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Using Homer Software for Cost Analysis of Stand-Alone Power Generation for Small Scale Industry in Nigeria: A Case Study Lumatec Aluminium Products

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ABSTRACT

Nigeria is one of developing countries in the world that experience shortage of electricity for her economic and social development. In Nigeria, most of the small-scale industries use diesel/petrol-based systems to generate their electricity. However, due to the cost fluctuation of oil and gas fuel, an alternative power generation should be considered. This paper targets to examine the cost analysis of system for supplying electricity to LUMATEC Aluminium products shop in Mubi, Adamawa state Nigeria. Hybrid Optimization Model for Electric Renewable (HOMER) is used as a tool for cost analysis. The scenario consider in this study was only stand-alone with battery system. Results revealed that the system have 10kW PV with cost of electricity (COE) of $0.312/kW. The initial capital cost and total net present cost (NPC) are $21.775 and $26.148 respectively, with payback period of 5.8years. In conclusion, this study provides the solution of power supply to the small-scale industries at cost effective and available throughout the year and it is feasible to solve the small-scale industries, rural and urban electricity supplying in this country (Nigeria). It is recommended that Nigerian Government & Law makers should promotes the use of standalone PV system for domestic and small-scale industry by providing financial assistance through soft loans, subsides and grants.

KEYWORDS

Solar radiation
Ambient temperature
Photovoltaic
Inverter
Battery
Off-grid & payback period

INTRODUCTION

Energy demand shows a vital role in our daily deeds worldwide with vast implications for the environment, economy and improvement. The utilization of renewable sources of energy in an ages back targets to reduce the consumption of fossil fuel which usually contribute to greenhouse gas (GHG) and make the world environmentally friendly. A common method used to generate electricity in must part of the world is the use of thermal power plant which depend on fossil fuels and cause global warming (Mourmouris et al., 2012; Olatomiwa et al., 2015). One

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major renewable energy source is solar energy technology which has better significantly in several attributes in recent years. It has been stated by Aba et.al. (Aba et al., 2019), that photovoltaic (PV) system was ranked as third most sustainable renewable energy technology in the world. Solar PV technology usually converts direct sun radiation into electricity which is the one of fastest growing and widely used renewable energy technologies worldwide. Recently, the solar PV modules prices had been fallen by 0.8 (80%) and also expected to continuing to falling in the nearest future (Al Garni & Awasthi, 2017; Ferroukhi et al., 2014).

Global energy consumption has been increased due to the up surge of human population. In the study of Martinez-Diaz et.al. (Martínez-Díaz et al., 2013) estimated that two billion people throughout the globe has not be connected to electric power and this lack of energy power is the barrier to economic and social development in developing countries communities which is similar to Akinyele et.al and Jimenez et.al research (Akinyele et al., 2015; Jimenez-Estevez et al., 2014).

Akinyele et.al reported (Akinyele et al., 2015)s that world bank estimated that about 1.2 billion people in the remote area in the world in remote area do not connect to grid electricity, this evident shown the wide gap between the Urban and rural communities in term of electricity assessment in many developing countries globally because government paid more attention to urban areas than the rural area. One fifth of the world population do not connect to grid and therefore they lack of social amenities that rely on electricity such as lighting bulb, communication and other services that depends on electrical energy (Crossland et al., 2015). The electricity shortage has become a major issue worldwide especially in developing and under developed countries. In order to fulfill the electricity demand, the worldwide electricity generation should be increased from 6144TWh in 1973 to 23391TWh in 2013 (Rawat et al., 2016). Akinyele (Akinyele et al., 2015)also reported that electricity access rates in sub-Saharan (Africa) alone had estimated of 50% of the global access shortfall and Nigeria is one of Africa Countries in this sub-Saharan Africa with about 190 million people which only provided electricity to 40% of her population while the remain population do not have access to that electricity supply network. Electricity is important to human being from domestic to industrial demand (Bhardwaj & Garg, 2014) and also prominent form of final energy being used in this modern age, Hence, the electricity demand globally has been increasing continuously at the rate of 3% per year due to the increasing at population because of human comfort level and the expanding of industrialization (Reddy et al., 2013).

