RESEARCH ARTICLE

Feasibility Analysis of a Stand-Alone Photovoltaic (PV)/Hydro Power System for Community Service Facilities

Ani Vincent Anayochukwu*[1], Ani Emmanuel Onyeka[2]

1. Department of Electronic Engineering, University of Nigeria, Nsukka (UNN), Nigeria
2. Department of Accountancy, University of Nigeria, Enugu Campus (UNEC), Nigeria
*-Corresponding Author; Ani Vincent Anayochukwu, Tel.: +2348054024629, vincent_ani@yahoo.com

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ABSTRACT There is the need for the provision of an alternative sustainable electric power supply system to provide electricity for Community Service Facilities (CSF) such as Information Communication Technology (ICT) for e-service to rural communities, rural banking, hospitals, and supply of potable water if the social and economic lives of rural citizens in Nigeria are to be improved. This paper presents the feasibility study of a stand-alone Photovoltaic (PV)/Hydro power system for CSF in Ogologo-Eji Ndiagu Akpugo in Nkanu-West L.G.A located in South-Eastern Nigeria on Latitude 6°35'N and Longitude 7°51'E with annual average solar daily radiation of 4.73kWh/m²/d. The river used for the study is Atavo stream also located in Ogologo-Eji Ndiagu Akpugo. In carrying out the flow measurement of the stream, the length, width, and depth of the stream were measured, while a floating object was used as the technique for the determination of the surface speed. The readings were taken over a period of 2 years (2010-2012) with an average stream discharge of 26.42 M^3/s. Load estimates of a typical rural ICT infrastructures, banking and hospital were estimated. The simulation results show that the renewable energy system (RES) is capable of supplying sufficient power, is reliable, economically viable and, most importantly, is environmentally friendly. The Optimization study indicates that energy requirements to provide electricity for community service facilities load demand of the 58 kWh/day with a 3.7 kW peak and a deferrable load of 6.6kWh/d with 1.1kW peak can be accomplished by a combination of the 3 kW solar PV array, 2.62 kW hydro turbine, 24 Surrette 6CS25P Battery, and a 4 kW AC/DC converter.

KEYWORDS Ogologo-Eji Ndiagu Akpugo, ICT, Power Generation, Renewable energy, PV/Hydro system, HOMER.

Introduction

One of the primary needs of socioeconomic development in any nation in the world is the provision of reliable electricity supply systems. Access to electricity is vital to community service facilities (CSF) in rural areas, such as information and communication technology (ICT) infrastructures, banks and hospitals. In rural health clinics, electric lighting provides public security and allows facilities to remain open in the evenings [Ani and Emetu, 2013]. Beyond lighting, electricity is used to power an array of appliances, such as vaccine refrigerators, and other specialized equipment; pump water; and run the ICT devices linking rural people to information, markets, and urban centers.

In many developing countries with large rural populations, rural electrification rates are low, and most community service facilities lack access to electricity. In Nigeria, about sixty-five percent (65%) of 140 million Nigeria populace is rural dwellers with majority of them live-in far-off grid areas [Adejumobi et al., 2007]. These rural dwellers whose socio-economic lives can only be improved when provisions are made to provide energy for their community service facilities such as ICT infrastructures, banking, hospitals, etc. ICT is one major key tool and means of fighting poverty and illiteracy in developing economics like Nigeria, through facilitating e-service programmes, especially to those institutions such as banks, hospitals and schools in rural and unreached communities. When this is achieved, the socio-economic lives of rural citizens will be improved. To provide ICT for Rural livelihoods, there is always the need to ascertain a steady power supply. Without the availability of a continual supply of electric energy, ICT provision to rural communities becomes almost impossible. Among the basic needs to actualize vision 2020 and Millennium Development Goals (MDGs) are the provisions of hospital and Banking facilities to rural environments [Adejumobi et al., 2011; Adejumobi, 2009]. One of the major needs to actualize functional and reliable rural banking and hospital is the availability of a continuous and reliable power supply system. Community service facilities without a connection to the national or local electricity grid must rely on alternative stand-alone power supply (SPS) systems (e.g., independent diesel generators, renewable energy systems, renewable mix energy system, hybrid energy systems), or do without.

