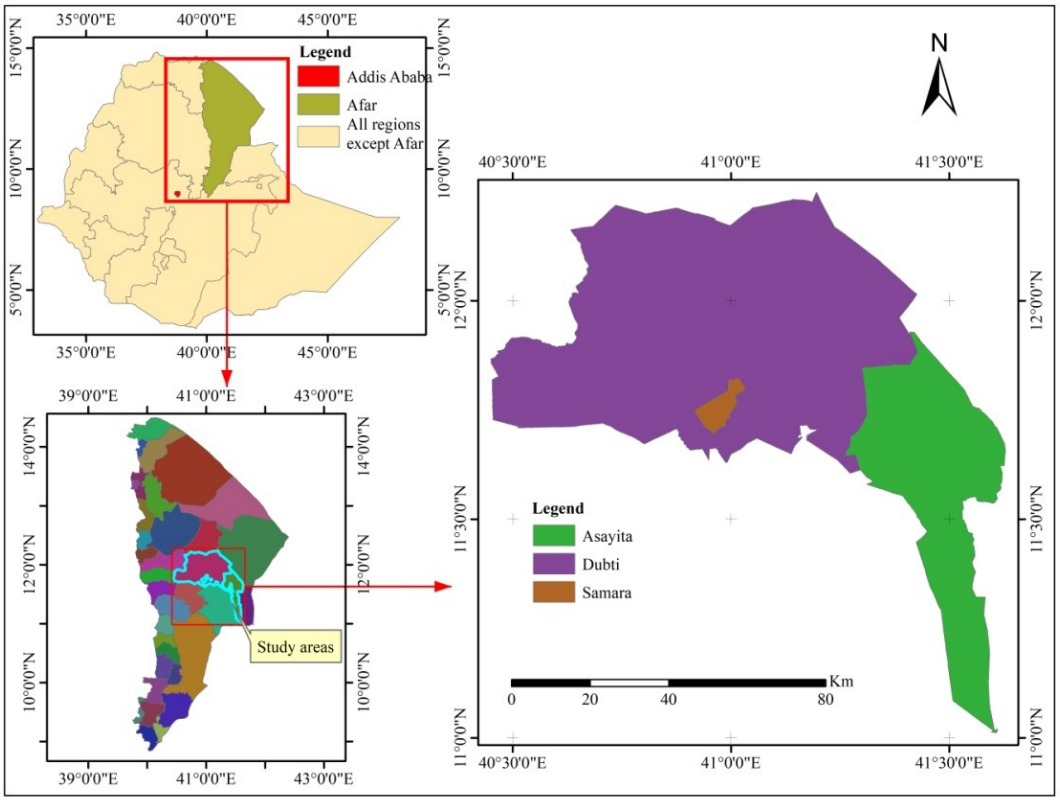


Figure 1. Map of the study area

2.2. Energy Demand

A small lamp called a "Kuraz" that burns kerosene to provide light at night is reminiscent of the way of life in a typical isolated Ethiopian village. Kerosene that is substantial enough to last for a long time must therefore be brought from a far-off city. It gives forth dangerous, eye-stinging smoke and a very faint light. Residential electricity is a huge advance over "Kuraz." It encourages health and cozy social gatherings since it avoids annoying smoke from burning kerosene and provides beautiful light that is good for the eyes. It also enables people to benefit from unstructured evening activities and convenient reading, which increases the rate of literacy. The table below shows the household power load (Table 1).

