Renewable Energy in Nigeria: The Challenges and Opportunities in Mountainous and Riverine Regions

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Abstract- Renewable energy system has become a salient alternative of power in remote small mountainous and riverine regions. High cost of electricity supply and carbon emission reduction could be achieved with the use of renewable energy. This work presents the challenges and opportunities of renewable energy in Nigeria. The various renewable energy sources in Nigeria and their potential was discussed in light of the established master plan of the energy commission of Nigeria. Some of the challenges facing renewable energy development and implementation were highlighted and the various opportunities available were also emphasized. A micro power off grid system made of Biomass, Hydro and Solar Photovoltaic (PV) was proposed to power a mountainous and riverine region that is not grid connected based on the renewable energy potentials available in the region. This topology would not only help reduce the cost of electricity production, but also improve the carbon credit, making the environment eco-friendly.

Keywords- Renewable Energy; HOMER; Grid system; Standalone system; Micro power

1. Introduction

The importance of electricity for economic growth and national development cannot be overemphasized. Due to the use of conventional fuels that leads to environmental degradation, it is pertinent to foster renewable energy sources to make the environment eco-friendly. The development of mountainous and riverine areas is slow in Nigeria, because the grid system could get reach these areas due to high cost, and scattered nature or terrain of the areas.

Renewable energy recently has been proposed for decentralized energy generation for remote areas having difficult terrains [1-5]. The present generating capacity in Nigeria cannot match up with demand, leading to energy crisis in the country. There are numerous energy resources (fossil and renewable energy types) in Nigeria. Despite the abundance of these energy sources in Nigeria, an estimated of only about 60% of the populace have access to the national grid [6-7]. A better mix of energy sources [8, 9] could be palliative to Nigeria energy problem. Therefore, utilizing and implementing renewable energy (Solar PV, Hydro and Biomass) resources, that are readily available in remote mountainous and riverine areas could help augment power generation and reduce energy crisis to some extent.

This work presents renewable energy in Nigeria in the light of the challenges and opportunities in mountainous and riverine regions. The renewable energy sources considered in this study are hydro, biomass and solar PV connected as a micro power off grid or autonomous system. It is assumed that the riverine area should have a hydro resource and since it is mountainous, the level of solar resource should be reasonable. In addition, the waste obtained from the remote community could be used as source of biomass resource to provide sustainable energy for the region. A small remote community close to Obudu Cattle Ranch in Cross River State with 195kWh/d, 20kW peak load was used in this study. The economic and technical evaluation of the system was carried out in the hybrid optimization model for electric renewable (HOMER) environment. HOMER software proffers optimal choice of power sources and configurations that supply electric loads based on various supply possibilities of the micro power system [10-13]. Based on the integration of these available energy sources potential in the region, in cost effective and sustainable pattern, a micro power system energy model was developed and optimized considering HOMER to meet the power needs of the area.

Some of the challenges in addition to the earlier mentioned in implementing renewable energy in these remote areas particularly and Nigeria in general are policy and regulation, finance and market size, technology background, educational and institutional organization and socio-cultural behaviour of the inhabitants. Some of the opportunities are encouraging research and development in renewable energy utilization, skilled manpower development, improved data acquisition for renewable energy potentials, developing extension programs to enhance the use of renewable energy technologies and lastly encouraging incentives for the development of renewable energy system in Nigeria.

2. Energy Policy in Nigeria

Details about energy system in Nigeria can be found in [14-17]. The Nigerian National Energy Policy (NEP) is concerned with the optimal utilization of the nation's energy resources for sustainable development based on the following benefits [6]:

- Optimum development of energy sources available in the country
- Energy sources diversification
- Energy security enactment
- Efficient energy supply
- Adequate, reliable and sustainable energy supply
- Development of human and institutional capacity
- Enforcing indigenous participation in the energy section
- Encouraging local and foreign investment in the energy sector.

3. Renewable Energy in Nigeria and Master Plan of NEP

A review of energy resources in Nigeria has been reported in [18-21], while the energy mix supply projection in Nigeria can be found in [6]. Solar radiation ascribes for 3.5-7.0kWh/m2/day (485.1 million MWh/day using 0.1 % Nigeria land area) making a production level of excess of 240kWp of solar PV or 0.01 million MWh/day ranging in excess of 0.01million MWph/day of solar utilization. A reserve of (2-4) m/s at 10m height could be ascertained for wind energy, because of its uncertain and stochastic nature. Biomass could be grouped into 3 as follows: fuel wood with 11 million hectares of forest and wood land at 0.11 million tonnes/day reserve and 0.120 million tonnes/day utilization; animal waste of which 245 million assorted in 2001 with 0.781 million tonnes of waste /day in 2001; energy drops and agricultural residue with 72 million hectares of agricultural land and all waste lands, with excess of 0.256 million tonnes of assorted crops residues / day in 1996 on production level.
The master plan of the National Energy Policy (NEP) in Nigeria proposes and improves energy mix in the generation of power in the country through the use of renewable energy. However, the adoption of these renewable and alternative forms of energies like solar photovoltaic, wind, small hydropower and efficient biomass is relatively recent. Unfortunately, the existing renewable energy works in the country are few and mostly anchored by foreign and non-governmental organizations especially in the remote rural areas, where their present would be widely felt. In addition, there are hardly standalone renewable energy system installed in large cities of the country to augment the erratic power supply from the national grid located at Oshogbo.

