Sustainability of Renewable Sources of Energy for Rural Communities in Anambra State

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Abstract This study assessed the sustainability of different alternative renewable sources of energy for rural communities in Anambra State. Through literature review a number of sustainability criteria were established and used in assessing the identified alternative sources of renewable energy in the state. A systematic SWOT analysis was further performed to synthesise the characteristics of individual renewable energy resource. 42 experts were engaged and given a structured questionnaire where they were expected to score each of the renewable energy sources on a 5-point scale based on the selected sustainability criteria. A scale of 1-5 was used to examine and rate the sustainability of each of the identified renewable energy options based on environmental social and economic criteria. Based on their individual scores, the total average score for each of the energy sources was computed and used in rating their level sustainability. The study found that among the six alternative renewable energy options considered, biomass was ranked the most sustainable renewable energy source for electricity provision in rural communities in the state with a sustainability score of 35.0. Solar and hydro energy resources were ranked 2nd and 3rd with scores of 31.2 and 31.0 respectively, while geothermal (24.5) energy was ranked the least. This implies that harnessing and investing in biomass, solar and hydro energy technologies in Anambra State could lead to sustainable energy provision in the rural Communities in Anambra State. The study further avers that genuine commitment through government investments in biomass, solar and hydro energy technologies with strong policy framework could minimise the electricity challenges of the rural communities in the state, and at the same time reduce pressure on urban infrastructure due to rural-urban migration.

Keywords Alternative Energy, Renewable Energy, Rural Communities, Sustainability, SWOT Analysis

1. Introduction

Lack of electricity in most rural communities in Nigeria has put severe pressure on the urban infrastructure due to rural-urban migration. Although the goal of Federal Government of Nigeria is to increase access to electricity to 75% and 90% by 2020 and 2030 respectively and at least 10% of renewable energy mix by 2025 as contained in the National Electric Power Policy (NEPP) of 2001 and the Rural Electrification Policy of 2005 respectively [1], the reality shows that this goal may not be achieved. The vast availability of natural resources in Nigeria notwithstanding, the country is still facing acute electricity problems. The problem is so pronounced in Anambra State that it is hindering any meaningful socio-economic development in the state. Efforts to expand the economic landscape of the state through rural development have been severely hindered by the absence and/or epileptic electricity provision in the area.

The privatisation of power sector and decentralisation of the Power Holding Company of Nigeria (PHCN) for anticipated improvement in electricity provision has not yielded the desired results. Generally, the nation's electricity generation and transmission capacities are saddled with too many challenges. For example, in 2005, the Nigeria's power generation installed capacity was approximately 6500 MW, but 3959 MW was the only capacity available [2]. IseOlorunkanmi [3] reported that since privatisation of PHCN in 2013, Nigeria's electricity generation capacity has declined from the peak generation level of about 4,517.6 mega- watts (MW) recorded in December, 2012 to about 3,670 MW in January, 2014. The Nigeria Power Baseline Report [4] indicated that Nigeria has 12,522MW of installed capacity, but due to maintenance, gas, water and transmission constraints, an average of only 3,879MW of capacity is operational from January to 15 August, 2015.

However, the Power Generation Statistics for First Quarter, 2017 reflected that a total average of 3,687 MW of

energy was generated by power stations in the first quarter of 2017 [5]; despite currently having 23 grid-connected generating plants in operation in the Nigerian Electricity Supply Industry (NESI) with a total installed capacity of 10,396.0 MW and available capacity of 6,056 MW [6]. This shows that the situation has not improve rather has degenerated. This further suggests that the fossil fuel system application for the provision of electricity in Nigeria has completely failed, thus creating an unfavourable environment for both multi-national and local investors [7].