Standalone/Off-grid solar PV can promote the economic through renewable energy system to produce electricity for remote communities and small-scale industries that are far from the grid (Ogunmodimu & Okoroigwe, 2018). The exploitation of off-grid solar PV has gain favor where vast locations are accessible and a significant amount of solar irradiation is available. Micro-grid solar PV systems are widely used to promote clear, safer, security to environment in terms of carbon emission, also more reliable and convenient to generate electricity in both urban and rural area (Balint, 2006). According to Crossland (Crossland et al., 2015) off-grid PV systems comprise a solar array, a maximum power point tracker (MPPT), inverter, battery bank and electrical loads whereas hybrid systems comprising a diesel generator as back up when there is deficient power generation from PV array or batteries. In fact, extensive research was made in this field, the off-grid electrification through standalone hybrid power supply for Uttar Pradesh (India) was presented by Bhardwaj and Garg (Bhardwaj & Garg, 2014), they carried out their worked with Homer energy software for simulation and their combination results for the feasible systems was determined by Net present cost (NPC). They concluded that solar-biogas-wind hybrid energy systems are the power solution for the remote areas over conventional energy supply in India. A review on hybrid renewable energy systems (HRES) based on power generation was exported by Siddaiah and Saini (Siddaiah & Saini, 2016) and stated that it is a cost effective alternative while compared with grid network supply. They also review some mathematical models presented by different researchers which based on economic analysis and reliability studies in their design parameters. They concluded that the researchers should compared their models based on cost analysis result and used it to develop customized designs for optimizing system size with least cost.

A review of techno-economic analysis of solar PV power generation was presented by Jamil (Jamil et al., 2012) in their report, they emphasis on important of renewable energy sources on environment and also mentions some such as solar, wind, hydro etc. and said that it had potential to provide energy required to the world if it is adopted, their reviewed was based on three categories: Design methods, techno-economic feasibility of solar PV generation and performance evaluations of various systems. A comprehensive reviewed on optimal planning of hybrid/standalone renewable energy systems using HOMER was reported by Bahramara et.al. (Bahramara et al., 2016), they reported on comparison between renewable energy and conventional energy source. They described HOMER simulation software has one of the most powerful tools for simulating renewable energy whenever to access minimum investment, costs analysis, optimal size and emission constraints and finally, concluded that HOMER is good for researcher(s) in term of optimal planning of hybrid/off-grid renewable energy system.

Liu et.al. (Liu et al., 2011) presented feasibility study of off-grid PV wind- biomass hybrid energy system in Australia. The system was design to suppling 2002kWh/day electricity to residential area in to provide energy required to the world, if it is adopted. Pal et.al. (Pal et al., 2015) presented the potential of solar PV system in Gurgaon, India. A resident build in Haryana was used for designing and developing of the system based on a resident occupant daily load demanded. Their design also pay attention on self-optimized and cost analysis (installation and maintenance). The results of this study required 13kW of power for electrifying the resident build with payback period of 15 years. The authors concluded that design procedures can be applied to any other locations in the world and recommended that government of any countries should provide soft load to the people on PV system to promote this energy solution. Mohamed et.al. (Mohamed et al., 2015) worked on sizing and techno-economic analysis of off-grid hybrid power generation systems with hope to meet the load demand at lowest energy generated price. The sites considered in simulation are Yanbu, Dhahran, Douhlom, Riyadh and Qayssuma in Saudi Arabia. They used New proposed simulation programme (NPSP) which was developed and written in Matlab software. The results obtained from the NPSP were compared with HOMER result, this comparison revealed that NPSP programme is superior to HOMER in term of optional sizing of off-grid hybrid PV-Wind-diesel–battery energy systems and validated the results of NPSP program with HOMER software result using less of load probability (LOLP) as technique of implementing a criterion for sizing of a hybrid system. They found that the best place to install the hybrid system is Yanbu.

Design and application of solar PV system for one-bedroom apartment was studied by Alkali (Alkali et al., 2004) to bridge the gap of electricity between the rural and urban areas. Their evaluation of the system shown that N710,896.20k will be required to set up the system at the current exchange rate of N140 per US dollar ($). Ajao (Ajao et al., 2011) worked on analysis of the cost benefit of a solar-wind hybrid power supply system using HOMER simulation software for faculty of engineering, University of Ilorin building (Block 10) in Nigeria. Their result from optimization revealed NPC ($4251), COE (1.74$/kWh) with initial capital cost of $3,455 and concluded that their system had payback period of thirty-three years. Techno-economic analysis of two hybrid power system were compared with diesel generation system in term of powering capacity for specific remote mobile base transceiver station (BTS) in Nigeria. The optimal systems configurations are PV–diesel–battery and PV-wind-diesel-battery systems. They founded that former option was better in term of economic feasibility with the total net present cost (NPC) of $69,811 per unit cost of electricity ($0.409), result was obtained from HOMER simulation software and finally, concluded that PV–diesel–battery system is environmentally friendly as compared to the stand-alone diesel generator system in term of omissions reduction (Olatomiwa et al., 2015).