Table 1. Electricity loads average house

No	Appliance	Watt (W)	Daily use/hour	Daily Energy /Wh/day	Daily Energy /KWh
1	Lamp 1(living room)	11	4	44	12.2
2	Lamp 2(kitchen room)	11	2	22	6.1
3	Lamp 3(bed room)	11	5	55	15.27
4	Radio / Caste player	5	4	20	5.56
5	21 inch color TV	65	2	130	36.1
6	AC/Fan	318	6	1908	530
	Total	414	23	271	75.27

2.3.Solar Radiation Estimations

It is crucial to evaluate the average annual total solar radiation received in order to calculate the solar power generating potential for a certain site. Unfortunately, most developing countries including Ethiopia lack accurate radiation information records. Data about the duration of sunshine is often available. Like many other poor nations, Ethiopia lacks accurately recorded data on solar radiation; instead, the only information available is data on sunshine length. However, with the use of empirical Equ.1 (Beckley, 2009). sunshine duration data can be used to predict monthly average solar radiation given information of the number of sunshine hours and local atmospheric conditions.

The following formula represents an excellent estimate of the daily extraterrestrial solar radiation H_o on a horizontal surface for an entire day in a month, excluding meteorological and environmental variables.

$$\frac{\bar{H}}{\bar{H}_o} = a + b\left(\frac{S}{S_o}\right) \quad (1)$$

Where $\bar{H}$ = monthly averaged daily solar radiation on a horizontal surface (MJ/m^2), $\bar{H}_o$ monthly average daily extraterrestrial radiation on a horizontal surface (MJ/m^2) S monthly average daily hours of bright sunshine, S_o monthly average of the maximum possible daily hours of bright sunshine, a = 1.02 and b=0.371 are regression coefficients. For study area specifically for Dubti city in Afar region eq.1 expressed as

$$\frac{\bar{H}}{\bar{H}_o} = 1.02 - 0.371\left(\frac{S}{S_o}\right) \Leftrightarrow H = \bar{H}_o \left[1.03 - 0.371\left(\frac{S}{S_o}\right)\right] \quad (2)$$

$$\bar{H}_o = G_{sc} \times \left(\frac{R_o}{R}\right)^2 \frac{24 \times 3600}{\pi} \times [\cos L . \cos \delta . \cos \omega + \sin L . \sin \delta] \quad (3)$$

L is the latitude and ω is the solar hour angle.

The solar declination (δ) is expressed by:

$$\delta = 23.45 \sin\left(\frac{360}{365}(284 + n_d)\right) \quad (4)$$

$$\omega_s = \cos^{-1}(-\tan L.\tan\delta) \quad (5)$$

$$S_o = \frac{2}{15}\omega_s = \frac{2}{15}.\cos^{-1}(-\tan\phi\tan\delta) \quad (6)$$

The monthly averaged daily diffuse radiation $\bar{H}_D$ is calculated from the monthly average daily global radiation $\bar{H}$ using [3]

$$\frac{\bar{H}_D}{H} = 1.02 - 0.371\left(\frac{S}{S_o}\right) \quad (7)$$

$$\frac{\bar{H}_d}{\bar{H}_o} = f\left(\frac{S}{S_o}\right) = \frac{H_d}{H} \Rightarrow \frac{H}{H_o} = f\left(\frac{S}{S_o}\right) \quad (8)$$

The monthly averaged daily beam radiation $\bar{H}_b$ is calculated from the monthly average daily. Global radiation ($\bar{H}_G$) and monthly average daily diffuse radiation $\bar{H}_D$ as

$$\bar{H}_b = \bar{H}_G - \bar{H}_D \quad (9)$$

The data of the monthly average daily global solar radiation from sunshine duration time estimated for the years of 2013 to 2017 from NMA of Dubti and Samara station. The monthly average daily extraterrestrial radiation (H_0) and the maximum possible sunshine duration (S_0) for each month of the year for each city in the Afar region was calculated from the fundamental mathematical expressions eq (1-8) as shown in Table 2.

