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Design of a Standalone Photovoltaic System for a Typical Household around Dessie City-Ethiopia

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Abstract Standalone, or off-grid, solar power systems consist of solar panels, charge controller, inverter and a battery bank. They are typically used in rural areas and regions where there is no access to the utility grid. They may also be appropriate where the grid is somewhat close to the site, but expensive to bring in - for example, across a neighbor's property. A number of systems have been installed with battery back-up where the grid is available but where the homeowner has experienced unreliable power in the past or believes that he/she will be subject to power outages in the future. This research deals with the design of a simple solar photovoltaic system for the house located around Dessie. Based on the house annual electric demand the photovoltaic (PV) system is selected and designed. The general over view of solar PV system starting from demand to design are explained in this research. The size of the PV panel, battery, inverter and cable are selected. Prices for electricity in US dollar's/kWh also are calculated.

Keywords: *photovoltaic system, standalone, Dessie, rural communities, battery, inverter, price of electricity*

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1. Introduction

Solar electricity is produced only when the modules are exposed to sunlight. The stronger the solar radiation, the more power is produced. The longer the day (for example, summer days) the more energy is produced. Cloudy or rainy weather will reduce both the power and energy. Shading (from trees or other obstructions) will also reduce both the power and energy produced. PV modules produce less power as their temperature increases.

The solar modules convert power from sunlight into DC electricity that can be used to recharge the battery bank. Although photovoltaic electricity competes well in remote power production away from the electricity grid, it is important to install the PV cells in our house to which the grid is contributing to supply the electricity demand for the different loads available in the house. The solar energy source is expected to be expensive to compete directly with conventional electricity sources in on-grid applications. The development of so-called 'thin-film' solar cells, which require very little semiconductor material solves the problem of cost determination. Two compound thin-film technologies, named after their constituents as CdTe and CIS ($CuInSe_2$), have shown the greatest potential and are now approaching commercialization.

Since there are often longer periods of bad weather, for the solar power system, a battery bank is necessary to composite the intermittent source during the time that the house is out of sun light. The size of the battery bank is an important issue to how much hours is expected to work before the battery becomes flat, and the battery bank can be increased to extend the period before the batteries go flat. A system will typically be supplied with a battery charge controller as a back-up to recharge the battery bank 'on demand' [1,2].

Different places on the globe experience different climatic conditions. Total solar irradiance that reaches the surface of earth varies with time of day, season, location and weather conditions. Therefore, design of a standalone solar system cannot have only one standard. Location is a major aspect that will affect photovoltaic power system design and it varies from place to place [1,2,3]. Ethiopia is blessed with enough sun shine which can meet our energy demand without any compromise and it is also pollution free. Standalone PV system is a popular concept in rural areas of Ethiopia where national electricity grid connection facility is not available. But in urban areas where grid connection system is easily available, it is not a common practice to use solar power. There is a general impression that grid energy from conventional sources is much less costly compared to solar and other alternate energy sources.

One of the objectives of this paper is to estimate the potential of solar photovoltaic power system in rural communities taking around Dessie in Ethiopia. For this purpose, a typical residential house around Dessie is taken up for designing and developing a system based on its daily load requirement. Equipment specifications are provided based on availability of the best components in market. In addition to the design considerations, a detailed cost analysis of the system has been done in this paper. As expected initial cost of solar power plant installation has been found to be very high and so, the cost of solar energy consumption unit is much more than conventional energy unit. Solar power plants can be implemented if the costs of solar panels are decreased in long terms and the government subsidizes the people.

Before presenting the results and analysis of the case under this study, that is, of a typical residential house around Dessie, different components of a standalone PV system and their functions in brief are presented in the following section.

2. Selection of the System Components

2.1. PV Panels

The three most common types of solar cells are distinguished by the type of silicon used in them: Monocrystalline, polycrystalline and amorphous. Monocrystalline cells produce the most electricity per unit area and amorphous cells the least. If we want to maximize solar electricity generation for a given area, then we should select the most efficient Monocrystalline PV panels we can afford. If, on the other hand, our goal is to cover a given area at the lowest cost, then we may wish to buy amorphous panels. If we are concerned with maximizing our solar electricity generation for the lowest cost, then it is best to look at the cost-effectiveness of a panel regardless of its technology by examining its cost per rated production [1,2].