4. Challenges and Opportunities of Renewable Energy in Nigeria

Some of the challenges facing the growth and implementation of renewable energy in Nigeria are discussed below.

4.1. Regulatory Policies

Regulatory policies are essential in the successful implementation of renewable energy in a country. Nigeria does not have a good regulatory policy on renewable energy. However, in 2005, the Energy commission of Nigeria (ECN) came up with a National Renewable Energy Master Plan (REMP), in light of the goals of National Energy Policy, National Policy on Integrated Rural Development, the Millennium Development Goals (MDGs) and the National Economic Empowerment and Development Strategy (NEEDS). These programs do not capitalize on the opportunities presented in the remote, rural, mountainous and riverine regions. Thus, the renewable energy master plan provides a good opportunity for the nation's renewable energy harness, but is not a national policy on renewable energy.

4.2. Finance and Market Size

Huge capital is the main obstacle for remote, rural, mountainous and riverine renewable energy projects [22]. Majority of renewable energy projects have very high initial cost, but long life span, with little or no running cost when compared to other conventional energy sources like diesel type. Unfortunately, many consumers especially in the remote rural, mountainous and riverine regions with low income prefer to keep the initial cost low rather than minimize the operating cost which would run over a long period of time [23]. Therefore a call for sustainable and realistic renewable energy market opportunity projects is needed by private sector as against governmental and foreign agencies projects.

4.3. Technological Knowhow

Average Nigerians lack the technical skills to contain modern trends of renewable energy technology. This is a big challenge especially in the areas of inadequate and inaccurate resource data, low product quality, little or no research and development activity, and lack of human and manufacturing abilities. The worst scenario is the lack of knowledge among users and installers in the event of distinguishing between good and bad equipment and make the right choice [24]. Nigerian University Commission (NUC) should be of help in this regard to include renewable energy education in the curriculum of Nigerian schools, and government should create enabling platform and environment for the encouragement of indigenous renewable energy technology.

4.4. Institutional Problem

Nigeria lacks good institutes to lead renewable energy technology, hence the direction and coordination of renewable energy activities in the country is a fiasco. The present research centres lack the ability to commercialize their developed products. On the other hand, there are opportunities for the present renewable energy master plan to establish national renewable energy agency that should encourage efficiency in the provision and use of the various types of energy. This would be with respect to improve the quality of training and management of energy, and also enlighten or create awareness of energy related matters to champion local institutional reforms in order to help meet policy targets to reduce environmental risk.

4.5. Socio Cultural Habits

Generally, renewable energy technologies are sensed to create discomfort or sacrifice rather than as providing relevant energy services with reduced cost [23]. The cultural and religious beliefs of the people have a role to play in terms of the understanding and concern of the people in the vicinity where renewable energy technology is enacted. The opportunities that renewable energy offers need to be intimated to the people in the small remote, mountainous and riverine area, as this would enhance the optimal operation of renewable technology in these areas.

5. The Proposed Hybrid System for the Regions

The proposed micro power hybrid system of Biogas, Solar PV and Hydropower system to power the mountainous and riverine region is shown in Fig. 1.

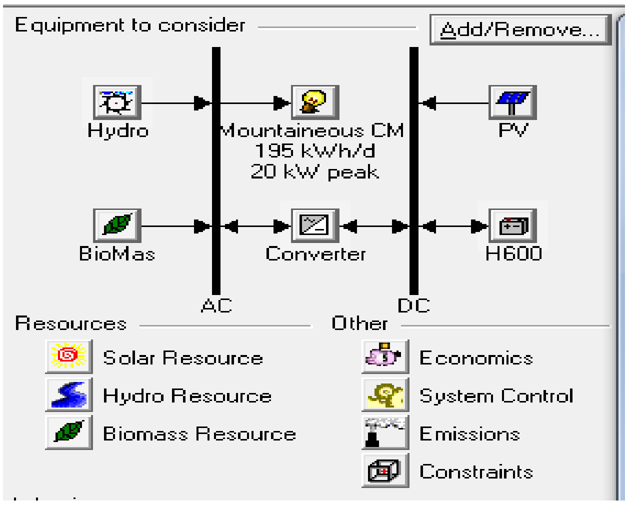


Fig. 1. Proposed Model System for the Region

The model system is made of a Biogas of 5kW, hydro power plant of 18.4kW and solar PV of 5kW was used to power the micro power off grid system. A Hoppecke 6 OPzS 600 battery was used alongside a converter system connected to a DC and AC bus bars for conversion and inversion respectively. The load profile of the mountainous and riverine region is shown in Fig. 2, with a capacity of 20kW, and 195kWh/day. The design parameters and data resources which are used for the proposed system are shown in the Appendix.