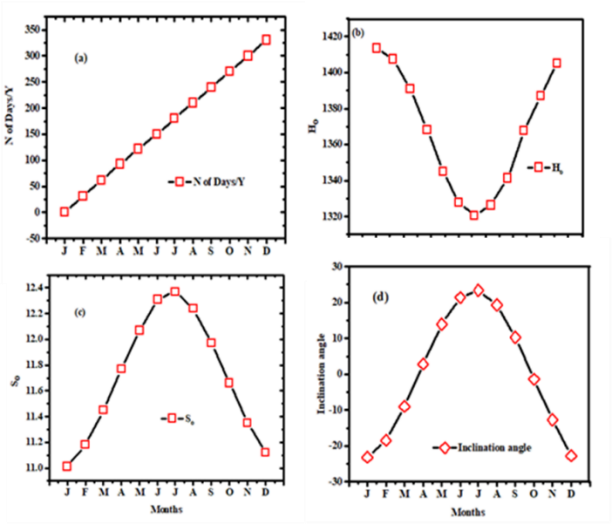


Figure 2. (a) Number of days of year, (b) Ho per number of days, (c) maximum sun shine per year, (d) inclination angle per years

The monthly average daily extraterrestrial radiation on a horizontal surface (H_0) was obtained from the following Equ. (1-8). The scattered radiation is called diffuse radiation. In the past, several empirical models have been developed to predict the monthly average diffuse solar radiation. These models expressed the monthly average daily diffuse solar radiation as a function of measured sunshine duration, measured global solar radiation and extraterrestrial solar radiation, as given below.

Table 2. Input parameters of study area.

	Dubti	ϕ =11.73	L=41.08		Altitude =381	
M	n_d	Ho	δ	ω_s	S	S_o
J	1	1413.48	-23.18	84.95	11.01	11.32
F	31	1407.43	-18.47	86.03	10.72	11.18
M	62	1390.86	-8.98	88.12	10.5	11.45
A	93	1368.09	2.814	90.57	10.98	11.77
M	122	1345.03	13.89	92.88	12.27	12.07
J	150	1327.69	21.38	94.64	12.46	12.31
J	180	1320.57	23.35	95.12	11.37	12.37
A	210	1326.31	19.31	94.18	10.41	12.24
S	240	1341.28	10.26	92.12	10.51	11.97
O	270	1367.72	-1.41	89.71	9.31	11.66
N	300	1387.01	-12.73	87.31	8.32	11.35
D	330	1405.09	-20.76	85.53	8.9	11.12

2.4. Analysis of Photovoltaic (PV) Power

The following steps were taken to calculate radiation on the plane of the PV array:

- ✓ Hourly global and diffuse irradiances on a surface for all hours of an "average day" having the same daily Global radiation as the monthly average were calculated.
- ✓ Hourly values of global irradiance on the tilted (or tracking) surface for all hours of the day were calculated; and then
- ✓ Sum the hourly tilted values were used to obtain the average daily irradiance in the plane of the PV array.

Hourly irradiance in the plane of PV array (I_T) can be calculated as Rietveld (1978)

$$H_T = H_b R_b + H_d\left(\frac{1+\cos\beta}{2}\right) + R_\rho\left(\frac{1-\cos\beta}{2}\right) \quad (10)$$

$$R_b = \frac{\cos\theta}{\cos\theta_z} \quad (11)$$

$$\beta = \phi + 15^o = 27.11^o \quad (12)$$

The monthly mean solar irradiance on a tilted surface can be

$$H_T = H_b R_b + H_d R_d + R_r H_{gh} \quad (13)$$

$$H_{gh} = H_b + H_d \quad (14)$$

$$R_r = \rho\left(\frac{1-\cos\beta}{2}\right) \quad (15)$$

Where: ρ = diffuse reflectance of the ground, β = slope of the PV array (for this study 27.11^0), R_b = ratio of beam radiation on the PV array to that on the horizontal, Angle of incident on an inclined surface (θ), Angle of incident on a horizontal surface (θ_z), latitude of the site (ϕ = 12.11°). The diffuse reflectance of the ground (ρ) (also called ground albedo) is set to 0.2 if the average monthly temperature is greater than 0°C, 0.7 if it is less than –5°C, with a linear

interpolation for temperatures between these values. Using equ.10 hourly irradiance in the plane of PVarray (I_T) for each month can be determined and the result is presented in Table 3. Collector tilt β the yearly optimum slope angle of solar collector as at a location with latitude (Raja and Twidell, 1989).