Hence, this paper deal with estimate of the potential of stand-alone solar PV power system in small scale industries (Lumatec Aluminium products Mubi, Adamawa State, Nigeria). The study considered an estimation of Lumatec Aluminium products shop. The current means of providing power to the shop is natural grid. Since the power supply (grid) is not reliable now and to avoid the production breakdown, which affect the consumer's continuity and to analyze the cost benefit of this PV power system with its payback period. The design and feasibilities were done by HOMER Pro trial fashion.

MATERIALS AND METHOD

Stress Intensity Approach

Mubi is a second largest city and also located in the Northeast region (Adamawa State) Nigeria which lying on Latitude 10.270N and Longitudes 13.270E with annual temperature of 260C. According to Luqman et.al (Shodiya et al., 2016), the annual average daily solar radiation in Northeast falls between 4.9 – 4.5kWh/m2/day, therefore, both researchers concluded that PV system is feasible with this favorable weather conditions. Mubi has highest electricity consumers, with more than 500 thousand customers leading it's to be second highest energy soles in Adamawa State as well as hosting thousands of visitors every year since insurgency 2014. In fact, the consequence of this, make Nigerian Government to considering standalone PV in domestic and industrial to supplement the power grid network to boost economic and standard of living of rural and urban small-scale industries. The location of the shop is along Ahmadu Bello way, Mubi near Kolere guest house as shown in the figure 2.

Figure 1. Location of Lumatec Aluminium Products Workshop (google maps)

The Load Profile and Load Inputs of The Study Area

The load was obtained for a Lumatec Aluminium products (LAPs) Mubi, through personal survey and literatures. Presently, the shop need basic electricity for lighting bulb, security bulb, Ceiling fan, Mitre saw (SH20MMSUL), Raider drill machine and SIEMENS 8MM Electric Router. Hence, for this study, the hourly lead demand for the shop was considered by surveying the necessary appliances with their corresponding power rating which supply in the manufacturer manual. The average daily load profile (kW) needed in the shop was evaluated through the components sizing and design as shown in figure 2.

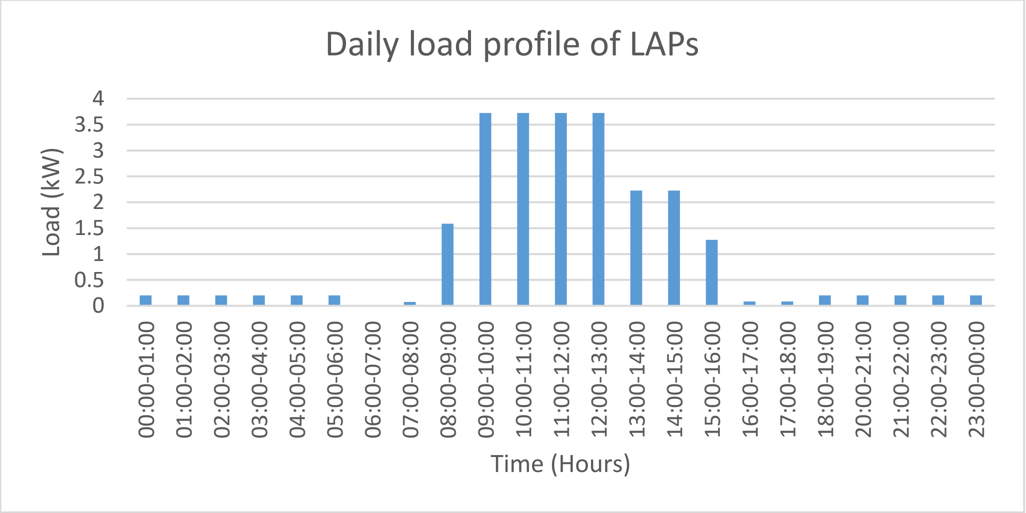

Figure 2. LAPs Mubi daily load profile

Availability of Weather Data in Study Area

The first thing to do whenever to study standalone/hybrid renewable power generate systems is to have particular information about the availability of energy source of that particular location