To this end, it is obvious that the electricity demand in Nigeria far outstrips the supply and the supply is epileptic in nature. According to the draft report on the Nigerian Power Sector Investment Opportunities and Guidelines, the Nigeria power system is characterised by huge gap between supply and demand; current power demand is estimated at 17,520MW including latent and suppressed demand, against 5,300MW peak generation [8]. The Nigeria Power Baseline Report [4] of the Advisory Power Team on the other hands revealed that about 95 million Nigerians (55% of the population) have no access to electricity and those who are connected to the grid face extensive power interruptions. The report further indicates that systemic issues affect all phases of the power value chain (generation, gas supply, transmission and distribution) forcing Nigerians to rely on self-generation [4]. Besides, majority (85%) of installed capacity is fuelled by gas, and availability of gas molecules is low due to insufficient production, economic disincentives, inadequate infrastructure and frequent vandalism [4]. Furthermore, notwithstanding the availability of abundant conventional and renewable energy resources [9], the country still grapples with the problem of electricity. The current privatisation of electricity has further compounded the problem of electricity provision in the country especially in the rural communities. The power problems have subdued the local economy and prevented the development of cottage industries and businesses [10]. This has therefore jeopardised the sustenance of small scale businesses of the rural dwellers. Although electricity access is not directly related to socio-economic growth, it is an impetus for development. It should be further noted that the declining electricity access in the rural areas needs attention, otherwise the negative effects will continue to affect the inhabitants including: increasing poverty level, endemic unemployment, and health deterioration. In addition, although self-electricity generation is generally common in the country, and is projected to be between 4,000-8,000 MW [11]; the economic capacity of the rural dwellers may not be able to carry them. The rural areas, which are generally inaccessible due to absence of good road networks, have little access to conventional energy such as electricity and petroleum products. The daily needs of the rural populace for heat energy are, therefore, met almost entirely from fuelwood. The current economic

situation of the country has aggravated the situation despite the so called introduction of social services scheme by the Federal Government.

Besides, majority of the rural dwellers in Nigeria are low energy consumers and living below poverty line of US\$ 1.25/day with electricity requirements below 1MW and around 10% electricity accessibility. Those who fit this description constitute over 60% of total population of the country [7]. Even though authorities have sought alternative and sustainable energy sources for rural areas in order to minimise rural-urban migration, and encourage the development of cottage industries, by minimising current security and unemployment problems in the country [7], both government and Independent Power Providers are finding it difficult to provide sustainable electricity to these communities. The strategy to promote a full menu of rural electrification options—grid and off-grid (mini-grid & stand-alone) from thermal & renewable, etc.; and encourage States, local communities and businesses to develop and contribute financially to rural electrification [1], seems unrealistic considering the country's centralised energy system (dependent on fossil fuel sources) which will require gridline extensions to provide this electricity. On this premise therefore, this study seeks to appraise the sustainability of various renewable sources of energy as alternative for conventional fossil fuel so as to ensure continuous provision of electricity in the rural communities in Anambra State, since the federal government strategy is illusive. This would be based on the environmental, social and economic consequences of each energy source.

2. Literature Review

Renewable energy and technologies have great potential to provide solutions to the long-standing energy problems being faced in Nigeria. Different studies [12-15] have affirmed the potentials of different renewable energy technologies in solving the Nigerian electricity problems. For instance, Simonyan and Fasina[14] revealed that energy from biomass can potentially be an alternative approach to solving the country's electricity problem. In promoting the diffusion of renewable energy into the country's energy supply mix for sustainable development, the government approved in November, 2005, the Renewable Energy Master plan (REMP). The REMP was prepared by the Energy Commission of Nigeria (ECN) in collaboration with the United Nations Development Programme (UNDP) [9].

In this present predicament as a nation, it is obvious that depending mainly on fossil fuel (petroleum and natural gas) is not enough to meet the energy needs of the country. Since Nigeria is blessed with abundant renewable energy resources such as hydroelectric, solar, wind, tidal, and biomass, there is a need to harness these resources and chart a new energy future for Nigeria. The draft report on

the Nigerian power sector investment opportunities and guidelines showed that currently, Nigeria's main energy carrier is biomass (81.25%), followed by natural gas (8.2%), petroleum products (5.3%), crude oil (4.8%), hydropower (0.4%), and others (< 1%) [8]. In the case of Anambra State that is struggling towards economic sufficiency, providing electricity to the rural communities in the state through the conventional means may no longer be sustainable. In this regard, the government has a responsibility to make renewable energy technologies available and affordable to all because different studies have shown that the country generally is endowed with a lot of renewable energy resources which include; solar energy, wind energy, hydropower, biomass geothermal energy and ocean energy. Even Nwulu and Agboola [16] have noted that there is a paradigm shift in the way energy resources are utilised in today's world. They argued that the shift to renewable source is not only environmental friendly but it is almost available in every country and sustainable. Akinbami [17] observed that most developed nations are increasingly doing away with traditional energy sources and embracing renewable energy to satisfy their energy needs. Akinbami [17] regretted that though Nigeria has abundant renewable energy technologies sources; only two sources are currently being used: hydropower and traditional biomass.