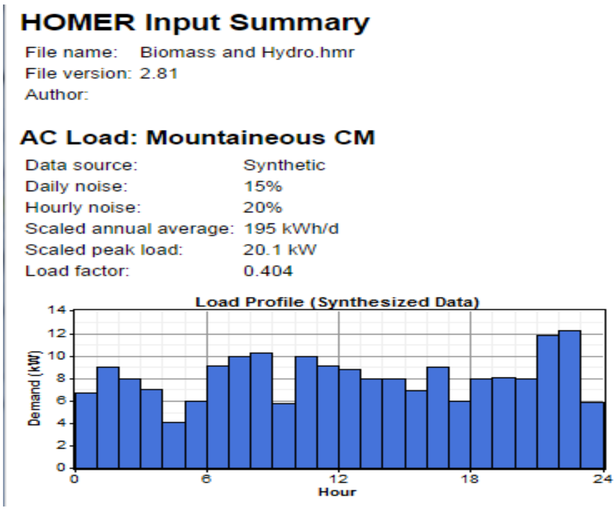


Fig. 2. Load Profile for the Region

6. Simulation Results and Analysis

The simulation results carried out considering the proposed biogas, solar PV and hydro micro power system to serve the mountainous and riverine region are shown in Figures 3 to 12. Simulations were carried out in the Hybrid Optimization Model for Electric Renewable (HOMER). HOMER helps choose the least cost combination of renewable and conventional power sources for small scale on or off grid power systems. HOMER's detailed simulation capability is essential for optimizing the mix of variable renewable and conventional power sources. HOMER compares multiple design options to predict performance and life cycle costs of different system configurations.