Generators which are often used as power supply systems for community service facilities are known to be run only during certain hours of the day, and the cost of fueling them is increasingly becoming difficult if they are to be used always (24 h/d). There is a growing awareness that renewable energies such as photovoltaic and hydro system have an important role to play in order to save the situation. Renewable mix energy (PV/hydro) is believed to contribute significantly to the reduction of energy cost, if properly integrated into the community service facilities' energy sources. Renewable Energy Systems (RESs) have been described as among the popular cost-saving energy applications in rural electrifications. But till date these systems (RESs) have found little or no applications in Nigeria. This may be attributed to the lack of information on the necessary facility and system parameters required to design suitable RESs to meet given loads of community service facilities. Hence, the use of uninterrupted power source, solar/hydro energy system would be advantageous to facilitate good rural banking, hospitals and ICT. Studies reveal that a perception exists that RES is incapable of supplying sufficient power [Dalton et al., 2006; Lowe and Lloyd, 2001], is unreliable [Dalton et al., 2006; Lloyd, 2000] and, most importantly, is not economically viable [Dalton et al., 2006; Lloyd, 2000; Deda, 2000]. This paper address this research gap: Can RES, in principle, adequately and reliably supply power for community service facilities (ICT, Hospital, Banking, and water supply)? To address this research question, a RES feasibility analysis was conducted using community service facilities load data situated in Ogologo-Eji Ndiagu Akpugo, in Nkanu-West Local government area of Enugu State. Feasibility study (in terms of reliability and costs) of RESs (PV/Hydro power system) in powering Community service facilities will be the focus of this paper.

Energy Demand

Energy Estimate for ICT facilities, Bank and Hospital in Rural Areas

In order to provide continuous electrical energy to the above mentioned facilities, the need to embrace renewable (Solar/Hydro) Power supply is more emphasized here. Since some of these rural communities suffer conventional electricity supply systems, the supply of these communities with renewable energy system will be of great economic and technological values. Tables 1, 2, and 3 show typical estimated energy to power ICT, Banks and hospitals, respectively, in rural communities. The daily load profile of the community service facilities (ICT, Banking, and Hospital) is shown in Figure 1.

Table 1 Energy needed for a typical ICT Center in Rural/Remote environments

Description of Item	Qty	Load (Watts per unit)	Total Load (Watts)	Daily Hour of Actual Utilization (hours)	Daily Watts Hours
Router	1	25	25	24 (0:00h – 23:00h)	600
Port fast Switch	1	15	15	24 (0:00h – 23:00h)	360
Wireless Access Point	2	12	24	24 (0:00h – 23:00h)	576
Server (plus accessories)	1	150	150	24 (0:00h – 23:00h)	3600
RF (Radio Communication)	1	40	40	24 (0:00h – 23:00h)	960
Laptops (with security cables)	10	40	400	24 (0:00h – 23:00h)	9600
VOIP Phones	2	20	40	8 (10pm-6am)	320
HP Deskjet 5943	2	44	88	4 (9am-10am; 1pm-4pm)	352
Laser Printer	1	100	100	3(11am-12am; 5pm -6pm; 9pm-10pm)	300
Lighting	4	15	60	24 (0:00h – 23:00h)	1440
Ceiling fans	4	60	240	24 (0:00h – 23:00h)	5760

Table 2 Energy needed for a typical Banking in Rural/Remote environment

Description of Item	Qty	Load (Watts per unit)	Total Load (Watts)	Daily Hour of Actual Utilization (hours)	Daily Watts Hours
ATM Machine	2	1,000	2,000	12 (8am – 8pm)	24,000
Premises/Street Lightings	4	40	160	12 (6pm – 6am)	1920
Wireless Access Point	1	12	12	24 (0:00h – 23:00h)	288
Laptop (with security cable)	1	40	40	12 (8am – 8pm)	480
HP Deskjet (three-in-one)	1	44	44	12 (8am – 8pm)	528

Table 3 Energy needed for a typical Hospital Service in Rural/Remote environmen

Description of Item	Qty	Load (Watts per unit)	Total Load (Watts)	Daily Hour of Actual Utilization (hours)	Daily Watts Hours
Cold Chain Storage (fridge)	1	60	60	24 (0:00h – 23:00h)	1440
Lighting for the operating Theatre	3	15	45	24 (0:00h – 23:00h)	1080
Lighting for Ward	6	15	90	24 (0:00h – 23:00h)	2160
Premises Lighting/Street Light	2	40	80	12 (6pm – 6am)	960
Television Colour	1	80	80	6 (4pm – 10pm)	480
Fans	6	15	40	12 (10am – 10pm)	480

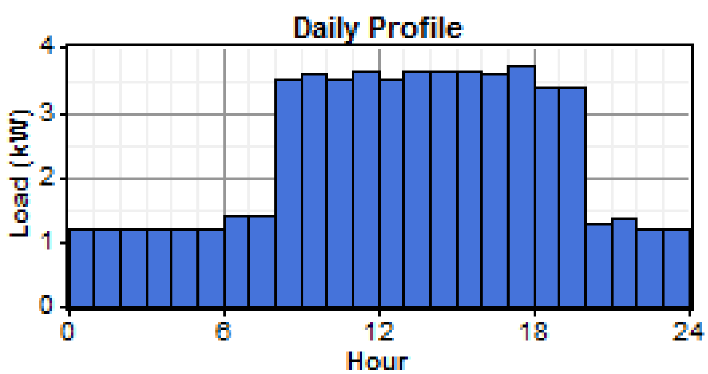

Figure 1 Daily load profile of the community service facilities (ICT, Banking, and Hospital)

Power demand for water pumping in Rural/Remote environment

The daily demand from the village water supply (pump rated 1.5HP) is to pump 50,000 L per day (50 m^3), and there is a 200 m^3 water tank. Fifty thousand liters are enough to supply 2,500 people with their daily water needs when using UNDP standards of 20 L per person per day [SELF, 2008]. Water Pumping machine (1.5 HP) Power demand = 1.5 0.746 = 1.119 kW [Adejumobi et al., 2011]. At full power, the pump draws 1119 W of electrical power and pumps 8.4 m^3 per hour.