For example, the World Wind Energy Association (WWEA) [18] even recognised that wind energy technology has experienced significant global growth in the last decade, with its installed capacity doubling every three years; unfortunately, the reverse is the case in Nigeria. Accordingly, the country is categorised under a poor-moderate wind regime, and so, wind energy cannot be applied on a bigger scale except for irrigation and village electrification which is even to the advantage of the rural community. Ajayi [19] found that wind energy resources are very poor in the southwest and south-south onshore regions of the country, but offshore areas of the same zones bound by the Atlantic Ocean have excellent wind energy resources. However, a lot of authors have recommended its application for specific locations [20-23]. According to Sopian, Ali and Asim [24], 2.2MW of electricity has been generated by wind energy in Nigeria, but reality suggests that it has been abandoned due to the lack of maintenance and technical knowhow. Other obstacles facing sustainable wind energy utilisation in Nigeria include the lack of a corresponding market, general apathy towards the development of wind technology, and poor budgetary allocation [25,26].

In another development, Onyebuchi [27] estimated the technical potential of solar energy in Nigeria with a 5% device conversion efficiency put at 15.0×10^{14} kJ of useful energy annually. According to Adeoti, Oyewole and Adegboyega [28], it is possible to use solar energy to generate enough electricity to meet the needs of people throughout the year in all locations throughout the country.

Unfortunately, solar energy systems are currently used in Nigeria for small- and medium-sized power applications including street lighting, domestic/office powering, water pumping, rural electrification, rural health centres (e.g., refrigeration of vaccines), powering of telecommunication booster stations and ATM machines. Accordingly, these limitations are partly due to lack of reliable policy framework, costs of components, use of sub-standard components, poor maintenance culture, lack of statistical data; and capacity utilisation [25,29,30].

In terms of hydropower, Nigeria has hydropower potential of approximately 14,735 MW, with waterways in excess of 3,000 KM. However, only 1,960 MW have so far been exploited, representing 14% of the total capacity (i.e., 1930 MW (Large hydro) and 30 MW (Small hydropower)) [9,31]. However, hydropower systems rely on the potential energy difference between the levels of water in reservoirs, dams or lakes and their discharge tail water levels down streams. This has seriously affected the efficiency of hydropower energy in Nigeria.

Meanwhile, the Nigeria's biomass resources include agricultural residues, forest biomass, municipal solid waste (MSW) and animal dung. The country's vegetation arrangement dictates the availability of these resources [17,31]. However, Martinot [32] revealed that biomass is the fourth largest energy source after oil, coal and natural gas. Martinot [32] reported that by the end of 2014 bio-power global capacity was around 93 Giga watts (GW) and 75% of electricity generated from biomass was from solid biomass fuel, biogas (17%), MSW (7%) and biofuel (1%). He further claimed that by the end of 2014, all the existing bio-power systems together produced around 1.8% of global electricity. However, biomass-effective supply chains and overall affordability will ultimately decide its viability for electrical generation. This is mainly because biomass resources have to be procured. In addition, residues, particularly forest biomass, have low density and low value, where transportation costs are high/energy units [33].

In Nigeria, available records show that bio-power technology has not been fully harnessed. The 2007 bioethanol policy birthed the 10% ethanol inclusion into petroleum products in the country. Present estimates show that around 61 million tonnes/year of animal waste can be achieved and that about 83 million tonnes/year of crop residue can be obtained. Although the government can extend the use of bioethanol into power generation which will produce significant effect since the feed stocks for bioethanol are renewable, the record of biomass contribution to power generation in Nigeria is not available.

Similarly, the existence of two locations of geothermal energy in Nigeria: Ikogosi warm spring and Wikki warm spring in Ondo state and Bauchi state, respectively; and the tendencies of high geothermal gradient in some other parts of the country like; the Lagos sub-basin, Auchu-Agbede,

Okitipupa ridge and also the Abakaliki anticlinorium [9]; notwithstanding, has not made any impact in harnessing the potential of geothermal technology for electricity generation in Nigeria. More so, despite having a lot of water bodies including the Atlantic Ocean, the country has not actual tapped the potential of this renewable energy technology in solving the her power crisis. ECN [9] argued that Nigeria seems not to have significant tidal energy resources; despite boasting estimated 150,000 TJ/annum of wave and tidal energy resources [7]. However, Sambo [34,35] identified lack of capacity and standard quality control, financial and fiscal incentives, lack of awareness, deregulated and liberalised energy industry, and high initial investment cost as limiting factors to utilisation this energy potential.