There are several types' commercially available PV modules from which the thin film amorphous module type is selected because of its cost and efficient power production. These are modules with cells deposited on a stainless steel substrate - the narrow cells are a uniform dark purple to black color. The cells are normally encapsulated without a glass cover.

2.2. DC versus AC Systems

The voltage requirements of our system loads are an important consideration in PV system design. PV modules and batteries produce direct current (DC) electricity, but most appliances in Ethiopia operate on 220-volt (V) alternating current (AC) and 50 Hz frequency.

The wiring in DC systems is also a consideration. DC systems are typically low voltage (12, 24, or 48 V) and high amperage relative to conventional AC (220 V) power supply. Therefore, DC systems require much thicker wiring than standard AC wiring to operate safely and efficiently. Wiring costs are directly proportional to thickness and length: the farther away the module/array is from the battery, the more expensive the wiring will be. Also, the high amperage capacity fuses and circuit breakers necessary in DC systems are expensive, and may be more difficult to obtain than standard 220 V AC types. Thick wiring is also difficult to work with. However, for systems with a small energy demand and a short array to battery power transmission distance, DC systems are the least expensive.

Powering AC appliances with a PV system requires an inverter. An inverter converts DC power from the battery and/or array to AC. Some appliances that require high quality power, such as laser printers, may not run well or at all on the power output of some inverters. You should consult with inverter dealers or manufacturers to determine what types of appliances their inverter will or will not operate. Inverters for residential systems, though becoming more sophisticated, reliable, and less expensive, can still be costly. They may also be noisy, and they consume 5% to 15% of the PV system power to operate [4]. We have considered the various tradeoffs in energy needs, lifestyle, costs, and spare parts' availability before choosing whether to use DC or AC power and we decided to have an AC supply to the loads in order to have the same loads as our house has the same loads as before for the grid system supplier of AC electricity.

2.3. Batteries and Inverters

For stand-alone power systems Batteries are the heart of any solar power system. They provide the energy storage necessary to ensure the availability of consistent power to the loads. If the system has batteries, then a battery enclosure that is vented and protected against freezing will be necessary. Car batteries are not optimal for PV systems as they are designed to deliver a high current for a short period, whereas backup batteries for household applications need to deliver a relatively continuous current over extended periods. Special deep-discharge batteries are best suited. Certain types of deep-discharge batteries release small quantities of hydrogen when being charged and should be kept in a ventilated enclosure, well away from open flames or sparks.

For stand-alone power systems an inverter provides a 220V AC output to run standard appliances from the DC power from the battery bank. They provide high quality AC power with features such as, low battery disconnect and over temperature / overload shutdown [17,18].

2.4. System Sizing

In off-grid PV system applications, the PV array and associated battery banks must be carefully sized to be able to meet the load demands through periods with the lowest solar availability. In grid-connected applications, the presence of the grid eliminates the need to closely match the system size with the year-round electrical loads. For net-metered systems where the utility does not pay for excess electricity generation, the estimated annual solar electricity generation should be less than or equal to the annual electricity consumption as there is no financial benefit to generating more electricity than you need. For systems with a battery bank serving an emergency sub-panel, the battery bank must be sized factoring in the size of the emergency electrical loads, the PV system size, and how long emergency backup power is needed [15,16].

The number of modules and the size of the battery bank, wires, controller, fuses, inverter, etc. mainly depend on the amount of power that we plan to consume, and the amount of solar radiation available at our location on a daily and seasonal basis. Our system sizing is usually based on the maximum energy demand during the month of lowest solar radiation intensity.