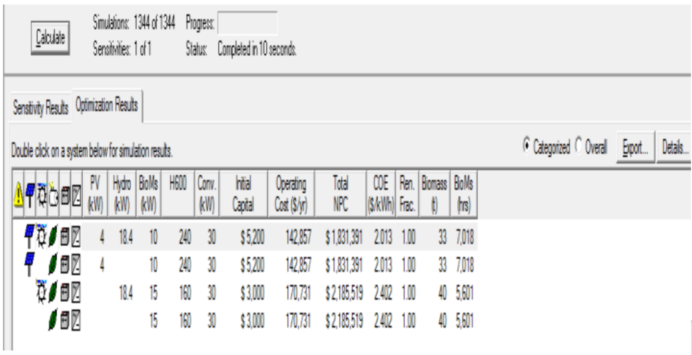


Fig. 3. Optimized configuration results

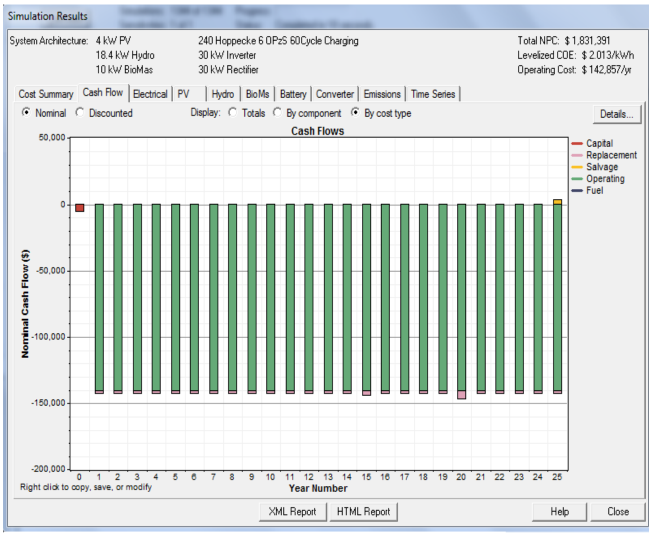


Fig. 4. Cash flow of the system

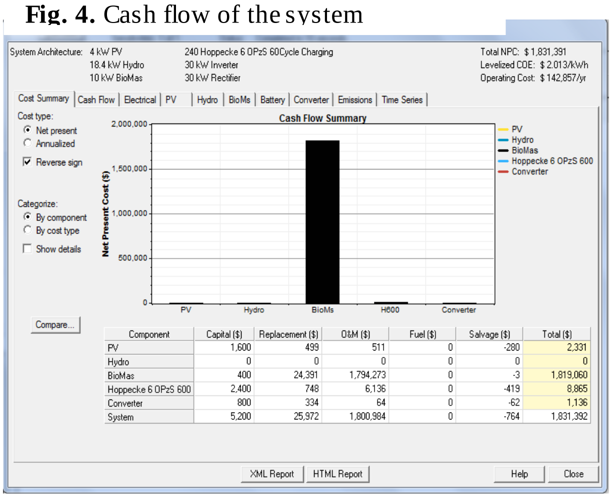


Fig. 5. Cash Flow Summary of the System

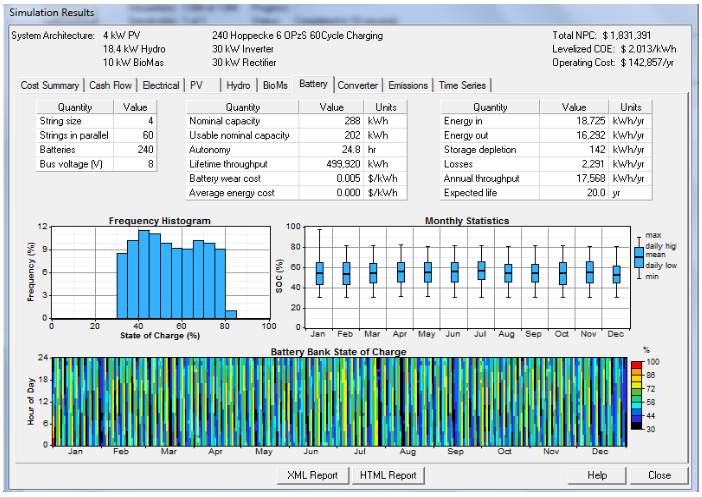


Fig. 6. Battery bank system

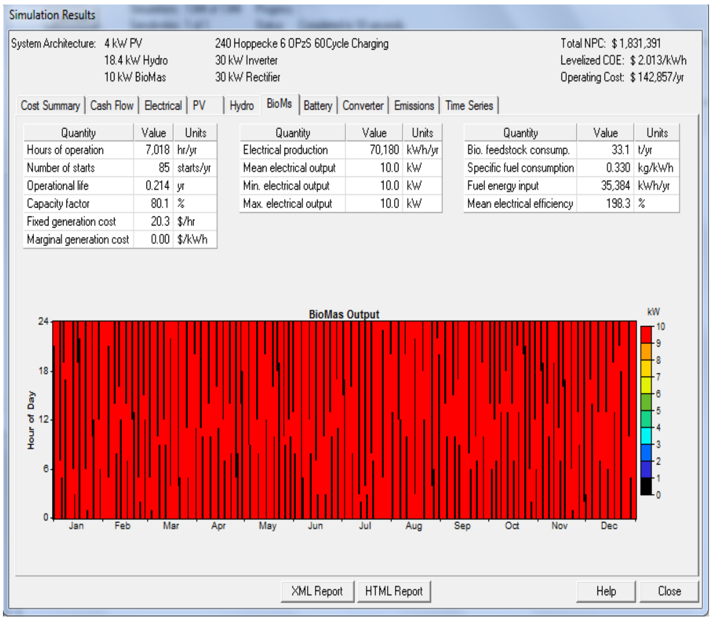


Fig. 7 Biomass plant output

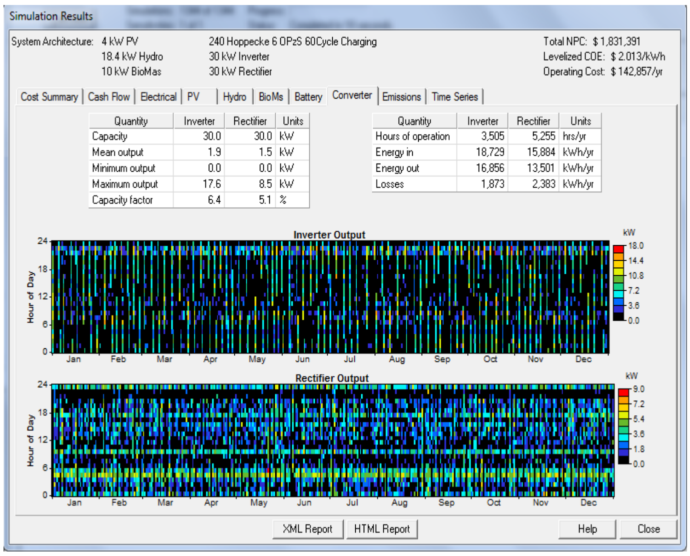


Fig. 8. Converter system output

Table 1. Economics and Generator Control

Economics

Annual real interest rate:	6%
Project lifetime:	25 yr
Capacity shortage penalty:	$ 0/kWh
System fixed capital cost:	$ 0
System fixed O&M cost:	$ 0/yr

Generator control

Check load following:	No
Check cycle charging:	Yes
Setpoint state of charge:	80%
Allow systems with multiple generators:	Yes
Allow multiple generators to operate simultaneously:	Yes
Allow systems with generator capacity less than peak load:	Yes