Thus to meet the developmental agenda of the Anambra State Government, it is pertinent to assess the potentials of these alternative sources of energy available for provision of electricity in the rural communities so as to determine the most sustainable option in which the government can invest in with the hope of solving many electricity problems of the rural communities in the state.

3. Methodology

A systematic review method has been used to examine various renewable energy technologies regarding their viability and applicability in the state. The sustainability of various renewable energy technologies is then evaluated using SWOT analysis to screen the technologies to be used in an energy supply mix in the rural areas and assess the potential of various renewable energy technologies (see Table 1).

From the literature review, important sustainability criteria were identified and incorporated in the questionnaire content. Sustainability characteristics of each of renewable energy source were also identified and synthesised from the literature. Based on the data obtained from the systematic review, a survey was conducted, where about 42 experts knowledgeable in alternative energy and sustainability were identified, selected and asked to express their judgement on the sustainability of the alternative sources of energy for rural communities on a 5-point weighting scale; and based on certain sustainability criteria. A questionnaire was designed and structured to capture the intention of the survey including the respondents' demographic information. Sustainability criteria included sustainable development objectives and resource criteria. This is because renewable energy technologies may not be sustainable if resources (e.g., water, materials, land) are constrained [36].

The experts' scores are strictly based on their personal opinions and on the available sustainability criteria. However, the scoring was on point-by-point bases. The average score is computed and used in ranking the

individual renewable energy technologies in relation to each sustainability criterion used, with 5 and 1 being the highest and lowest marks, respectively. For example, where the renewable energy technology resource is continuously and readily available, it scores 5, while continuous and but not readily available is 4, where it is moderately continuously available is 3, while partially intermittently available is 2 and intermittently available is 1.

Since the questionnaire was distributed personally and directly to the respondents all the questionnaires were retrieved and used for analysis. While the individual characteristic of each of the renewable energy source is presented, the average score for individual characteristic of each of the renewable energy source is enclosed in parenthesis as shown in table 2. The total average score of each renewable energy source was achieved by adding up these individual average scores (shown in parenthesis). Finally, the total average scores were then used in ranking the renewable energy sources to ascertain the most sustainable renewable energy source for rural communities in Anambra State.

4. Results

Table 1 shows the result of systematic review using SWOT analysis for various renewable energy sources based on sustainability criteria. The SWOT analysis compares each of the renewable energy source against the other and the conventional fossil energy source. The SWOT analysis took note of certain criteria which include the availability, affordability, contribution to GHG, energy efficiency, dependability, available skill, impact on environment, etc. For example, apart from hydropower energy, other sources of renewable energy are generally available. Likewise, while other sources reduce GHG when compared with fossil fuel sources, geothermal energy generates the highest amount of GHG among the RETs. Apart from the solar energy, every other source of RETs has one effect or the other on the climate change.

In overall, it shows that all the renewable energy technologies available for rural communities in the state meet and fail one sustainability criterion or the other. But far outweigh in terms of sustainability, the conventional fossil fuel source in use in Nigeria. However, the result suggests that the renewable energy technologies have potentials for providing sustainable electricity for the rural communities in Anambra State. Table 1 further reveals that in one way or the other, all the renewable energy technologies show some strength as well as weaknesses in different areas of judgement, but very importantly, capitalising on the strength of each option while harnessing the opportunities is the sure way of maximising the utilisation of the renewable energy technologies. At the same time, taking note of the weaknesses and threats and

providing solutions to the challenges also key for renewable energy technologies utilisation in the state.

However, the outcome of the analysis is the basis for expert assessment of each of the renewable energy source which is presented in table 2. For example, on the point-by-point assessment, the result of the SWOT analysis in table 1 shows that wind energy emits the least GHG while geothermal energy emits the highest amount of GHG. Solar energy is the most expensive, while hydro has the

highest energy efficiency. In terms of social effect, wind energy has the least effect and at the same time consumes least water. However, solar and geothermal energies require the least amount of land for their use, but while biomass and ocean energies are continuously available, biomass is generally available and ocean energy is location specific. Among the RETs, solar energy has the highest potential to be harnessed while geothermal energy has the greatest capacity factor.