The peak deferrable load is 1.1 kW, which is the rated power of the pump. It would take the pump 24 hours at full power to fill the tank, so the storage capacity is 24 hours times 1.1 kW, which is 26.4 kWh. Therefore, it would take the pump 6 hours at full power to meet the daily requirement of water (50 m^3), so the average deferrable load is 6 hours per day times 1.1 kW, which is 6.6 kWh/day. The monthly deferrable load of water pumping is shown in Figure 2. Water pumping is normally classified as a deferrable load because they have some storage associated with them - there is some flexibility as to when the pump actually operates, provided the water tank does not run dry. Deferrable load is electrical load that must be met within some time period, but the exact timing is not important.

Figure 2 The monthly deferrable load of water pumping

Methodology

The study is on the simulation analysis of PV/Hydro power generation system for off-grid community service facilities. A computer simulation software – Hybrid Optimization Model for Electric Renewables (HOMER) was used to evaluate the different situations to determine the possible sizing configuration that will provide acceptable reliability at the lowest lifecycle cost. The description of HOMER can be found in [Ani and Emetu, 2013].

Mathematical model

As detailed models of hydro and PV systems have already been published, only the final expressions for the electrical power output of these components are given. The following equations, used in this study, are based on the equations used by [Ani, 2013; HOMER, 2012; Kamaruzzaman et al., 2008; Lambert, 2009; Ashok, 2007], to derive the power supplied by renewable, battery charging and discharging.

The PV Power: Eq.(1)

$$P_{pv} = \eta_{pv} \cdot N_{pvp} \cdot N_{pvs} \cdot V_{pv} \cdot I_{pv}$$

The Hydro Power: Eq.(2)

$$P_h = \eta_h \cdot \rho_{water} \cdot g \cdot H_{net} \cdot Q$$

Total Renewable Power: Eq.(3)

$$P(t) = \sum_{pv=1}^{n_{pv}} P_{pv} + \sum_{h=1}^{n_h} P_h$$

Battery Discharging: Eq.(4)

$$P_b(t) = P_b(t-1) \cdot (1-\sigma) - \left[\frac{P_{bt}(t)}{P_{bl}(t)} \right]$$

Battery Charging: Eq.(5)

$$P_b(t) = P_b(t-1) \cdot (1-\sigma) + \left[P_{bt}(t) - P_{bl}(t) \right] \cdot \eta_{bb}$$

Where,

V_{pv}	: Operating voltage of PV panels
N_{pvs}	: Numbers of PV panels in series
η_g	: Efficiency of the gravitational acceleration
ρ_a	: Density of air
P_{pv}	: PV power output
η_{pv}	: Conversion efficiency of PV
N_{pvp}	: Number of PV panels in parallel
N_{pvs}	: Number of PV panels in series
I_{pv}	: Operating current of PV panels
P_b	: Battery energy at time interval
P_{bt}	: Total energy generated
σ	: Self discharge factor
P_{bl}	: Load demand at time interval
η_{bb}	: Battery charging efficiency
P_h	: Hydro turbine power output
η_h	: Efficiency of hydro turbine

ρ_{water} : Density of water

g : Gravitational acceleration

H_{net} : Effective head

Q : Flowrate

The dispatch strategy is such that the battery charges, if the renewable energy is in excess after meeting the demand and discharges, if load exceeds the renewable energy.

Study area

The study area of Ogologo-Eji Ndiagu Akpugo has been chosen as a sample case. Ogologo-Eji Ndiagu Akpugo is in Nkanu-West L.G.A of Enugu State in South-Eastern Nigeria on Latitude 6°35'N and Longitude 7°51'E with annual average solar daily radiation of 4.73 kWh/m²/d. The data for solar resource shown in Table 4 were obtained from the National Aeronautics and Space Administration (NASA) Surface Meteorology and Solar Energy web site [NASA, 2012]. While the river used for the study is Atavo stream also located in Ogologo-Eji Ndiagu Akpugo in Nkanu-West Local Government Area of Enugu State. In carrying out the flow measurement of the stream, the length, width, and depth of the stream were measured, while a floating object was used as the technique for the determination of the surface speed. The time taken for the float to move from one point to another was taken. These readings were taken over a period of 2 years (2010-2012). The readings for the year 2012 and the result analysis obtained from the Atavo stream are shown in Table 5.