(Place) such as solar radiation, temperature, wind speed etc. The literature review revealed that there are different ways to acquired information about any place(s) in the world: real data from a meteorological station in the site or close, estimation through probabilistic models generated (Martínez-Díaz et al., 2013). The PV array generated power in each hour through average daily solar radiation and ambient temperature data of a particular location. For this case study, National Aeronautics and space Administration (NASA) surface meteorology and solar energy Data base provides the weather condition data for the Mubi town through (Canada, n.d.). The data provided an annual average daily solar radiation horizontal (5.74kWh/m2/day) and annual average temperature (26.40C) as shown in figure 2.2. These meteorological data were introduced on the energy model in HOMER Pro which generated clearness index of that area.

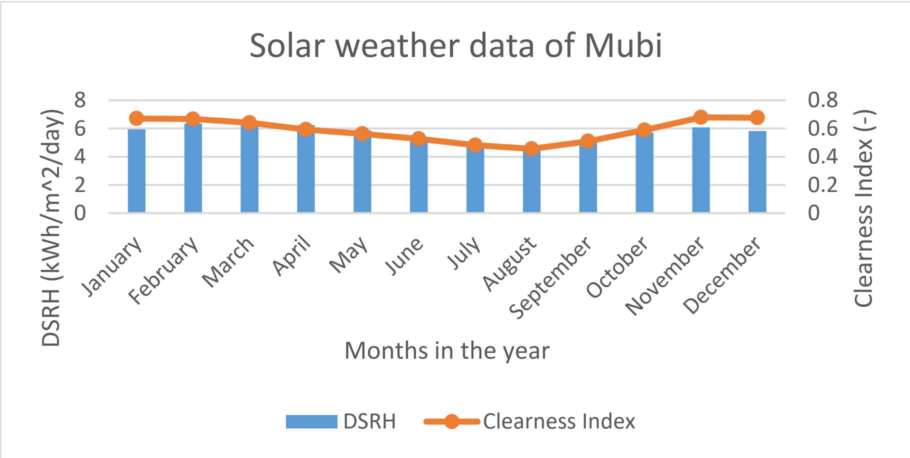

Figure 3. Monthly weather data conditions of Mubi

Model of Solar Power Generation

Design and Sizing of Solar Photovoltaic (SPV) Components

The design of SPV components for proposed shop load demand would use some of inbuilt modeled equation in the HOMER software (tool). In this design, 10.5% would be considered in the economic window of software, as the annual real interest rate. Some other things we considered are project life time (20 years), the system fixed cost i.e. To take care of distribution cost and cost of building a place for the batteries and the system fixed cost operation and maintenance cost per year for technician, who supervise the system through its lifetime.

Solar Panel Model Output, Specifications and Selection

According to Acakpovi et.al. and Akinyele et.al. (Acakpovi et al., 2015; Akinyele et al., 2015) the model of PV array output power generated depend on cell temperature (oC) and solar radiation in fixed or in tilted at that time (kW/m2 or kWh/m2/day). The PV array output was carried out using equation 1 (HOMER, 2016)s.

$$P_{pvo} = PV_{arc} \times PV_{adf}\left(\frac{G_{ipv}}{G_{istc}}\right)\left[1 + \eta_p\left(T - T_{cell,stc}\right)\right] \qquad (1)$$

Where P_{pvo} is PV array output

PV_{arc} is PV array rate capacity (kW)

PV_{adf} is PV array derating factor (%)

G_{ipv} is the incident radiation on the array at that time (kW/m^2)

G_{istc} is the incident radiation on the array at STC, (kW/m^2)

η_p is the temperature coefficient of power (%/^{o}C)

T is the cell temperature of PV (^{o}C).

$T_{cell,stc}$ is the cell temperature of PV at STC (25^{o}C)

According to HOMER (HOMER, 2016), the cell temperature, Tcell can be calculated as given in equation 2.

$$T_{cell} = T_s + \left(T_{cell,NOCT} - T_{s,NOCT}\right)\left(\frac{G_R}{G_{R,NOCT}}\right)\left(1 - \frac{\eta_{mpp}}{\tau_\alpha}\right) \qquad (2)$$

Where, T_s is the surrounding temperature (^{o}c)

$T_{cell,NOCT}$ is the nominal operating temperature of the cell (^{o}C).