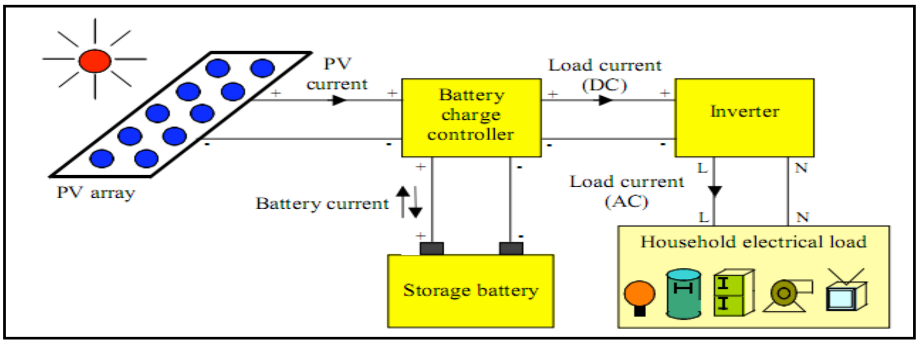

Figure 1. The Standalone PV System

3. Sizing the PV System

3.1. Panel Inclination and Solar Radiation

Dessie is situated 11.1° north latitude and 39.6° east longitude. Therefore, the panel inclination will be 11.1 degree facing south [5]. This research is designed to be implemented around Dessie so that the irradiance data used in the study is taken for the nearby rural areas.

3.2. Load Specification with Daily Load Profile

For a house, which is located around Dessie, different loads are used in order to install the PV solar module are listed in the following tables according to the present energy saving loads for the house, which are in application for the grid system electric supplier Ethiopian Electric Utility (EEU).

Table 1. Monthly Irradiance of Dessie

Month	Daily Solar Radiation - Horizontal (kWh/m^2/day)
January	6.08
February	6.41
March	6.52
April	6.54
May	6.39
June	5.77
July	5.28
August	5.35
September	5.85
October	6.19
November	6.07
December	5.85
Annual	**6.02**

Table 2. Electricity Consuming Components for Lighting

No	Location	Quantity	Power Consum-ption (W)	Total Power (kW)	Working hours/day	Total kWh/day
1	Kitchen	1	11	0.011	2	0.022
2	Dining Room	5	11	0.055	3	0.165
3	Bed Room 1	1	11	0.011	1	0.011
4	Bed Room 2	1	11	0.011	1	0.011
5	Bath Room	1	60	0.06	1	0.06
6	Toilet	1	60	0.06	1	0.06
7	Corridor	2	60	0.12	3	0.36
8	Garden Area	2	60	0.12	1	0.12
	Total			0.448		0.81

Total daily average power consumption for light: = 0.81 kWh/day.
Total annual average power consumption for light: = 0.81 kWh/day, *365 day/year = 295.65 kWh/year.

Table 3. Electricity Consuming Appliances in the House

No	Appliances	Quantity	Power (kW)	Total Power in kW	Working hour/day	Total kWh/day
1	Refrigerator	1	0.1	0.1	12	1.2
2	Electric Mitad	1	2.5	2.5	0.05	0.125
2	Electric iron	1	1	1	0.5	0.5
4	Stove	1	1	1	1	1
5	Video/ DVD	1	0.034	0.034	3	0.102
6	Telephone	2	0.014	0.028	24	0.672
7	Computer	2	0.2	0.4	2	0.8
8	Radio	1	0.02	0.02	4	0.08
9	Television	1	0.075	0.075	4	0.3
10	Shaving Machine	1	0.05	0.05	1	0.05
11	Boiler	1	1.2	1.2	0.5	0.6
Total				6.407		5.43

Total daily average appliances consumption = 5.43 kWh/day.
Total annual average appliances power consumption = 1,981.95 kWh/year.
Total power consumption of the household = 0.448+6.407= 6.855 kW
Total daily power consumption of the household = 0.81+5.43 = 6.24 kWh/day.
The total annual power consumption of the household = 295.65+1,981.95 = 2,277.6 kWh/year.

Table 4. Hourly based Load Profile

Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Total Power Rating (kW)	0.03	0.03	0.03	0.03	0.60	0.60	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.19	1.30	1.71	2.63	3.13	0.43	0.03	0.03