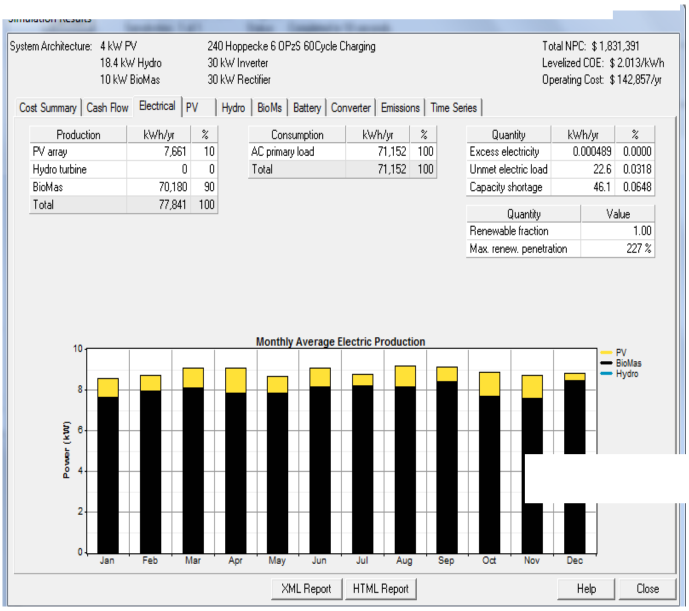


Fig. 9. Electrical Production of the System

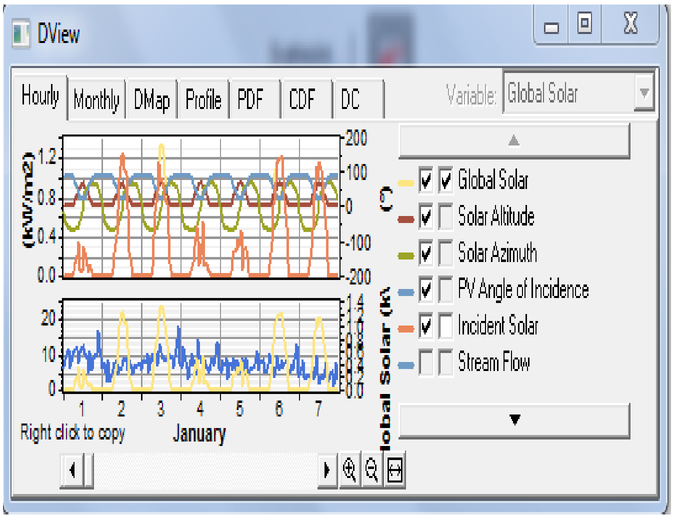


Fig. 10. Radiation System for the month of January

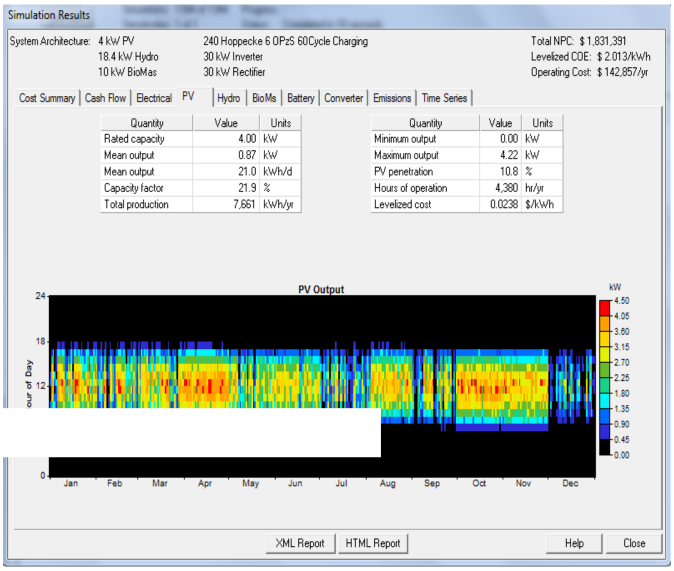


Fig. 11. Solar PV Output of the System

Table 2. Emissions of the System

Simulation Results

System Architecture: 4 kW PV, 18.4 kW Hydro, 10 kW BioMas; 240 Hoppecke 6 OPzS 600Cycle Charging, 30 kW Inverter, 30 kW Rectifier

Total NPC: $ 1,831,391
Levelized COE: $ 2.013/kWh
Operating Cost: $ 142,857/yr

Cost Summary | Cash Flow | Electrical | PV | Hydro | BioMs | Battery | Converter | Emissions | Time Series

Pollutant	Emissions (kg/yr)
Carbon dioxide	5.72
Carbon monoxide	0.215
Unburned hydrocarbons	0.0238
Particulate matter	0.0162
Sulfur dioxide	0
Nitrogen oxides	1.92