In solar resource, February was the sunniest month of the year. During this month (February), the solar energy resource is 5.4 kWh/m^2/day while in July it is only 3.6 kWh/m^2/day. In the months of February, March, April, May, June, and December, the solar radiation increases with differences from month to month as (0.09), (0.29), (0.48), (0.29), (0.63), and (0.01), respectively; while in the months of July, August, September, October, November, and January, the solar radiation decreases with differences from month to month as (0.70), (0.02), (0.32), (0.46), (0.13), and (0.15), respectively. The difference in months fall in the range of 0.1-0.7, as shown in Table 4.

In hydro resource, April is the least flow rate month of the year, while October, November, and December are the highest flow rate. The expected maximum stream discharge is about 26.42 m^3/so. In the months of March, August, and December, the flow rate increases with differences from month to month as (0.28), (0.13), and (0.66), respectively; while in the months of April, May, June, July, September, and January, the flow rate decreases with differences from month to month as (0.14), (0.08), (0.06), (0.13), (0.41), and (0.25), respectively; in the remaining months (February, October, and November), there is no change in the flow rate from month to month as shown in Table 5. The difference in months fall in the range of 0.1-0.4 except in the month of December which is 0.7.

The differences show that solar radiation has higher variation than the stream flow, where there are months of no change in the flow rate.

Table 4 Solar Resource for Ogologo-Eji Ndiagu Akpugo (Enugu State) and month to month solar variation.

Month	Clearness Index	Average Daily Solar Radiation ($kWh/m^2/day$)	Month to month variation
Jan	0.560	5.221	-0.147
Feb	0.543	5.368	0.088
Mar	0.510	5.280	0.289
Apr	0.478	4.991	0.478
May	0.443	4.513	0.289
Jun	0.424	4.224	0.627
Jul	0.358	3.597	-0.702
Aug	0.418	4.299	-0.022
Sep	0.418	4.321	-0.321
Oct	0.466	4.642	-0.458
Nov	0.542	5.100	-0.134
Dec	0.576	5.234	0.013
Scaled annual average		4.728	

The measurement of the length, width, depth and the constant factor of the stream

Length of the stream – 29 m
The width of the stream – 29m
Depth of the stream – 9.5m
Constant factor of the stream – 0.64

The equations for the generation of the results analysis shown in Table 5 are as follows:

$$\text{Sectional Area (A)} = \text{Depth} \times \text{Width} \quad \text{Eq.(6)}$$

$$\text{Surface speed (Ss)} = \frac{\text{Length}}{\text{Time}} \quad \text{Eq.(7)}$$

$$\text{Average speed (Sa)} = \text{Surface speed} \times \text{Constant factor} \quad \text{Eq.(8)}$$

$$\text{Stream Discharge (Q)} = \text{Average speed} \times \text{Sectional Area} \quad \text{Eq.(9)}$$

Table 5 The readings and the result analysis obtained from the Atavo stream and month to month stream discharge variation.

Month	Time taken for the float to move from point A to B (Sec)	Surface speed (m/s)	Average speed (m/s)	Stream Discharge (Q) M^3/s	Month to month variation
January	195.8	0.1481	0.0948	26.12	-0.25
February	194	0.1495	0.0957	26.37	0.00
March	194	0.1495	0.0957	26.37	0.28
April	196	0.1480	0.0947	26.09	-0.14
May	195	0.1487	0.0952	26.23	-0.08
June	194.4	0.1492	0.0955	26.31	-0.06
July	194	0.1495	0.0957	26.37	-0.13
August	193	0.1503	0.0962	26.50	0.13
September	194	0.1495	0.0957	26.37	-0.41
October	191	0.1518	0.0972	26.78	0.00
November	191	0.1518	0.0972	26.78	0.00
December	191	0.1518	0.0972	26.78	0.66
Scaled annual average				26.42	

Configuration and Simulation of the energy system

The energy system proposed for the community service facilities consists of solar PV and hydro power as depicted in Figure 3. These facility's energy consumption is a 58 kWh/day with a 3.7 kW peak demand load, and deferrable load of 6.6 kWh/d with 1.1 kW peak; and the energy system consists of 3 kW solar PV array, 2.62 kW hydro turbine, 24 Surrette 6CS25P Battery, and a 4 kW AC/DC converter.

The diesel only energy system consists of 4.5 kW diesel generator, 24 Surrette 6CS25P Battery Cycle Charging, and a 4 kW AC/DC converter as shown in Figure 4. The lifetime of the project is estimated at 20 years with a fixed annual interest rate of 6%. Details of the energy system components for the simulation are shown in Table 6. The selection of components of the energy system is done using Hybrid Optimization Model for Electric Renewable (HOMER). HOMER is general purpose hybrid system design software. It was developed to address the need for a system design tool accurate enough to reliably predict system performance.