Table 1. SWOT analysis of Renewable Energy Technology

	STRENGTHS	WEAKNESS	OPPORTUNITIES	THREATS
WIND ENERGY	Reduce GHG by approximately 98% when compared with coal.	Experience intermittency and idleness	High turnover US\$75 billion in 2012 as against US\$3.9 billion in 2000	Landscape distortion
	Major source of RET after hydro source.	Good resource location restriction	Use of flown turbines (kites) as wind speed at jets streams are high	Birds deaths and displacement
	Cost competitive with fossil fuel source	Many experience high transmission line	Use of aluminium conducting secure anchored in space generating wing power	Noise
	Zero fuel utilisation	Cost because good resources are located far from energy demand centres	Installed capacity doubling every 3 years	Growth decline in the last 5 years
	Generally available	Low energy efficiency (24 - 54%)		Installation error
	Contributing over 3% of global power energy	Low capacity factor (21%)		
	Use in over 100 countries	Cannot produce base load		
SOLAR ENERGY	Reduce GHG by approximately 95% when compared with coal	Experience intermittency and idleness	Experience unit cost priced reduction (20-30%) in 2012 alone	Removal of incentives in 2008 in some European countries such as Spain
	Extremely modular	Most expensive among RETs	Proposed advanced application of satellite and ground solar farm (e.g. satellite solar power, Desertec)	General policies uncertainties
	Require little or no maintenance cost	Low energy efficiency (22%)		Saturation of local grid particularly in Europe
	Zero fuel utilisation	Low capacity factor (19%)		Market saturation
	Contribute around 100GW of global electricity energy in 2012	Cannot produce base load		Fierce competition (more than 100 closed up between 2011-2013)
	Generally available	Deployment is quite small considering global potential		A lot of companies went bankrupt
	Highest global energy potential capacity (170,000TWh/year)			
HYDROPOWER ENERGY	Reduce GHG by approximately 95% when compared with coal.	Partially intermittent especially tropical and Amazonian reservoirs	Can be started and stopped at any time and modular in nature	Declining hydro dam construction because of resistance from habitats and pressure
	Largest source of RET (contributing of over 16% of global electricity generated in 2012)	May be responsible for earthquake	More new electricity from BRIC and other developing countries as with nesses in 2012	Effect on biodiversity
	Cheapest form of RET/unit of electricity	Location specific		Effect on water quality and hydrological regimes
	Zero fuel utilisation	Displacement of populations		Climate change effect
	Most available, reliable and flexible form of RET	Declining fisheries		
	Can provide base load and peak load	Low energy efficiency (24-54%)		
	Most energy efficient among RET (>90%)	Partially low capacity factor (20-70%)		

GEO THERMAL ENERGY	Continuous available energy source	Resource tapping is unsustainable	Electricity generation is expected to rise because of improved technology (enhanced Geothermal System) in 2015	Rivers and lake pollution
	Has the highest capacity factor (>90%)	Lowest energy efficiency among RETs (10-20%)		Cause land subsidence
	Cost competitive with fossil fuel sources	Growing capacity is low		Operation can induce micro seismic
	Can provide base load and peak load	Lowest global potential among RETs		
	Can provide 17% of global energy needs	Location specific		
		Low potential for further expansion (using convention geothermal technology)		
		Highest source of GHG emission among RETs (6 times that of wind energy)		
BIOMASS ENERGY	Generally available	Deforestation as result of land use expansion	Arid land plantation can increase soil carbon	Could worsen global climate change
	Carbon natural (Reduces GHG by approximately 95% when compared with coal)	Application cause food price increase. Huge water utilisation/KWh electricity (about 150-260 kg/KWh)	Develop international policy mechanism for sustainable land use	It is not naturally available (majority of the resource has to be sought)
	Good capacity factor (60-70%)	Food usage for energy generation	High priority to none/less land bioenergy	Continuous expansion leads to displacement of communities
	Cost competitive with fossil fuel sources	Highest land utilisation among RETs	Strengthen sustainability requirement and certification schemes	Water scarcity
	Continuous source of energy	Low return on investment when biomass is used for energy production		
	Generate more employment than fossil fuel energy source/TJ energy			
	Good energy efficiency particularly if its gasification technology			
OCEAN ENERGY	Generally available	Location specific	Enjoying policy supports particularly in Europe	Experiencing pressure from environmental campaigners
	Reduces GHG by approximately 95% when compared with coal	Low capacity factor (23%)	Has no significant impact on environment	Ecological concern
	Highly dependable and predictable	Lowest total installed capacity among RETs (only 0.53 GW in 2012)		Effect on ocean wild life
	Continuous source of energy	Most expensive after solar energy form of RET/unit of electricity		
	Good energy efficiency particularly if its gasification technology	Faces engineering challenges		
	Energy potential more than human needs			