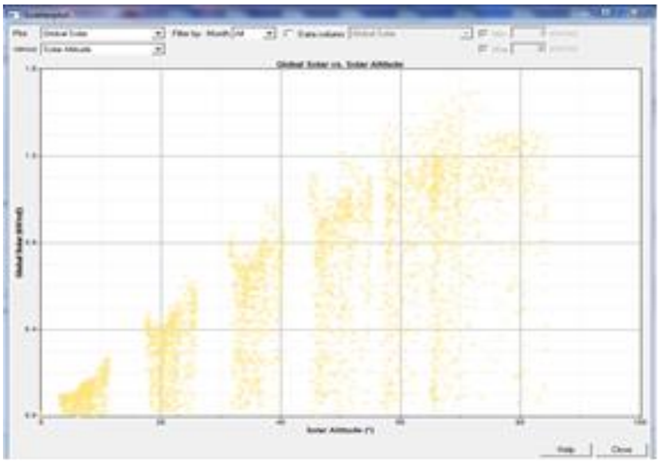


Fig. 12. Global Radiation of the system

7. Discussion of Simulated Results

Figure 3 shows the various optimized results obtained for the solar PV, hydro and biomass system. The best optimized results for the three mix of power generation gives a total net present cost (NPC) of $1,831.391, levelized cost of electricity (COE) of $2, 013/kwh and operating cost of $142.857/yr as shown in Figures 3 and 4 respectively. In Fig. 4, the operating cost of using fuel was zero because only renewable was considered with no diesel powered plant in the proposed micro power off grid system, hence there is a great save of expenses, with little replacement value as shown in the figure. The cash flow summary of the system is shown in Figure 5, where it could be observed that much of the power generation of the system is coming from the Biomass, as it is a cheap means to generate power. The battery bank system is shown in Figure 6, where the pattern of the percentage of the battery charge is displayed. Figure 7 shows the biomass out of the system with the values of the bio feedstock and fuel consumption, fuel energy input and other essential data and parameters of the biomass system that help generate electricity. The high frequency of the biomass output is also displayed in the figure. The inverter and converter system used for the ac to dc to ac conversion is shown in Fig. 8. The inverter has about 3, 304 hours of operation, while the rectifier has 5, 255 hours. Indicating more rectification was done in the course of the study than inversion, due to the presence of more energy of the biomass and hydro type plants at the ac bus bar compared to the presence of only the solar PV systemat the dc busbar.

The project has a life of 25yrs, with 6% real annual interest rate and a generator setup state of charge of 80% as shown in Table 1. The electrical power production for the system is shown in Fig. 9, where an excess electricity production of 0.000489kwh/yr and AC primary load of 71,152kWh/yr. Table 2 shows the low carbon and other gases emissions of the system. It would be observed that the emissions are very low for the year life cycle compared to what would have been obtained if fossil or diesel fuelled generators were used. Hence, improving the carbon credit and making the environment of the mountainous and riverine region eco-friendly. Figure 10 shows the radiation of the system in the month of January for global solar, solar attitude, PV angle of incidence and incident solar, while Fig. 11 shows the PV out with an operating time of 4,380hr/yr having a capacity factor of 21.9%. The global radiation of the system is shown in Fig. 12, where it could be seen that the radiation has a very high frequency in the scatter diagram.

8. Conclusions

Energy is a major determinant of every country's economic and social development. Appreciable renewable energy sources of Solar Photovoltaic (PV), Wind, Biomass and Hydro is available in Nigeria. However, the National Energy Policy (NEP) that is supposed to encourage the harvesting and integration of these renewable energy resources is not effective enough for sustainable development. In order to encourage the use of renewable energy sources in Nigeria, there exist a national renewable energy master plan to speed up renewable energy development in the country.

This work has presented the challenges and opportunities of renewable energy in Nigeria considering mountainous and riverine regions. Some of the key challenges are regulatory policies, finance and market size, technological background, availability of institutions and socio-cultural behaviour of consumers. However, there are many opportunities like training of local engineers and craftsmen, developing extension programs on renewable energy, data acquisition intensification, etc.

The benefits of using renewable energy sources for generating power in remote mountainous and riverine regions are obvious and more compared to their shortcomings. Transportation of fossil fuels to such regions is challenging and very expensive, coupled with the effects of climate change and global warming. In this work, a micro power system composed of hydro energy, biomass, and PV was proposed to power the regions. The simulated results were encouraging considering the economic analysis if the system. Therefore, it is recommended that renewable energy should be used to power small remote mountainous and riverine regions based on the available renewable potential resources they possess and the numerous opportunities they may offer in sustainable development.

References

[1] A. Al-Ammar Essam, H. Nazar Malik, and Mohammad Usman, "Application of using Hybrid Renewable Energy in Saudi Arabia", Engineering Technology and Applied Science Research, Vol. 1, no. 4, pp. 84-89, 2011.