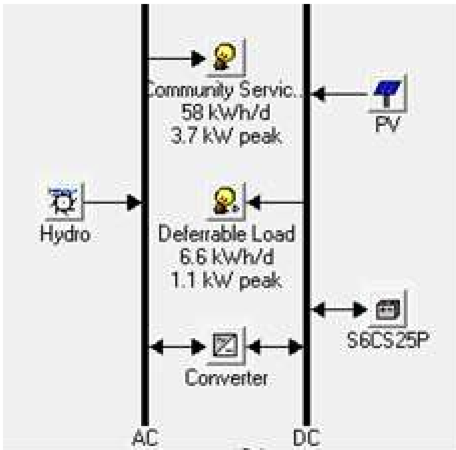

Figure 3 Proposed stand-alone Hydro-solar PV system

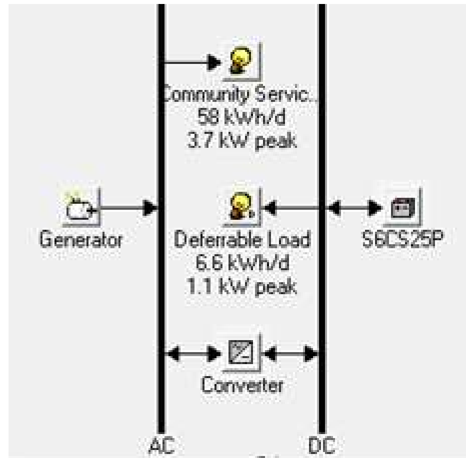

Figure 4 Stand-alone single system (diesel only)

Table 6 Details of the energy system components

component	Description	Data
PV	Size	3kW
	Lifetime	20yrs
	Tracking system	No tracking
Hydro Turbine	Nominal power	2.62kW
	Available head	13.5m
	Design flow rate	26.4L/s
	Minimum flow ratio	25%
	Maximum flow ratio	100%
	Efficiency	75%
Storage battery	Battery type	Surrette 6CS25P
	Nominal voltage (1 battery per string)	6V
	Nominal capacity	1156Ah (6.94kWh)
	Round Trip Efficiency	80%
	Minimum State of Charge	40%
	Lifetime Throughput	9,645kWh
Converter	Size	4kW
	Lifetime	15yrs
	Efficiency	85%
Diesel generator	Number	1
	Size	4.5kW

Results

Economically viable

The Net Present Cost (NPC) of PV is $27,000, hydro is $58,602, Surrette 6CS25P is $70,367 and the converter is $1,048 making a total NPC of the PV/Hydro Power configuration system $157,017 as shown in Figure 5 and in the appendix (Figure A1 and Table A2). The NPC of the diesel generator is $5,160,048, Surrette 6CS25P is $70,367, and converter is $1,048 making a total NPC of diesel only power configuration system $5,231,463 as shown in Figure 6 and in the appendix (Figure A2 and Table A3). Comparing the PV/Hydro system with diesel only, a difference of $5,074,446 which is the savings coming from the use of PV/Hydro in powering the community service facilities. This shows that the PV/Hydro system is economically viable.