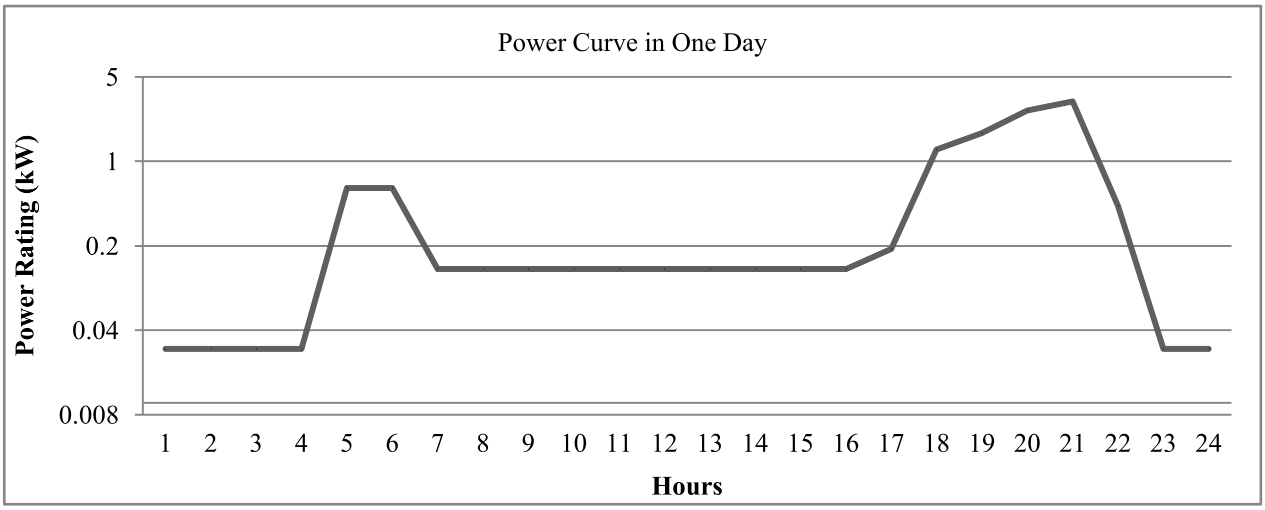

Figure 2. Daily Power Curve

In Table 2 and Table 3, the load specifications were classified according to their power rating. While Table 4 and Figure 2 are used for proper design of energy supply from PV system on hourly based load profile, so it is very important.

3.3. The Household PV System Configuration

Figure 1 shows the suggested block diagram of the house-hold stand-alone PV system. Where, the function of the PV array is to convert the sunlight directly into DC electrical power and that of the battery is to store the excess power through using the battery charge controller. The inverter is used to convert the DC electrical power into AC power; to match the requirements of the common household AC appliances [15,16].

3.3.1. Site Meteorological Data

To predict the performance of a PV system in a site, it is necessary to collect the meteorological or environmental data for the site location under consideration. The monthly average daily solar radiation data incident on both horizontal and south facing PV array tilted by the latitude angle of the site is shown in Table 1. It is clear from the table that the annual average daily solar radiation is 6.02 kWh/m^2/day on horizontal.

3.3.2. Energy Requirement in a Household

The household around Dessie is simple and does not require large quantities of electrical energy used for lighting and electrical appliances. The electrical load data in a residential house are given in Table 4.

3.3.3. PV System Design

To design a stand-alone PV system for the considered household, the following steps are required [15,16].

- The Average Daily Solar Energy Input,
- The Average Daily Load Demand,
- Sizing of the PV Array,
- Sizing of the Battery,
- Sizing of the Inverter,
- Sizing of the Battery Charge Controller, and
- Sizing of the conductor.

(i). Average Daily Solar Energy Input

Table 1 and Table 4 can be used to calculate the average daily solar energy input over the year (G_{av}) on a south facing surface tilted at an angle equal to the site latitude (11.1°) to be about 6.02 kWh/m^2/day.

(ii). Average Daily Load Demand

The average daily load demand E_L is calculated as shown in Table 4 above and is equal to 6.24 kWh/day.

(iii). Sizing of the PV Array

The size of the PV array, used in this study, can be calculated by the following equation [1]:

$$\text{PV area}=\frac{E_L}{G_{av}*\eta_{PV}*TCF*\eta_{out}} \tag{1}$$

Where:

- G_{av} is average solar energy input per day
- TCF is temperature correction factor
- η_{PV} is PV efficiency
- η_{out} = battery efficiency (η_B) x inverter efficiency (η_{Inv})

If the cell temperature is assumed to reach 60°C in the field, then the temperature correction factor (TCF) will be 0.8 as indicated in [1].