[2] L. Amaral, N. Martins and J. Gouveia, "Optimization of a Renewable Energy Supply System on a Remote Area: Berlega Island Case Study", World Renewable Energy Congress, 8-13 May, Linkoping, Sweden, 2011.

[3] P. Wolfe, "The Implication of an Increasingly Decentralized Energy System". Energy Policy, Vol. 36, no. 12, pp. 4509-4513, 2008.

[4] R. B. Hiremath, S. Shikha, and N. H. Ravindranath, "Decentralized Energy Planning: Modeling and Application-A Review", Renewable and Sustainable Energy Reviews, Vol. 11, no. 5, pp. 729-752, 2007.

[5] Association of RE (Renewable Energy), et al, *Sustainable Energy Manifesto,* 2006.

[6] Energy Commission of Nigeria (2003-2012): *Nigerian Energy Sector and Sustainable Development.*

[7] A. S. Sambo, Renewable Energy Electricity in Nigeria: The Way Forward, Renewable Energy Electricity Policy Conference, Abuja, 2006.

[8] S. Olayinka Oyedepo, *Energy and Sustainable Development in Nigeria: The Way Forward*, Energy Sustainability and Society, Springer, 2012.

[9] Bala E. J., "Status of Energy Access in Nigeria", Workshop on Energy Access and Villages Inventory Organized by the World Energy Council, Johannesburg, South Africa, 2013.

[10] F. D. Surianu, I. Borlea, D. Jigoria-Oprea, and B. Lustrea, "Comparative Study of the Opportunity to use Renewable Energy Sources to Supply Residential Consumers", International Conference on Renewable Energies and Power Quality, pp. 1-5, Spain, 2012.

[11] A. K. Akella, M. P. Sharma and R. P. Saini, "Optimum Utilization of Renewable Energy Sources in a Remote Area", Renewable and Sustainable Energy Reviews, Vol. 11, pp. 894-908, 2007.

[12] Global Climate Network, *Investing in Clean Energy*, www.globalclimatenetwork.info, 2010.

[13] K. E. Agbo and J. I. Eze, "Anaerobic Digestion of Municipal Solid Waste for Generation of Energy: Prospects and Challenges in Nigeria", Nigeria Journal of Solar Energy, Vol. 22, pp. 130-137, 2011.

[14] Temilade Sesan, "Status of Renewable Energy Policy and Implementation in Nigeria", Institute of Science and Society, Faculty of Social Sciences, Law and Education, University of Nottingham, United Kingdom, 2008.

[15] E. Oladosu et al Nigeria's Household Energy sector: Issues and Supply/Demand Frontiers, Energy Policy, Vol. 22, no. 6, pp. 538-49, 1994.

[16] *Power Holding Company of Nigeria (PHCN)*, Annual Report, 2005.

[17] Federal Ministry of Energy, *The Role of Energy in Achieving Millennium Development Goal (MDGs)*, National Engineering Technology Conference, Zaria, 2008.

[18] *Nigerian National Petroleum Corporation (NNPC)* Report, 2007.

[19] *Renewable Energy Master Plan* Report (2005-2013).

[20] *Ministry of Mines and Steel Development* Report, 2008.

[21] *Central Bank of Nigeria* Annual Report, 2005-2007.

[22] C. R. Monroy, A. S. Hernandez, "Strengthening Financial Innovation in Energy Supply Projects for Rural Exploitations in Developing Countries", Renewable and Sustainable Energy Reviews, 2007.

[23] F. Reddy et al, "Diffusion of Renewable Energy Technologies –Barriers and Stakeholders Perspectives", Renewable Energy, Vol. 29, no. 9, pp. 1431-47, 2004.

[24] G. Wilkins, *Technology Transfer for Renewable Energy*: Overcoming Barriers in Developing Countries, London: Earthscan, 2002.

Appendix

Data and Resources

PV

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
5.000	2,000	2,000	50

Sizes to consider: 0, 1, 2, 4 kW
Lifetime: 20 yr
Derating factor: 80%
Tracking system: No Tracking
Slope: 0 deg
Azimuth: 0 deg
Ground reflectance: 20%

AC Hydro:

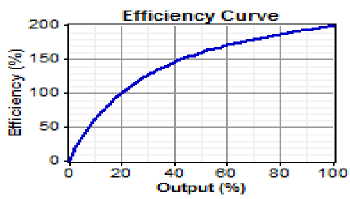
Capital cost: $ 0
Replacement cost: $ 0
O&M cost: $ 0/yr
Lifetime: 25 yr
Available head: 5 m
Design flow rate: 500 L/s
Min. flow ratio: 50%
Max. flow ratio: 150%
Turbine efficiency: 75%
Pipe head loss: 15%