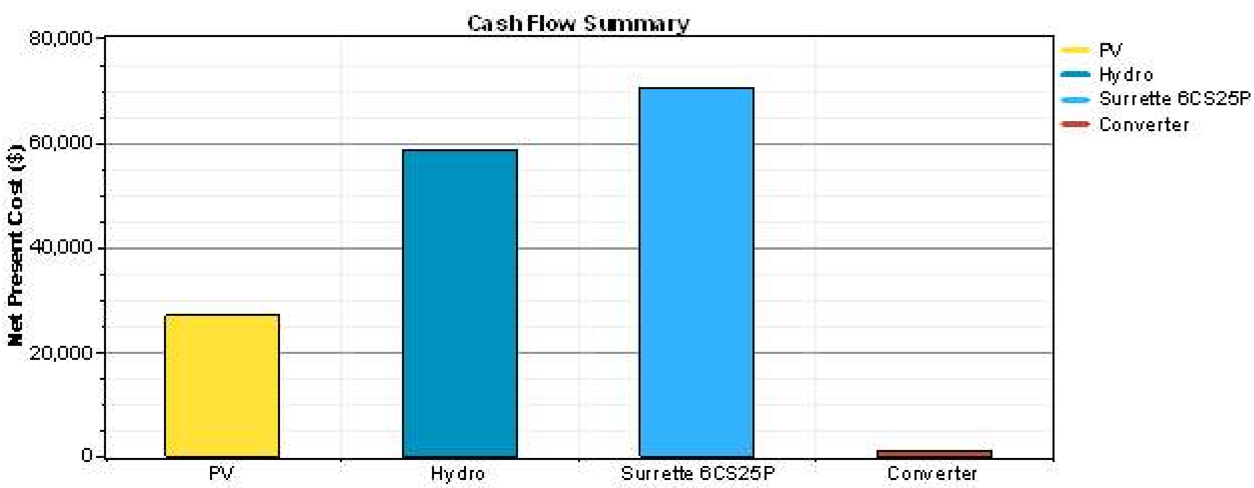

Figure 5 The NPC of PV/Hydro Power configuration system

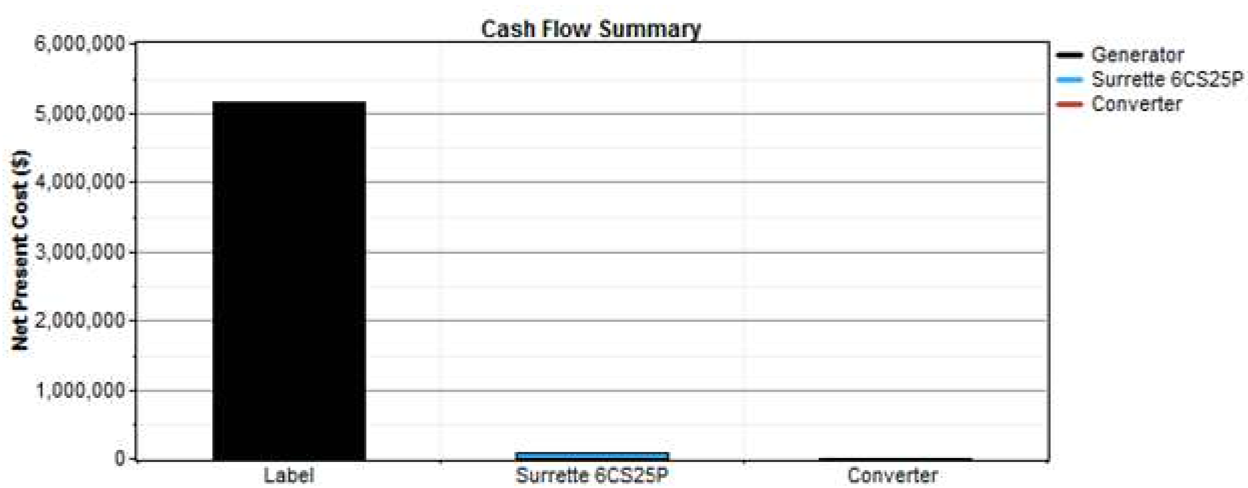

Figure 6 The NPC of diesel Power configuration system

Reliability

The PV/Hydro system generates 26,560 kWh/yr and has a total loss of 1,733 of the battery and the converter, has an excess energy of 1,359 and supplied a total energy of 23,468 to the load as shown in Table 7. This shows that the PV/Hydro system is capable of supplying sufficient power and is also reliable. Moreover, the results show that in the months of June and July on a cloudy, rainy day when the solar photovoltaic cells are producing lower levels of energy, the hydro is supplying a considerable amount of power to the loads as shown in Figure 7. An important feature of the PV/hydro power system for Community Service Facilities power supply is the compensatory performances of the composite renewable components. In the month of August when the solar radiation decreases (0.02), the flow rate increases (0.13). Then again, in the months of April, May, and June when the flow rate decreases as (0.14), (0.08), and (0.06), the solar radiation increases as (0.48), (0.29), and (0.63) as can be seen from Tables 4 and 5.

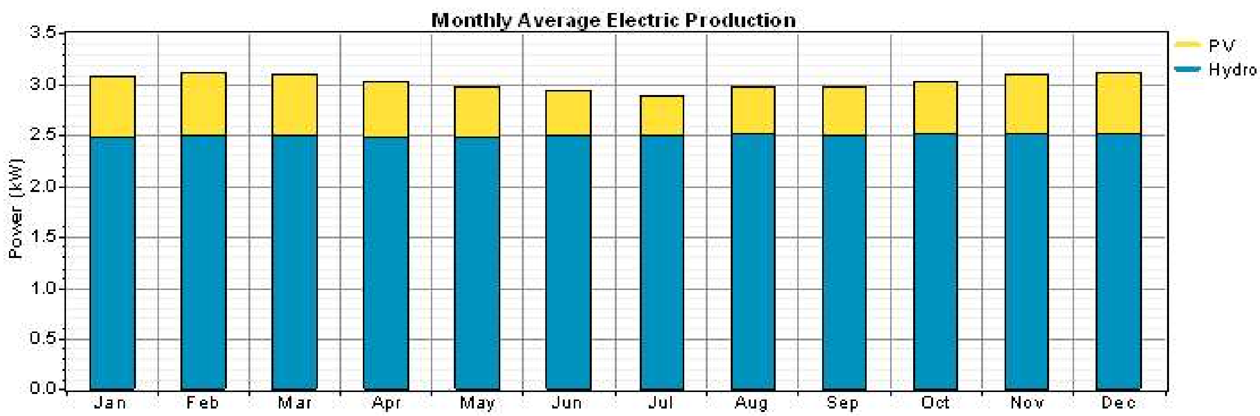

Figure 7 Contribution of electrical energy produced by various energy sources

Table 7 Comparison of simulation results of the electricity production (kWh/yr), Battery and converter losses, and excess energy of the energy system configuration (PV/Hydro and diesel only)