The beam irradiance incident on a tilted surface is given as

$$H_b = H_g - H_d \tag{16}$$

2.5. Daily Total Tilted Irradiances

The total solar irradiance incident on a tilted surface is written as (eq.6). Once tilted irradiances for all hours of the day are computed, the daily total H_T is obtained by summing values for individual hours.

Table 3. Monthly Average daily global radiation, Monthly Average daily diffuse radiation (MJ/m^2/day), Monthly Average daily beam radiation on horizontal surface (EpWh/m^2/).

M	J	F	M	A	M	J	J	A	S	O	N	D
HG	22.7	23.7	24.8	24.5	23.9	23.6	22.6	23.5	23.9	23.6	22.5	21.5
HD	6.9	7.8	7.9	9.1	9.3	9.5	10.1	10.2	10.3	7.5	7.1	7.3
HB	15.8	15.9	16.9	15.4	14.6	14.1	12.5	12.9	13.2	16.1	15.4	14.2
HT	6.7	6.9	7.3	6.7	6.9	7.1	7.2	6.8	7.2	6.8	5.9	6.8
H_{NASA}	6.1	6.7	7.1	6.9	6.9	6.8	6.5	6.4	6.2	6.1	5.9	5.6
Ep	804	828	876	804	828	852	852	818	864	816	708	818
E_A	764.1	786.9	832.2	763.8	786.9	809.4	809.4	777.1	820.8	775.2	672.6	777.1

The monthly average daily tilted solar irradiance in the plane of PV array are shown in Figure 3. The maximum monthly average daily Global solar radiation on the plane of PV array occurred in March and September. The minimum occurred in November (5.9KWh/m^2/day). Between May-August there was almost identical radiation. The numbers of monthly sunshine hours of Dubti district are changes from 8.9h in December and 12.47 in March, monthly 126.76h per month with average 6.8 kwh/m^2 day in a months as shown in Figure 3. Figure 3d shows the comparison solar radiation calculated and NASA measured for Dubti district. The estimated solar energy of Dubti district is in the range between 5.9 kwh/m^2 days and 6.9 kwh/m^2 days, (Figure 3d) and the NASA measured is in the range between 5.6 kwh/m^2 and 7.1kwh/m^2 (Augustine and Nnabuchi, 2009).