Consider systems without hydro: Yes

AC Generator: BioMas

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
5.000	200	200	10.000

Sizes to consider: 0, 5, 10, 15 kW
Lifetime: 1,500 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: Biomass
Fuel curve intercept: 0.08 L/hr/kW
Fuel curve slope: 0.25 L/hr/kW



Battery: Hoppecke 6 OPzS 600

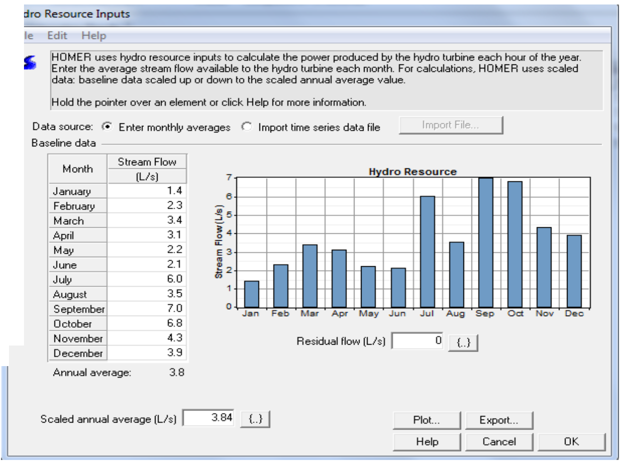
Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
50	500	500	100.00

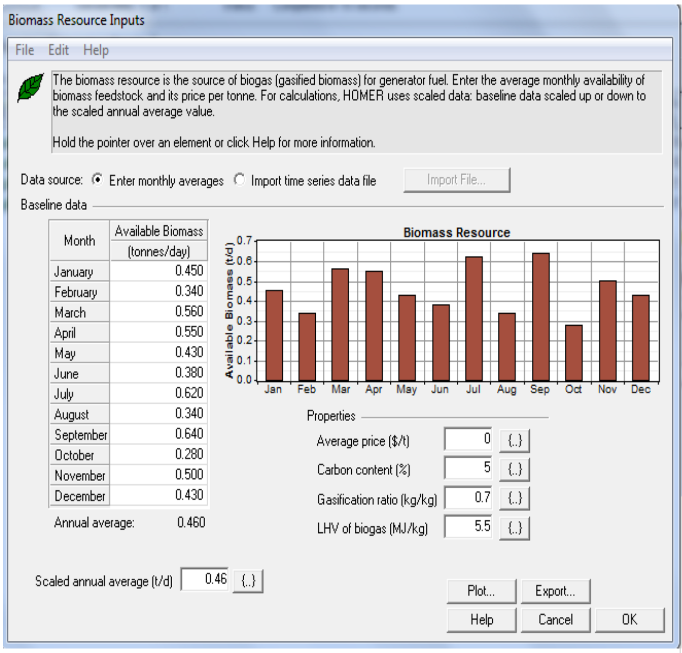
Quantities to consider: 0, 10, 20, 40, 60, 100
Voltage: 2 V
Nominal capacity: 600 Ah
Lifetime throughput: 2,083 kWh

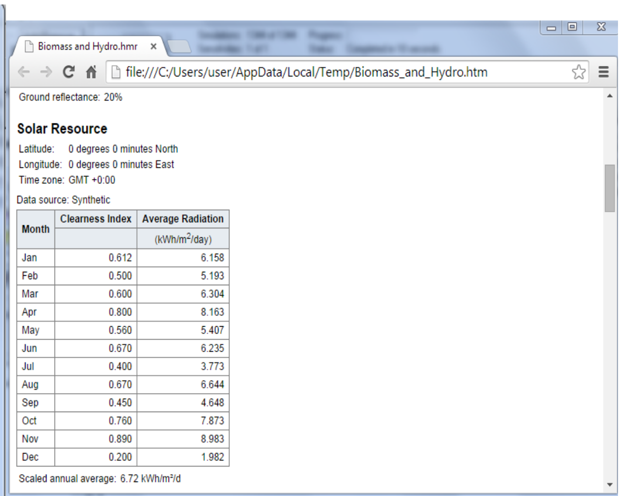
Converter

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
150.000	4,000	4,000	25

Sizes to consider:	0, 30, 50, 60, 80, 100, 200 kW
Lifetime:	15 yr
Inverter efficiency:	90%
Inverter can parallel with AC generator:	Yes
Rectifier relative capacity:	100%
Rectifier efficiency:	85%







Biomass Resource

Data source: Synthetic

Month	Available Biomass (tonnes/day)
Jan	0.45
Feb	0.34
Mar	0.56
Apr	0.55
May	0.43
Jun	0.38
Jul	0.62
Aug	0.34
Sep	0.64
Oct	0.28
Nov	0.50
Dec	0.43

Scaled annual average:	0.46 t/d
Average price:	$ 0/t
Carbon content:	5%
Gasification ratio:	0.7 kg gas/kg biomass
LHV of biogas:	5.5 MJ/kg