System Operation	PV/hydro		Diesel only	
Consumption	kWh/yr	%	kWh/yr	%
AC primary load	21,059	90	21,059	90
Deferrable load	2,409	10	2,409	10
The total load to be supplied	23,468	100	23,468	100
Production	kWh/yr	%	kWh/yr	%
PV array	4,705	18		
Hydro turbine	21,855	82		
Generator			28,256	100
Total energy generated	26,560	100	28,256	100
Losses	kWh/yr		kWh/yr	
Battery	529		1,848	
Inverter	514		774	
Rectifier	690		2,125	
Total losses	1,733		4,747	
Excess energy	1359		41	
Energy Supplied	kWh/yr	%	kWh/yr	%
Total energy supplied to the load	23,468	100	23,468	100

The excess electricity occurs in the months of January, February, March, April, October, November, December and few days in May, June, August and September, but occur most in November (as can be clearly seen in Figure 8), when the energy generated by the solar energy system and the hydro system are at the highest (Tables 1 and 2). This excess electricity of about 1359 kWh/yr power supply is guaranteed in the location simulated in order to give room for future facility expansion.

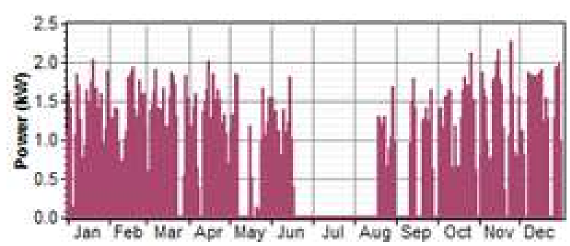

Figure 8 Excess electricity generated by the PV/Hydro energy system.

Environmentally friendly

The diesel generator operates for 6,279 h/yr and consumes 9,324 liters of fuel per annum thereby generates the pollutant emissions as shown in Table 8. Whereas the PV/Hydro system does not generate any pollutant emission as shown also in Table 8. This shows that the PV/Hydro system is environmentally friendly.

Table 8 Comparison of simulation results of emissions

Pollutant	Emissions (tons/yr)	
	PV/Hydro	Diesel only
Carbon dioxide	0.000	24.554
Carbon monoxide	0.000	0.061
Unburned hydrocarbons	0.000	0.007
Particulate matter	0.000	0.005
Sulfur dioxide	0.000	0.049
Nitrogen oxides	0.000	0.541

Conclusion

The provision of solar/hydro energy system to power ICT infrastructures, banks and hospitals in rural and the unreached communities that are not connected to National Grid Power supply system is very important so as to maintain a continuous electricity supply. As shown in the study, the stream flow is high in the rainy season, particularly in the months of June, July and August, and thus compensates for the shortfall in solar radiation in this season (rainy season), when the sunshine is quite low. It was shown that the obtained optimal configuration of the PV/Hydro-Battery system could overcome the effect of the climate change on the reliable supply of the load. The simulation results prove that RES is capable of supplying sufficient power, is reliable, economically viable and, most importantly, is environmentally friendly. Moreover, the system is very promising for a long term policy. Therefore, the deployment of solar/hydro system for off- grid communities will go a long way to improve socio-economy lives of people.

A more study should be carried out, especially in the context of minimizing losses.

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Appendix

Table A1 Economic data (Initial System Costs, Replacement Costs and Operating & Maintenance Costs) of all the components of the hybrid system used in the Simulation [Renewable energy shop in Nigeria, 2013]

Item	Initial System Costs	Replacement Costs	Operating & Maintenance Costs
PV modules	$9,000/kW	$8,500/kW	$0/yr
Hydro turbine	$50,000	$45,000	$750/yr
2kW Diesel Generator	$950/kW	$750/kW	$0.1/hr
Surrete 6CS25P battery	$1,145	$1,000	$200/yr
Converter	$220/kW	$200/kW	$0/yr