Assuming η_{PV} = 12.4% [19] and η_{out} = 0.85x 0.9 = 0.765.

$$\text{PV area}=\frac{6.24}{6.02*0.124*0.8*0.765}=13.65\text{m}^2.$$

Thus, using equation (1) the PV area is 13.65 m^2. The PV peak power, at peak solar insolation (PSI) of 1000 W/m^2, is thus given by [1,2]:

$$\text{PV peak power}=\text{PV area}*\text{PSI}*\eta_{PV} \tag{2}$$

PV peak power = 13.65 *1000 * 0.124= 1,692.6 W_p.

The selected modules are polycrystalline silicon photovoltaic module with 162 W nominal power (NDQ2E3E/ND162E1), and with the following specifications at standard test conditions (i.e., 1000 W/m^2 and 25°C) [19]:

- Peak power: 162 W_P
- Peak-power voltage: 22.8 V
- Peak-power current: 7.11 A
- Short-circuit current: 7.92 A

$$\text{Number of Modules}=\frac{1{,}692.6W_p}{162W_p}=10.45.$$

Thus, **12 Modules** are used to supply the required energy for the residential house. The series and parallel configuration of the resulted PV array can be adjusted according to the required DC bus voltage and current, respectively.

The number of solar modules connected in series is given by:

N_s = System Voltage(battery Voltage)/Operating Voltage of a single module:

N_s = 24/22.8 = 1.05

Approximating, **N_s = 2 Modules**

The number of solar modules connected in parallel which are called strings (N_p) can be calculated as:

$N_p = N/N_s$

∴ N_p = 12/2 = **6 Modules.**

If the DC bus voltage is chosen to be 24 V, then 2 modules will be connected in series and 6 strings (each of 2 modules in series) will be connected in parallel.

(iv). Sizing of the Battery

The storage capacity of the battery can be calculated according to the following relation [2,3]:

$$\text{Storage Capacity}=\frac{N_C E_L}{DOD^*\eta_{out}} \quad (3)$$

Where,

- N_C is largest number of continuous cloudy days of the site
- DOD is maximum permissible depth of discharge of the battery

The largest number of continuous cloudy days N_C in the selected site is about 4 days. Thus, for a maximum depth of discharge for the battery DOD of 0.8:

$$\text{Storage Capacity}=\frac{4*6{,}240}{0.8*0.765}=40.784\text{kWh}$$

$$=40{,}784.314\text{Wh}.$$

The storage capacity becomes 40,784.314 Wh (Equation (3)). Since, the selected DC bus voltage is 24 V, then the required ampere- hours of the battery = 40,784.314/24 = 1,699.35 Ah.

Based on the calculations, the battery type selected is N50ZL [8]. If a single battery (N50ZL) of 12 V and 450 Ah is used,

Number of batteries = 1,699.35Ah/450Ah

=3.776 ≈ **4 Batteries.**

Thus, 2 batteries are connected in series and 2 strings of batteries are connected in parallel; to give an overall number of 4 batteries.

(v). Sizing of the Battery Charge Controller

The battery charge controller is required to safely charge the batteries and to maintain longer lifetime for them. It has to be capable of carrying the short circuit current of the PV array. Thus, in this case, it can be chosen to handle 47.52A (i.e., 7.92 Ax6) and to maintain the DC bus voltage to about 24 V. The type of charge controller selected is EPSOLAR; Model Number VS6024N [7].

(vi). Sizing of the Inverter

The used inverter must be able to handle the maximum expected power of AC loads. Therefore, it can be selected as 20% higher than the rated power of the total ac loads that presented in Table 4. Thus the rated power of the inverter becomes 8,226 W. The specifications of the required inverter will be: 6,855 W+ (0.2*6855W) =8,226W, 24 V_{dc}, 220 V_{ac}, and 50 Hz. The selected inverter type is SMA sunny boy 7000-US [6].

(Vii). Sizing of the Conductor

The conductor size can be determined using equation 4 [1,3].

$$\text{VDI}=\frac{\text{Ampsx Cable length in feet}}{\text{\% volt dropx Voltage}(\text{DC})} \quad (4)$$

$$\text{VDI}=\frac{47.52\text{x}82}{4\text{x}24}=40.59$$

Where: VDI is Voltage Drop Index, Amps indicate the nominal current of the PV module; cable length is assumed to be 25 meter = 82 feet as most modules are installed on the roofs of the house it is a reasonable assumption. % Volt drop is the acceptable voltage drop level (<10%). Typical allowable voltage drop is 2% or 4% depending on the application and Voltage (DC) is the system DC bus voltage. Then according to VDI result, an appropriate conductor size will be selected from the table.