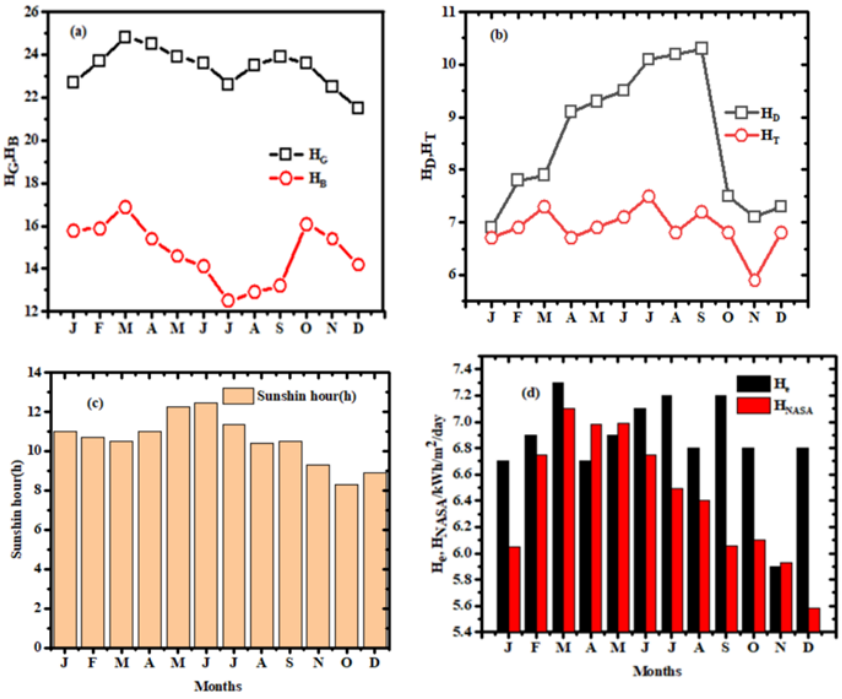


Figure 3. (a) Global radiation of and beam radiation, (b) daily diffuse radiation and total radiation kWh/m^2/day of Dubti district, (c) sunshine duration in Dubti(d) Global radiation of estimated and NASA data Dubti district

2.6.Energy of the PV Array

The power delivered by the PV array (EP) can be calculated as [12]:

$$E_p = A_p \eta_P H_T \quad (17)$$

Where: A_P = module area (1m^2) & η_P= Efficiency of PV Module (for this study 12%). The array energy available to the load and the battery (E_A) can be obtained by the following relations [12]

$$E_A = A_p \eta_P H_T (1 - \lambda_P)(1 - \lambda_c) \quad (18)$$

Where: $\boldsymbol{\lambda_P}$ = Miscellaneous loss like dust cover on the PV array commonly taken as 4%, $\boldsymbol{\lambda c}$ =Power conditioning losses commonly taken as 10%. Using equation (7) and (8), daily averaged power delivered by the PV array (EP) and daily average total energy available from the PV array (EA) were determined (Augustine and Nnabuchi, 2009).

Figure 4. shows that major maximum monthly average daily energy available (EA) during the months of January March (764.1Wh/m^2) to October (775.2Wh/m^2). The minimum monthly average daily energy available to the load occurred during the month November (672.6Wh/m^2). The power delivered by the PV array (EP) that occurred during the months of January (804Wh/m^2/D) and October (816 Wh/m^2/D). The minimum power delivered by the PV array (EP) available to the load occurred during the month November (708Wh/m^2/D).

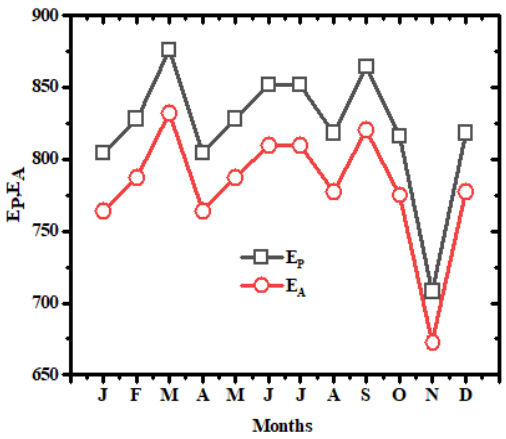


Figure 4. Monthly average daily energy available to the load

2.7. Sizing of the Solar Panels

2.7.1. 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 (Eh). In this study, it occurs in the month of November (with a value of 672.6Wh/m^2) as determined. Thus, the net energy to the load from the panel per unit area is given by (Eq.19) (Rietveld, 1978).

$$E_{net} = E_h \eta_b \eta_c = 544.81\ \text{Wh/m}^2\ \text{day} \tag{19}$$

Where: η_b=efficiency of battery (assuming to be 90%),η_c=efficiency of charge controller (assuming to be 90%). The maximum daily energy consumption of each household is 271Wh/day. Hence the required PV panel area will be

$$A_P = \frac{DE_d}{E_{net}} = \frac{271\text{Wh/day}}{544.81\ \text{Wh}/m^2\ \text{day}} = 0.497m^2 \tag{20}$$

The energy delivered by this size of the PV panel can be calculated as follows:

$$\boldsymbol{E_p} = E_h \times A_P = 672.6\frac{\text{Wh}}{\text{m2}} \times 0.497m^2 = 334.28\text{Wh/day} \tag{21}$$