$T_{cell,NOCT}$ is the surrounding temperature where NOCT is (20^{o}C)

G_R is the radiation acting on the array (kW/m^2)

$G_{R,NOCT}$ is the radiation acting on the array where it is 800W/m^2

η_{mpp} is the efficiency at maximum power point (%)

τ_α is the PV array solar absorbance (%)

There are many types of PV cells in the market: Monocrystalline, Polycrystalline, thin firm and Amorphous cells but a monocrystalline 10kW PV cell was chosen in this proposed design because of its advantages that possesses over other types of PV cell and its specifications shown in Table 2.

Table 1: Design parameters, cost and specifications of PV cell module

S/no	Describe of parameters	Values	Units
1	Maximum Power (Model SM660-250)	250	W
2	Project lifetime	20	years
3	Slope	10.3	^{o}C
4	Derating Factor	75	%
5	Temperature Coefficient of Power	-0.39	%/ ^{o}C
6	Azimuth (^{o}C W of S)	0	^{o}C
7	Ground Reflectance	20	%
8	Nominal Operating Cell Temperature	47	^{o}C
9	Efficiency at Standard Test Condition	15.4	%

S/no	Describe of parameters	Values	Units
10	Capital cost	253	$
11	Replacement Cost	0	$
12	Operation and Maintenance cost	0	$/year
13	Nominal Voltage	12	V

Sizing of the Battery Storage

A 30 AGM BG Max 12V 200AH battery is chosen which produced by AGM BG battery company was used in this system. It has a norminal voltage of 12v, nominal capacity of 200AH and it has lifetime of 917kWh. The replacement cost is $341 while capital cost is $521. The considered quantities are: 0, 2,3,4,5,10,15,20. The storage batteries input was considered by HOMER in the simulation. The model used in this battery bank life for this design is taken from Lambert et.al. (Lambert et al., 2006) as given in equation 3.

$$L_{be} = Min\left[\frac{N_b \times Q_{tl}}{Q_{pt}}, L_{fb}\right] \quad (3)$$

Where, L_{be} is battery bank life (years)

N_b is number of batteries in the battery bank

Q_{tl} is lifetime throughout of a single battery (kWh)

Q_{pt} is annual battery throughput in kWh/year, and

L_{fb} is Float life of battery (years)

Converter/Inverter Used

The HOMER software considers a converter as inverter ie. DC to AC, rectifier (AC to DC) or both (Saheb-Koussa et al., 2011). For this, design a 12VDC to 220/50HZ Ac pure sine wave inverter was chosen because it has some good properties such as: an inbuilt maximum power point tracking (MPPT) charge controller of 10-40A which regulate up to 10 pieces of 2kW -20kW solar modules and also with Ac charger of 20A which can charge up to 2 pairs of 200AH batteries at the same time and isolation transformer which move its good for inductive load re it required so much surge current for its first time energize red. The inverter and rectifier efficiencies in this simulation were taken as 90% and 95% respective when considered the sizes as shown in figure 2.3 and the capital cost of inverter is $285.

Proposed Configuration of the System

System equipment configuration

The equipment chosen in the optimization was shown in figure. The equipment's considered are PV cells, converter (inverter), battery bank and loading system (load demanded).

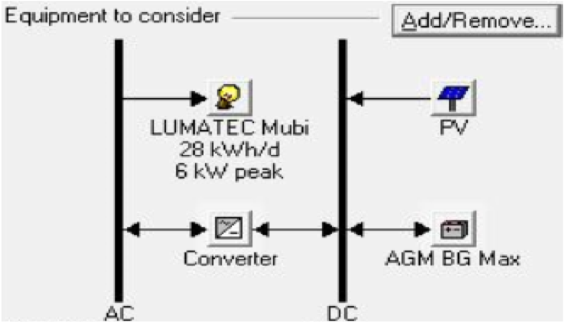

Figure 4. Configuration of proposed system

The structure (figure defined energy model of standalone PV and batteries is defined in HOMER as in figure 2.3. The system is composed of 24.16kW PV system and also shown the system configuration of the HOMER program, the system was designed to have a lifetime of 20 years before PV panels can be replaced.

Mathematical Energy Cost of a System

Optimization software package called HOMER was described by Lambert (Lambert et al., 2006), similarly to Akinyele et.al. (Akinyele et al., 2015) also stated that HOMER software is a good package for modeling simulation of renewable energy because is reliable software to use in simulate various renewable energy system which used net present cost (NPC) to assess all costs that will obtain within the project lifetime such as initial cost, operations & maintenance (O & M) cost and components replacement as given in equation 4. Several research (Al Garni & Awasthi, 2017; Alsharif, 2017; Olatomiwa et al., 2015) reported that at time NPC is referred to as life cycle cost of a system.

$$NPC = \frac{TAC}{CRF} \tag{4}$$

Where, *TAC* is the total annualized cost in US dollar ($)
CRF is capital recovery factor as expressed in equation 5.