Table 2. Respondents Scores on Sustainability Indicators for Renewable Energy Source in Rural Communities in Anambra State

CRITERIA	Wind	Solar	Hydro	Geothermal	Biomass	Ocean
ENVIRONMENT						
Green house emission (gkwh)	25 (5.0)	90 (3.0)	41 (4.1)	170 (1.1)	70 (3.4)	41 (4.1)
ECONOMY						
Affordability–cost/kwh (N)	0.07 (4.1)	0.24 (1.2)	0.05 (4.5)	0.07 (4.1)	0.06-0.08 (4.3)	0.12 (2.2)
Energy efficiency (%)	24-54 (2.0)	4-22 (1.4)	>90 (5.0)	10-20 (1.0)	60-70 (4.1)	55-75 (2.7)
SOCIAL						
Visual, displacement, noise, pollution, seismic, etc	Visual, noise and bird strike (4.8)	Toxin and visual (4.2)	Displacement, health, agric and earthquake (1.1)	Seismic, noise, pollution and odour (1.0)	Food shortage, biodiversity loss, more labour used (3.1)	Effect on marine life, visual (3.1)
RESOURCES						
Water consumption (kgkwh)	1 (5.0)	10 (4.8)	36 (4.2)	12-300 (2.1)	150-260 (1.1)	28-40 (4.0)
Land use /TWh	72km ² (2.5)	28-64 km ² (4.1)	73-750 km ² (2.3)	18-72 km ² (4.3)	462 km ² (1.0)	73-750 km ² (2.3)
Continuity of resources	Intermittent (1.0)	Intermittent (1.0)	Partially Intermittent (2.0)	Continuous but not readily (4.0)	Continuous (5.0)	Continuous (5.0)
Resource availability type	Location specific (1.2)	General available (5.0)	Partially location specific (2.1)	Location specific (1.2)	Generally available (5.0)	Location specific (1.2)
OTHERS						
Nigeria potential (TWh/year)	1 (1.1)	17,702 (5.0)	58 (2.3)	No record (1.0)	225 (3.7)	41.7 (1.3)
Capacity factor (%)	21 (1.9)	19 (1.4)	20-70 (3.3)	>70 (4.7)	60-70 (4.3)	23 (2.2)
Total average score	28.6	31.2	31.0	24.5	35.0	28.1
Rank	3	2	4	6	1	5

Note: the values in parenthesis represent the individual average score for each sustainability indicator under different sources of renewable energy.

Table 2 shows the result of respondents' scores to determine the most sustainable source of renewable energy for rural communities in Anambra State. As shown in table 2, the values in parenthesis represent the average individual score for each of the identified sustainability criteria for each renewable energy source, while the total average score represents the sum of individual average scores for each renewable energy source.

On the basis of environmental sustainability, wind energy was found to be the most environmentally sustainable source of renewable energy in the state while geothermal energy was found to be the least. This is same for social sustainability. However, hydro power energy was the most economical sustainable renewable energy source, followed by the biomass energy; while solar energy was the least.

When the overall sustainability of all the renewable energy sources considered in relation to resource utilisation and otherwise, biomass was ranked 1st as the most sustainable renewable energy for rural communities in Anambra state with an overall sustainability score of 35.0, while solar and hydro energy sources were ranked 2nd and 3rd with overall sustainability scores of 31.2 and 31.0 respectively. However, geothermal (24.5), ocean (28.1) and wind (28.6) were ranked 6th, 5th and 4th respectively when overall sustainability of the sources of renewable

energies were considered.

The implication is that biomass energy holds greatest potential for providing sustainable alternative and renewable energy for rural communities in Anambra state. This further implies that investment into the most sustainable sources of renewable energies for example biomass and solar energies in the state would lead to provision of sustainable renewable energy in the rural communities in the state, since these are the two most sustainable renewable energies available for the state.