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 25°C.The monthly global irradiance ranges from 5.9 KWh/day in November to 7.3 KWh/day in March. Hence, the effective hours with peak radiation (1000W/m^2) for the minimum case is 6.3 hours. As the temperature of the PV panel is not constant, a given correction factor (ft) is taken as 0.89 (Beckley, 2009). From this, the peak power for a given PV panel from the daily available electrical energy of the panel can be obtained as follows:

$$P_p = \frac{E_P}{E_H * f_t} = \frac{334.28\text{Wh/day}}{6.3 \times 0.89} = \frac{334.28\text{Wh/da}}{5.607} = 59.618\text{Wp} \tag{22}$$

The standard size of solar module 30Wp AEE Solar PV Modules (AE-37G) was considered; to fit the size two Modules are required for the household. The cost data was collected from importer of solar PV system and the average cost of the PV panel per peak watt was found to be Birr 68 (Gueymard and Thevenard, 2009). Hence, the total cost price of modules (30Wp) are Birr 4080

2.7.2. Battery

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

$$\mathrm{E_b} = \frac{\mathrm{E_u}}{\eta_\mathrm{b}} = \frac{271\mathrm{Wh/day}}{0.9} = 301.\frac{1Wh}{day} \quad (23)$$

Where: E_u=Energy demand of the household (253Wh//day), E_b = Energy that can be stored by the battery and, η_b =efficiency of battery assuming 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

$$\mathrm{C_{bn}} = \frac{\mathrm{E_b}}{\mathrm{V_{cc}}} = \frac{301.1\frac{Wh}{day}}{12V} = \frac{25.09\mathrm{Ah}}{\mathrm{day}} \quad (24)$$

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 of the battery is calculated as

$$\mathrm{C_b} = \frac{\mathrm{C_{bn}}}{\mathrm{DDP}} = \frac{25.09\mathrm{Ah/day}}{0.3} = 83.63Ah \quad (25)$$

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.

$$\mathrm{C}_b = 2 * 83.63Ah = 167.26Ah \quad (26)$$

Hence, the capacity of the battery for the each household is taken as 167.26 Ah. Considering the battery type of Battery (65Ah) deep cycle, hence three of such kind of batteries is required for the household. The unit price of Battery (65 Ah) deep cycle is Birr 974.95 (Degarege *et al*., 2015), and (Dag˘tekin *et al*., 2014). Since three times such batteries are needed, and then the total cost of the battery is Birr 2924.85.

2.7.3. Charge controller

The power output required per household if all appliances are functional at the same time is 253W and the voltage required for the solar home system is usually 12V. So, the charge controller must work at a maximum current of

$$I_T = \frac{P_{op}}{V_{cc}} = \frac{271W}{12V} = 22.58A \quad (27)$$

2.7.4. Inverters

To transform a photovoltaic (PV) solar panel's variable direct current (DC) output into utility frequency alternating current (AC) that may be supplied to an off-grid electrical network, a solar inverter, also known as a PV inverter, is added to the PV system. As a result, the DC voltage is transformed into a sine wave at 50 Hz and 220 V. The numbers of inverter units that will be used in a PV system can be calculated according to the following equation:

$$n_i = \frac{P_{rmax}}{P_{imax}} \quad (28)$$

Where n_i: The number of required converter units, P_{rmax}: the required amount of maximum power (W) and P_{imax}: The highest power of inverter(W) (Ulgen and Hepbasli, 2002).

3. RESULT AND DISCUSSION

3.1.Cost Evaluation

It is believed in rural households of Ethiopia electric energy demand is limited to lighting and radio/cassette player. The total cost of the solar PV for Solar Home System (SHS) for each household of the village is Birr 9068.50. At minimum and addition of color television at maximum (Bimrew, 2007).