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \tag{5}$$

n is the project lifetime (20 years) and i is the annual real interest rate is given by equation.

$$i^a = \frac{i - a_{inf}}{1 + a_{inf}} \tag{6}$$

i^a is norminal interest rate (rate at which a bank can give loan) and a_{inf} is annual inflection ration (17.78% as at 2020).

The software (HOMER) used an annual real interest rate rather than a nominal interest rate and also assumes that all prices evaluate at the same rate. HOMER also determine the discount factor (d_f) of the present value of a cash flow in energy year lifetime of the project using the expression in equation 7.

$$d_f = \frac{1}{(1 + i^n)} \tag{7}$$

The software normally, consider the salvage cost (*SC*) after it had been calculated by equation 8.

$$SC = R_{cc}\left(\frac{R_{ltc}}{L_{tc}}\right) \tag{8}$$

Where, R_{ltc} is the replacement cost of the component, R_{ltc} is the remaining lifetime of the component and L_{tc} is the total lifetime of the component.

Payback period (PBP) can be defined as span of time required to recover any total cost invest on the system. The payback period is usually expressed in years. The PBP is considered in this proposed off-grid power supply as given in equation 9 (Bansal & Singh, 2019).

$$Payback\ period = \frac{Total\ installed\ system\ cost}{Annual\ units\ generated\ \times cost\ of\ one\ unit} \tag{9}$$

RESULTS AND DISCUSSION

Simulation results were obtained from the proposed off-grid power system after running the inputs data through HOMER software, an optimal result for power the system at Lumatee Aluminium products (shop) revealed the solar PV system components capacity that required in serve the shop load (28.20kWh/d) are: PV array of 10kW; 30AGM batteries and 10kW converter (inverter) in the system. The profile load revealed the peak load demand of 6.0kW which would be required around 13:00 to 14:00h, which was increased to 8kW to cater for contingencies in the input window software. Solar PV Optimization results presented in the Table 2.

Table 2: Optimization results of solar PV

PV (kW)	AGM BG	Converter (kW)	Initial Capital	Operating Cost	Total NPC	COE ($/kWh)	R.F	Capacity Shortage	Battery Life(year)
10.00	30	10	$21.775	531	$26.148	0.312	1.00	0.15	10.00

NB: R.F is Renewable Fraction, AGM BG is the Batteries

Total Net present cost (NPC) is the HOMER tool main economic output. HOMER used NPC to rank the system and others economic outputs are determined in order to obtaining NPC. The result attained from the simulation revealed initial capital cost ($21775), operating cost ($531/year). The total NPC ($26,148) and energy cost ($0.312/kWh).

An off-grid power system revealed a payback period (PBP) of 5.8 years out of 20 years proposed. In fact, the purposed system is not economical cheap at current cost but power will be available at all time for this small-scale industry (shop). In fact, if there are reasonable reduction in the system component cost installation, the system will be cost effective throughout the world and also lowering the investment cost/kilowatts. This type of system is a desirable of power supply because its availability, sustainability and environmentally friendly. The model developed is visibly and acceptable generally for preliminary results of energy consumption cost for domestic and small-scale industrial sector willing to use renewable energy sources for his/her business. The future research should consider the implementation of prototype to conform the claimed.

CONCLUSIONS AND RECOMMENDATION

In the present system, the design and techno-economic viability of stand-alone PV in order to provide electricity demand for Lumatech Aluminum products shop was investigated. HOMER pro was used for this analysis, which indicated that the system consisted of solar PV (100W), 30AGM 12V 200AH batteries and a 10kW converter make the system feasible to provide the proposed load due to the availability of solar radiation and its viability was fixed based on NPC of $21,148 and COE of $0.312/kWh can initial capital of $21,775, a salvage value of $0.15 and a payback period of 5.8 years.

From this study, we found that the solution of supply power to the small scale industries are cost effective but available throughout the year and also feasible to resolve the small scale industries, rural and urban electricity supplying in Nigeria. In view of the above, it is recommended that Nigerian Government & Law makers should promotes the use of standalone PV system for domestic and small scale industry by providing financial assistance through soft loans, subsides and grants. And also, for further investigation the prototype of this energy power system should be set up to verify the authors claimed by promoting renewable energy sources in order to be more competitive in the future of this country (Nigeria).