From the universal cable size data sheet the nearest voltage drop index (VDI) to this value is found to be 40.59.Therefore, the size of the cable corresponding to this VDI is 53.5 mm^2 [20].

4. Life Cycle Cost Analysis

In this section the Life Cycle Cost (LCC) estimation of the designed stand-alone PV system is discussed. The LCC of an item consists of the total costs of owning and operating an item over its lifetime, expressed in today's money.

The costs of a stand-alone PV system include acquisition costs, operating costs, maintenance costs, and replacement costs. All these costs have the following specifications [9]:

- The initial cost of the system (the capital cost) is high.
- There are no fuel costs.
- Maintenance costs are low.
- Replacement costs are low (mainly for batteries).

The LCC of the PV system includes the sum of all the present worths (PWs) of the costs of the PV modules, storage batteries, battery charger, and inverter, the cost of the installation, and the maintenance and operation cost (M&O) of the system.

The lifetime N of all the items is considered to be 25 years, except that of the battery which is considered to be 5 years. Thus, an extra 2 groups of batteries (each of 2 batteries) have to be purchased, after 5 years, 10 years, 15 years and 20 years, assuming inflation rate i of 3% and a discount or interest rate d of 10%. Therefore, the PWs of all the items can be calculated as follows [9]:

- PV array cost (C_{PV}) = \$3.14/w*12*162 = \$6,104.16 [11]
- Initial cost of batteries (C_B) = 0.24x6000 = \$1,440 [10]
- The PW of the 1st extra group of batteries (purchased after N = 5 years), CB1PW can be calculated, to be \$1,036.54, from:

$$C_{B1PW} = C_B\left(\frac{1+i}{1+d}\right)^N. \quad (5)$$

The PW of the 2nd extra group of batteries (purchased after N = 10 years) CB2PW, the 3rd extra group (purchased after N = 15 years) CB3PW, and that of the 4th extra group (purchased after N = 20 years) CB4PW are calculated, using Eq. (5), to be \$746.41, \$537.38 and \$386.893, respectively.

- Charge controller cost C_C = \$1,110 [13]
- Inverter cost C_{Inv} = \$2,555.75 [12]
- Installation cost C_{Inst} = 0.1x6,104.16 = \$610.416.
- The PW of the maintenance cost C_{MPW} can be calculated to be \$1,311.73, using the maintenance cost per year (M/yr) and the lifetime of the system (N = 25 years). And maintenance cost is taken to be 2% of the total PV cost, which is equal to \$122.1.

$$C_{MPW} = \left(\frac{M}{yr}\right)*\left(\frac{1+i}{1+d}\right)*\left[\frac{1-\left(\frac{1+i}{1+d}\right)^N}{1-\left(\frac{1+i}{1+d}\right)}\right]. \quad (6)$$

Hence,

$$C_{MPW} = (122.1)*\left(\frac{1+0.03}{1+0.1}\right)*\left[\frac{1-\left(\frac{1+0.03}{1+0.1}\right)^{25}}{1-\left(\frac{1+0.03}{1+0.1}\right)}\right]$$

$$= \$1,448.79.$$

Therefore, the LCC of the system can be calculated, to be \$15,976.34, from equation (7):

$$\begin{aligned}LCC=&CPV+CB+CB1PW+CB2PW+CB3PW\\&+CB4PW+CC+C_{Inv}+C_{Inst}+C_{MPW}.\end{aligned} \quad (7)$$

Hence, LCC = \$6,104.16 + \$1,440 + \$1,036.54 + \$746.41 + \$537.38 + \$386.893 + \$1,110 + \$2,555.75 + \$610.416 + \$1,448.79 = **\$15,976.34.**

It is sometimes useful to calculate the LCC of a system on an annual basis. The annualized LCC (ALCC) of the PV system in terms of the present day dollars can be calculated, to be \$1,260.60 per year, from equation (8).