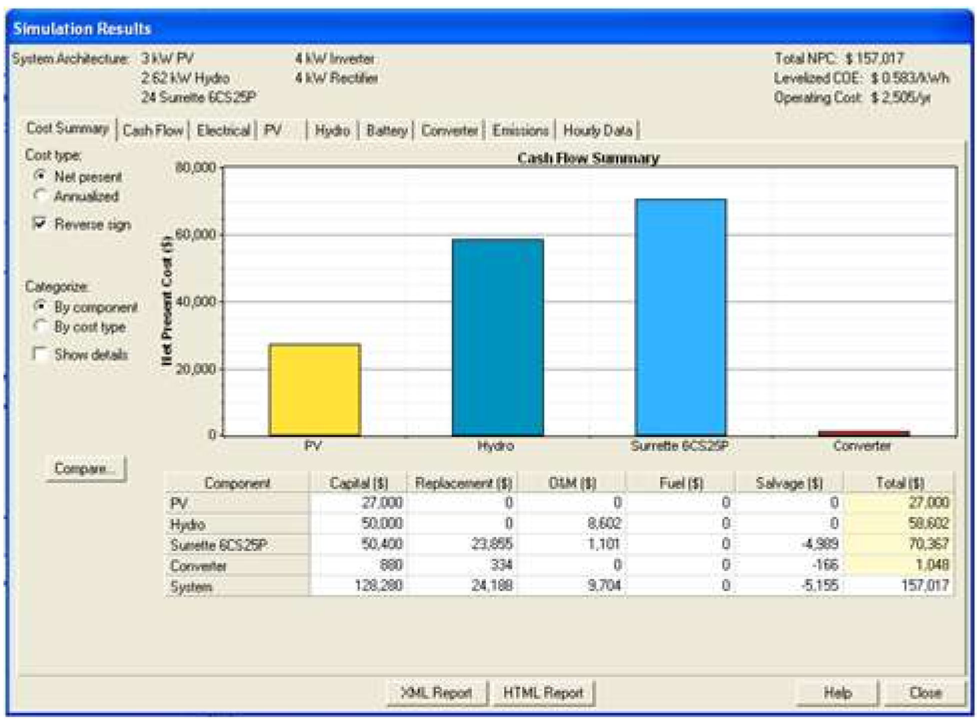

Figure A1 Cost sheet of the PV/Hydro power system

Table A2 Simulation results of Economic cost of PV/Hydro Power configuration system

Component	Capital ($)	Replacement ($)	O&M ($)	fuel ($)	*Salvage ($)	Total NPC ($)
PV	27,000	0	0	0	0	27,000
Hydro	50,000	0	8,602	0	0	58,602
Surrette 6CS25P	50,400	23,855	1,101	0	-4,989	70,367
Converter	880	334	0	0	-166	1,048
System	128,280	24,188	9,704	0	-5,155	157,017

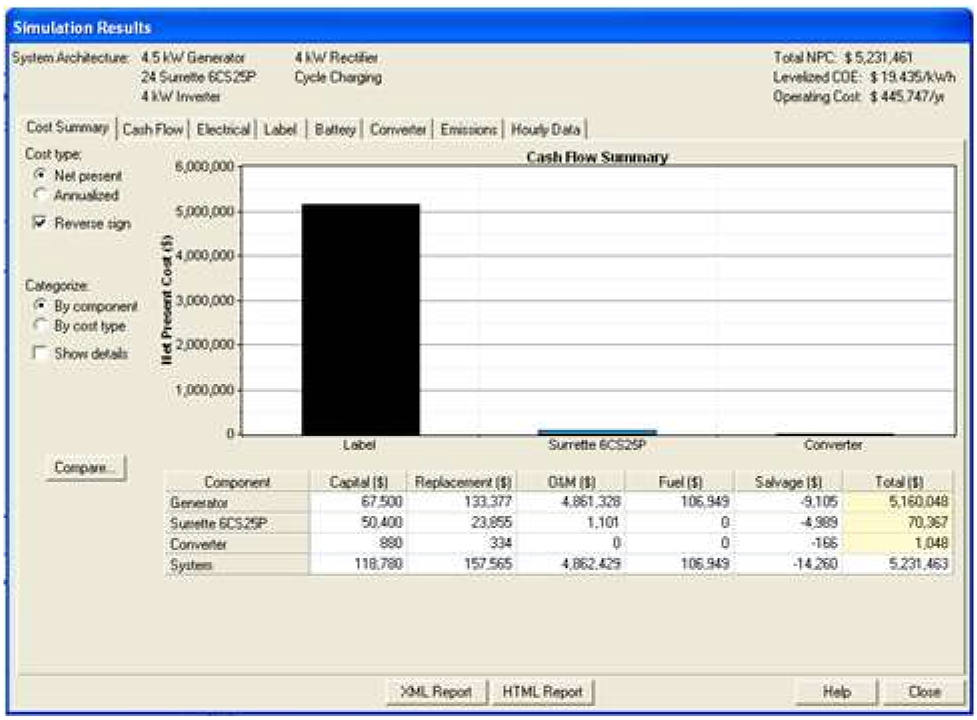

Figure A2 Cost sheet of the diesel power system

Table A3 Simulation results of Economic cost of Diesel Power configuration system

Component	Capital ($)	Replacement ($)	O&M ($)	fuel ($)	*Salvage ($)	Total NPC ($)
Diesel	67,500	133,377	4,861,328	106,949	-9,105	5,160,048
Surrette 6CS25P	50,400	23,855	1,101	0	-4,989	70,367
Converter	880	334	0	0	-166	1,048
System	118,780	157,565	4,862,429	106,949	-14,260	5,231,463