Table 4. Cost break down of solar PV system

No	Description	Quantity	Unit price [Birr]	Total Price [Birr]
1	Module (65Wp)	2	68/Wp	4080.00
2	Battery (65 Ah) deep cycle	3	974.95	2924.85
3	Charge Regulator	1	742.00	742.00
4	DC-AC inverter for 21" color TV	1	750.00	750.00
5	DC lamps (11w)	3	96.76	290.28
6	Cabling, Switch, Holder, plug, Divider and PV panel support structure cost		300.00	300.00
	Total			9068.50

3.2.Financial Evaluation of PV Power System

The annual cost of the investment and the annual operating cost, which is mostly maintenance expense, are used to compute the monthly energy cost that the user must incur. In a similar manner, one may determine the unit energy cost by dividing the annual total cost by the annual energy output (Table 4) (Helwa *et al*., 2000).

3.2.1. The annual payment

To evaluate the system, an assumption of 10% interest rate and 25 years life span are taken into consideration. The initial capital cost (C) of the PV system for a single household is Birr

4080 (Table 4). Then, the annual payment will be (Kassem *et al*., 2020):

$$C_A = \frac{C_I/(1+i)^n - 1}{i(1+i)} + C_m = \frac{9068.50/(1+0.1)^{25} - 1}{0.1(1+0.1)} + 116.994$$

$$= 1116.05 \text{ ETB} \quad (28)$$

$$C_m = \frac{B_{tc}}{n} = \frac{2924.85}{25} \text{ETB} = 116.994 \text{ ETB} \quad (29)$$

Where: C_A = Annual payment, C_I = Capital cost, C_m = maintenance cost, n = life span (assuming 25 years) & i = interest rate (Assuming 10%),B_{tc}; total battery cost of single house hold (Bimrew, 2007).

Monthly Payment (MP) of the Systems

$$M_P = \frac{C_A}{m} = \frac{116.994 \text{ ETB}}{25} = 93.05\text{ETB} \quad (30)$$

The unit energy cost will be:

$$P_e = \frac{C_A}{365 * E_d} = \frac{1116.05 \text{ ETB}}{365 * 271Wh/day} = 11.28\text{ETB/KWh} \quad (31)$$

Where: Ed = daily energy consumption (single household =271Wh/day).

The results revealed that solar PV system is found as having a cost of energy about ETB12.09/kWh, which is high compared to the current global electricity tariff and the tariff in the country for below 50kwh postpaid 10.00ETB and above 50kWh ,42.00ETB and for prepaid Up to 50kWh, 3.5ETB and above 50kWh 14.70 ETB.

Table 5. Overall energy cost of solar energy system vs hydropower

(PeH/KWh/ETB)pop			(PeH/KWh/ETB)prp	
PeSKWh/ETB	KWh<50KWh/ETB	KWh>50KWh/ETB	KWh<50KWh/ETB	KWh>50KWh/ETB
11.28	10	42	3.5	14.7
11.28	5kWh/ETB	1.19KWh/ETB	14.28Wh/ETB	3.41kWh/ETB

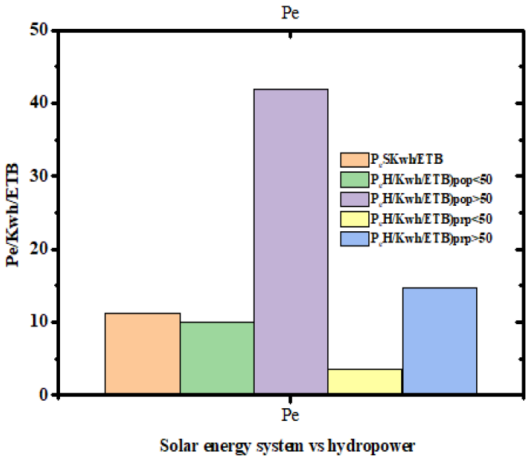


Figure 5. The unit energy cost energy

Figure 5 show that comparative advantage solar over currently available hydropower. In terms of cost the overall cost solar PV system for single home system only 12.09/kWh ETB. For hydropower lower than 50kWh postpaid 10.00ETB equivalent to 5kWh/ETB, and higher than 50kwh postpaid 42ETB equivalent to 1.19 kWh/ETP. In case of prepaid lower than 50kWh postpaid 3.5ETB equivalent to 14.28KWH/ETB, and higher than 50kwh postpaid 14.7 ETB equivalent to 3.14 kWh/ETP.