REFERENCES

Aba, M., Ladeinde, A., & Afimia, E. (2019). Economic Evaluation of Hybrid Renewable Energy Systems for Electricity Generation in Nigeria: A Discounted Cash Flow Analysis. *Journal of Energy Research and Reviews*, 1–10. https://doi.org/10.9734/jenrr/2019/v2i230075

Acakpovi, A., Ben Hagan, E., & Bennet Michael, M. (2015). Cost Benefit Analysis of Self-Optimized Hybrid Solar-Wind-Hydro Electrical Energy Supply as compared to HOMER Optimization. *International Journal of Computer Applications*, *114*(18), 32–38. https://doi.org/10.5120/20081-2133

Ajao, K., Oladosu, O., & Popoola, O. (2011). Using HOMER power optimization software for cost benefit analysis of Hybrid-solar power generation relative to utility cost in Nigeria. *International Journal of Research and Reviews in Applied Sciences*, *7*(1), 96–102. http://www.arpapress.com/Volumes/Vol7Issue1/IJRRAS_7_1_14.pdf

Akinyele, D. O., Rayudu, R. K., & Nair, N. K. C. (2015). Development of photovoltaic power plant for remote residential applications: The socio-technical and economic perspectives. *Applied Energy*, *155*, 131–149. https://doi.org/10.1016/j.apenergy.2015.05.091

Al Garni, H. Z., & Awasthi, A. (2017). Solar PV power plant site selection using a GIS-AHP based approach with application in Saudi Arabia. *Applied Energy*, *206*, 1225–1240. https://doi.org/10.1016/j.apenergy.2017.10.024

Alkali, A. B., Abdulrahim, A. T., & Mustapha, B. M. (2004). Viability of Solar Photovoltaic System for Rural Electrification in Nigeria: a Case Study of a Single Bedroom Apartment. *Arid Zone Journal of Engineering*, *4*, 23–29. www.azojete.com.ng

Alsharif, M. H. (2017). Techno-economic evaluation of a stand-alone power system based on solar/battery for a base station of global system mobile communication. *Energies*, *10*(3). https://doi.org/10.3390/en10030392

Bahramara, S., Moghaddam, M. P., & Haghifam, M. R. (2016). Optimal planning of hybrid renewable energy systems using HOMER: A review. *Renewable and Sustainable Energy Reviews*, *62*, 609–620. https://doi.org/10.1016/j.rser.2016.05.039

Balint, P. J. (2006). Bringing solar home systems to rural El Salvador: Lessons for small NGOs. *Energy Policy*, *34*(6), 721–729. https://doi.org/10.1016/j.enpol.2004.07.010

Bansal, N., & Singh, G. (2019). Techno-economic analysis and performance evaluation of 25 MW solar PV power plant in actual environmental condition in India. *International Journal of Engineering and Advanced Technology*, *8*(6 Special issue), 659–669. https://doi.org/10.35940/ijeat.F1131.0886S19

Bhardwaj, S., & Garg, S. K. (2014). Rural Electrification by Effective Mini Hybrid PV Solar , Wind & Biogas Energy System for Rural and Remote Areas of Uttar Pradesh. *International Journal of Computer Science and Electronics Engineering (IJCSEE)*, *2*(4), 178–181.

Canada, M. of N. R. (n.d.). *RetScreen International: Clean energy project analysis software*. http://www.retscreen.net/ang/home.php

Crossland, A. F., Anuta, O. H., & Wade, N. S. (2015). A socio-technical approach to increasing the battery lifetime of off-grid photovoltaic systems applied to a case study in Rwanda. *Renewable Energy*, *83*, 30–40. https://doi.org/10.1016/j.renene.2015.04.020

Ferroukhi, R., Gielen, D., Kieffer, G., Taylor, M., Nagpal, D., & Khalid, A. (2014). *REthinking Energy: Towards a new power system.*

HOMER. (2016). *HOMER (Hybrid Optimization of Multiple Energy Resources) Microgrid Software,*. http://www.homerenergy.com/software.html

Jamil, M., Kirmani, S., & Rizwan, M. (2012). Techn-economic feasibility analysis of solar Photovoltaic power generation: A review. *Smart Grid and Renewable Energy*, *3*(4), 266–274. https://doi.org/10.4236/sgre.2012.34037