$$ALCC=LCC*\left[\frac{1-\left(\frac{1+i}{1+d}\right)}{1-\left(\frac{1+i}{1+d}\right)^N}\right] \quad (8)$$

Hence,

$$ALCC=(15,976.34)*\left[\frac{1-\left(\frac{1+0.03}{1+0.1}\right)}{1-\left(\frac{1+0.03}{1+0.1}\right)^{25}}\right]=1,260.60.$$

Once the ALCC is known, the unit electrical cost (cost of 1 kWh) can be calculated, to be \$0.553/kWh, from equation (9):

$$\text{Unit Electrical Cost}=\frac{ALCC}{365E_L}. \quad (9)$$

$$\text{Unit Electrical Cost}=\frac{\$1,260.60/yr}{365*6.24kWh/yr}=\$0.553/kWh$$

Therefore, in remote sites that are too far from the Ethiopian power grid, the PV installers are encouraged to sell the electricity of their PV systems at a price not lower than \$0.553/kWh to earn a profit. It is to be noted, here, that this price is very high compared to the current unit cost of electricity in Ethiopia is 0.5 Birr/kWh. That is, 0.5 Birr/kWh)*(\$1/28.18Birr) = \$0.017/kWh [14]. PV energy generation will be important in the future household electrification (in Ethiopia) due to its expected future lower unit electricity cost, efficiency increase, and clean energy generation compared to the conventional utility grid.

5. Conclusion

Solar energy can be utilized as thermal energy, direct electricity, or a combination of both. Within a variety of renewable and sustainable energy technologies in progress, photovoltaic technology appears to be one of the most promising ways meeting the future energy demands as well as environmental issues.

Electrification of remote and isolated sites worldwide is very important especially in the developing countries as Ethiopia. The photovoltaic systems are considered as the most promising energy sources for these sites, due to their high reliability and safety. They represent, at the same time, a vital and economic alternative to the conventional energy generators.

An electrification study for a single residential household in a remote isolated site of Dessie is carried out using a stand-alone PV system. This research presents a complete design of a solar PV system step by step and its life cycle cost analysis. The results of this study indicate that at the optimal configuration for electrifying a typical household about 6.855 kW of power is needed. The initial installation cost of the standalone PV system is high, about USD \$15,976.34. However, it is beneficial and suitable for long term investment as the system life expectancy period is about 25 years. If the initial prices of the PV systems are decreased, this is expected with the advent of technological uplift and the increase in production volume. So standalone PV energy source is a viable energy solution for rural areas. With the help of this system we can fulfill our daily energy requirement at any scale. In this study, cost estimation of the whole system including cabling, design, labor, control devices and maintenance has also been provided. The same design procedure can be applied to other locations.

As a final remark, respective governments should get involved in providing financial support for procurement and installation of PV system, make it a popular choice and propagate this energy solution.

Nomenclature

\$/kWh	Dollar per Kilo Watt Hour
η_B	Battery Efficiency
η_{Inv}	Inverter Efficiency
η_{PV}	PV Efficiency
^oC	Degree Celsius
A	Amperes
AC	Alternating Current
Ah	Ampere Hours
ALCC	Annualized Life Cycle Cost
C_B	Cost of Battery
C_C	Cost of Charge Controller
CdTe	Cadmium Telluride
C_{Inv}	Cost of Inverter
C_{Inst}	Cost of Installation
C_{MPW}	Present Worth of Maintenance Cost
C_{PV}	Cost of PV array
CuInSe2	Copper-Indium-Diselenide
d	Discount or Interest Rate
DC	Direct Current
DOD	Depth of Discharge
EEU	Ethiopian Electric Utility
E_L	Average Daily Load Demand
G_{av}	Average Daily Solar Radiation
Hz	Hertz
i	Inflation Rate
kW	Kilo Watt
kWh	Kilo Watt hour
LCC	Life Cycle Cost
m	Meter
mm	Millimeter
M&O	Maintenance and Operation Cost
N	Number of Years
N_c	Number of Largest Continuous Cloudy Day
N_P	Parallel Number of Modules
N_S	Series Number of Modules
PSI	Peak Solar Insolation
PV	Photovoltaic
PW	Present Worth
TCF	Temperature Correction Factor
USD	Dollar of United States of America
V	Volts
W	Watts

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