5. Discussion

This study has shown that there are enormous renewable energy potentials in Anambra state. However, whether these renewable energy sources are sustainable, environmentally, economically, socially and otherwise have been a subject of determination. There is no better way to determine this than to systematically review the potentials of each of these energy sources through SWOT analysis and synthesise the characteristic of each of these energy source; and thereafter subject such information to expert judgement. This is exactly what this study has done.

Thus, the result of the systematic analysis confirmed the availability of various renewable energy sources in Anambra state. Based on the scores of expert judgement,

this study revealed that though each of the renewable energy sources can be harnessed and utilised in the state, when considered in terms of sustainability, biomass and solar energies hold greatest potentials to provide sustainable renewable energy for rural communities in Anambra State. However, biomass is the most preferred renewable energy for rural communities in the State. Although, Eltrop [37] acknowledged many different effects associated with the use of renewable energies, and questioned the sustainable per se of all renewable energy technologies, the result of this study shows that biomass, solar and hydro energy sources are more sustainable when compared against other alternative energy sources. A critical look at the factor upon which the judgement was based indicate that availability of agricultural residues, forest biomass, community solid waste and animal dung in Nigerian rural communities, availability of resources, affordability and proximity play very significant role in determining the most sustainable renewable energy in the state.

The result of this study then implies that the problem of sustainable energy for rural communities in Anambra State can be solved if government invest in biomass and solar energy technologies. Since, these energy technologies are readily available with minimal environmental, economic and social consequences there is great potential in achieving sustainable renewable energy for rural communities from these sources of energies. More importantly, now the conventional energy sources in Nigeria are no longer reliable and sustainable, it is high time to seek for more reliable and sustainable energy which is found in biomass, solar and hydro energies.

The result of this study is however in agreement with that of Garba, Kishk and Moore [38] who affirmed decentralised Biomass Energy Technology as the most suitable means of electricity provision in rural communities given the biomass resources availability in relation to their low energy consumption. This study also aligned with the results of [7,29-31] who posited that renewable energy technologies have the potential of providing sustainable electricity to Nigeria rural areas. The same is also with Nadabo [12], Uduma and Arciszewski [13], Oyedepo [15]. Specifically, Simonyan and Fasina [14] affirmed that energy from biomass can potentially be an alternative approach to solving the country's electricity problem.

6. Conclusions

Affordable and reliable energy availability is an important precondition for sustainable development. Sustainable development calls for an efficient, reliable and decentralised energy economy, based on local and clean energy sources, in which the price paid by the consumer will reflect the real cost of energy products to the economy.

There is clear evidence that Nigeria as well as Anambra State is blessed with abundant resources of fossil fuels as well as renewable energy resources. The major challenge is inefficient utilisation of energy in the country especially in the rural communities.

The residents of Anambra State are experiencing a dearth of electricity that is affecting their socio-economic standing, particularly in the rural areas. Generally, the causes of Nigeria's electricity problems include power generation limitations, investment pattern limitations, and the economics of gridline networks and infrastructures. Renewable energy technology is recognised to be the solution because of its strategic benefits in identifying when and where electricity is actually required. Anambra State has abundant renewable energy resources, particularly biomass, hydro and solar energy sources, with good potential for providing sustainable energy to rural areas in the state.

On this premise, this study has critically analysed the sustainability of various renewable energy sources for rural communities in Anambra State. The study has successfully established that biomass energy resources hold that greatest potential for providing sustainable alternative energy for rural communities in Anambra State. This is followed by solar and hydro energy respectively, while the geothermal energy holds the least potential even though it can serve as alternative energy source to conventional fossil fuel.

Unfortunately, the level of utilisation renewable energy technologies in the state is low. This may be as result of lack of implementable policy framework, government apathy towards renewable energy technology development, and the low purchasing power of the majority of citizens. In line with sustainability assessment of renewable energy technologies in the state rural areas, the following energy sources should be adopted by order of priority for sustainable electricity: Biomass, solar and hydro sources; this should be supported with robust and consistent policy framework for implementation. Also, there is the need to correct the government's preference for fossil fuels over renewable energy technology as a source for generating electricity.

Many of the Government of Nigeria energy initiatives are merely green paper policies that lack the resolve to be taken into the implementation realm. To facilitate greater uptake of 'clean' energy, the Anambra State Government needs to develop the 'Clean Energy Future' framework aimed at increasing deployment and innovation of renewable energy in the state and can be extend to other part of the country. Further work includes the application of whole life costing (WLC) to optimise the economic performance of biomass RET within its whole life cycle rather than during the construction phase only.

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