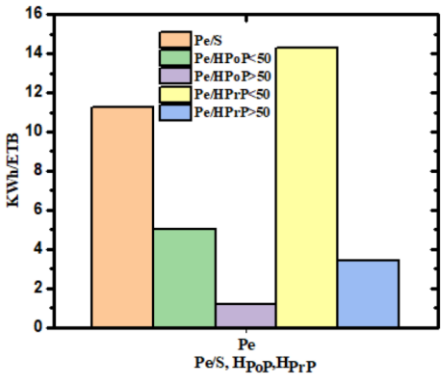


Figure 6. The unit energy cost energy per kWh

Figure.6 shows the comparative price of unit energy of hydropower vs Solar. It indicates that for unit kWh solar cell 11.28 ETB, but hydropower prices could be variable conditionally. That means for a KWh hydropower lower than 50kwh postpaid 10.00ETB, and higher than 50kwh postpaid 42ETB. In case of prepaid lower than 50kwh postpaid 3.5ETB equivalent, and higher than 50kWh postpaid 14. 7ETB.The overall estimation show that the daily demand for average family 75.27KWh. According to Ethiopia energy utility pricing rate, for prepaid above 50 KWh is 42ETB Per daily consummation for hydropower. Figure7 show that the daily consumption price in ETB. The daily energy price in solar 11.28 KWh/ ETB and hydropower daily piece 14.7KWh/ETB.

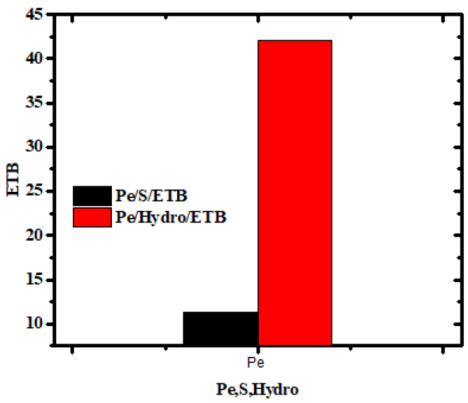


Figure 7. Daily demand price of Solar and hydropower

4. CONCLUSION AND RECOMMENDATION

There is no accurate solar radiation database in the country; instead, only sunshine hour data is provided. As a result, empirical models capable of incorporating existing sunshine hour data while also providing the necessary solar radiation statistics were utilized to assess the site's potential. Origin8 analyzed the solar energy resources data.

Theses research results have following findings

- ✓ The findings confirmed that the study site had a significant amount of accessible solar energy (6.8KWh/m^2/day).
- ✓ The NASA estimated solar radiation of Dubti 6.4 KWh/m^2/day
- ✓ The solar PV system has an energy cost of ETB12.09/kWh, which is high compared to the current global electricity tariff and the tariff in the country (< 50kwh for Postpaid 10.00ETB and >50kWh) 42.00ETB. And for prepaid Up to 50kwh, 3.5ETB and above 50kwh 14.70 ETB. However, considering the shortage of electricity in the country (<20% coverage) and the absence of electricity usage in rural areas (<2% coverage).

The following recommendations are made out of this paper;

- Afar region has abundant solar energy resources for off-grid electrification, but challenges include low purchasing power, adverse conditions, and a lack of knowledge about how to use these resources.
- To boost electrification in the Afar region, the author suggests the government and Samara University take the initiative to generate solar energy

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