Jimenez-Estevez, G. A., Palma-Behnke, R., Ortiz-Villalba, D., Nunez Mata, O., & Silva Montes, C. (2014). It takes a village: Social SCADA and approaches to community engagement in isolated microgrids. *IEEE Power and Energy Magazine*, *12*(4), 60–69. https://doi.org/10.1109/MPE.2014.2317419

Lambert, T., Gilman, P., & Lilienthal, P. (2006). Integration of Alternative Sources of Energy. *Integration of Alternative Sources of Energy*, 301–332. https://doi.org/10.1002/0471755621.ch12

Liu, G., Rasul, M. G., Amanullah, M. T. O., & Khan, M. M. K. (2011). Feasibility study of stand-alone PV-wind-biomass hybrid energy system in Australia. *Asia-Pacific Power and Energy Engineering Conference, APPEEC*. https://doi.org/10.1109/APPEEC.2011.5749125

Martínez-Díaz, M., Villafáfila-Robles, R., Montesinos-Miracle, D., & Sudrià-Andreu, A. (2013). Study of optimization design criteria for stand-alone hybrid renewable power systems. *Renewable Energy and Power Quality Journal*, *1*(11), 1266–1270. https://doi.org/10.24084/repqj11.598

Mohamed, M. A., Eltamaly, A. M., & Alolah, A. I. (2015). Sizing and techno-economic analysis of stand-alone hybrid photovoltaic/wind/diesel/battery power generation systems. *Journal of Renewable and Sustainable Energy*, *7*(6). https://doi.org/10.1063/1.4938154

Mourmouris, J. C., Potolias, C., & Jacob, F. G. (2012). Evaluation of renewable energy sources exploitation at remote regions, using computing model and multi-criteria analysis: A case-study in samothrace, Greece. *International Journal of Renewable Energy Research*, *2*(2), 307–316. https://doi.org/10.1234/ijrer.v2i2.194.g119

Ogunmodimu, O., & Okoroigwe, E. C. (2018). Concentrating solar power technologies for solar thermal grid electricity in Nigeria: A review. *Renewable and Sustainable Energy Reviews*, *90*, 104–119. https://doi.org/10.1016/j.rser.2018.03.029

Olatomiwa, L., Mekhilef, S., Huda, A. S. N., & Ohunakin, O. S. (2015). Economic evaluation of hybrid energy systems for rural electrification in six geo-political zones of Nigeria. *Renewable Energy*, *83*, 435–446. https://doi.org/10.1016/j.renene.2015.04.057

Pal, A. M., Das, S., & Raju, N. B. (2015). Designing of a Standalone Photovoltaic System for a Residential Building in Gurgaon, India "Designing of a Standalone Photovoltaic System for a Residential Building in Gurgaon. *Sustainable Energy*, *3*(1), 14–24. http://pubs.sciepub.com/rse/3/1/3

Rawat, R., Kaushik, S. C., & Lamba, R. (2016). A review on modeling, design methodology and size optimization of photovoltaic based water pumping, standalone and grid connected system. *Renewable and Sustainable Energy Reviews*, *57*, 1506–1519. https://doi.org/10.1016/j.rser.2015.12.228

Reddy, V. S., Kaushik, S. C., & Panwar, N. L. (2013). Review on power generation scenario of India. *Renewable and Sustainable Energy Reviews*, *18*, 43–48. https://doi.org/10.1016/j.rser.2012.10.005

Saheb-Koussa, D., Koussa, M., Belhamel, M., & Haddadi, M. (2011). Economic and environmental analysis for grid-connected hybrid photovoltaic-wind power system in the arid region. *Energy Procedia*, *6*, 361–370. https://doi.org/10.1016/j.egypro.2011.05.042

Shodiya, S., R, L., M., N. G., B., O. M., & B., M. A. (2016). Pre-assessment models of global solar radiation using sunshine duration in Maiduguri. *ATBU Journal of Science, Technology and Education*, *4*(1), 174–178. https://www.atbuftejoste.com/index.php/joste/article/view/212

Siddaiah, R., & Saini, R. P. (2016). A review on planning,configurations,modeling and optimization techniqes of hybrid renewable energy systems for off-grid applications. *Renewable and Sustainable Energy Reviews*, *58*(2016), 376–396. https://doi.org/10.1016/j.rser.2015.12.281