

## ASSESSMENT OF RENEWABLE ENERGY SOURCES FOR SUSTAINABLE DEVELOPMENT IN NIGERIA

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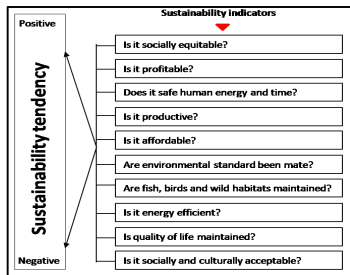
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### Graphical abstract



### Abstract

The knowledge regarding how new materials, technologies and innovation are used, as well as their resulting implications to the society is growing. The study aimed at understanding the trend and views of researchers in defining sustainability of renewable energy sources as it is embedded in within the general concept of sustainable development. Related literatures are reviewed and structured interviews were conducted. It was found that sustainability of any system encompasses ecological (biophysical), economic and social sustainability indicators. Therefore, the paper concludes that any source of energy should be evaluated along the identified sustainable indicators. It also attempted to provide an approach for assessing the sustainability of renewable energies to perfectly serve the primary objectives of integrating renewable energy sources in power generation.

Keywords: Sustainability, renewable energy and sustainable development

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## 1.0 INTRODUCTION

The technological advancement in the economy has dramatically changed the traditional understanding of energy as an halfway contribution in the manufacture process to a critical primary factor of production because all money-making effort and practices can only run with adequate supply of energy. Capital and labor are factors in production that transformed energy into valuables that will satisfy the needs of the consumers in form of goods or services provided for sustainable development. This description of energy and its implication to sustainable development spur researches to study its source from nature, and evaluate the activities that transform this energy in to

various units for utilization in industry and household consumption [3].

Productive energy services have become an essential element of sustainable development. Productive energy services take part in economic, social and environmental mainstay of sustainable development. Energy is a medium for economic development by propelling industrial growth, agriculture, transportation, communication and trade. A dependable and cost-effective energy supply attracts foreign direct investment by providing access to international markets and trade [4]. The economy of a country is a depiction of an integrated energy system which is made up of tributaries of energy-producing activities and energy-using activities, through which it drives all economic activities. The cross link of energy and other mechanism for

achieving sustainable development tells more of reasons why the realization of energy sustainability became increasingly recognized as an important drive towards attaining sustainable development [5]. The implication here required that for a society to achieve a sustainable development, energy sustainability issues must first be tackled adequately. Thus, the article discusses some critical technical issues that should be addressed when analyzing the sustainability of a technological change.

### 1.1 Framework for Sustainable Development

Despite the variety of definitions [6-8], The World Commission on Environment and Development which has been called the Brundtland Commission gives the famously used definition of sustainable development which entails satisfying the needs of the present generation without compromising the ability of future generations to meet their own needs [9]. Further discussions on this definition described the constraining forces which the technological development and innovations imposed on the environment and the ability for the environment to absorb such influences.

In line with the above definition, Smith and McDonald [6] emphasized that sustainable development can be described in terms of inheritance of heir. Anon [10] regards sustainability as a common acknowledged perception that has integral parts categorized in to ecological, economic and social components. This gives the basis to the mosaic approach which described sustainable development into three main basic elements:

- Ecological sustainability has target both at the national and international level which requires that ecological system is adequately maintained during development processes;
- Economic sustainability that focused on achieving economically realistic development and
- Social sustainability which mediates in between innovations for development and its social acceptance.

The basis of this study is rooted from the mosaic approach to sustainable development. Robèrt [11] stressed that, one can be able to deliberate sustainably on acquiring sufficient understanding of the objectives of sustainability in order to adequately manage the system precincts and select adequate mechanisms for the development by manipulating sustainable resources and combining forces across divisions and disciplines. [12-14] added that, a system must be ecologically sustainable or it cannot persist over the long term, and thus cannot be productive and profitable. Likewise, a system must be productive and profitable over the long term or it cannot be sustained economically, no matter how ecologically sound it is.

### 1.2 Sustainability Consideration in Renewable Energy

Sustainable energy development must entail energy security, affordable, low carbon, renewable and environmentally friendly energy systems. The current pattern of energy production and utilization shows a sharp gap in sustainable development and threatens biodiversity and other environmental concerns [15]. Energy use in an unsustainable manner has several concerns on; Degradation, Deterioration, Fragmentation and Habitat alteration. Researcher in the field of Sustainability upheld projecting criteria as the most productive method of sustainability evaluation. Such criteria according to [6] includes; multiple qualitative and quantitative attributes that fit in within 'sustainability as a property of energy.

Criteria for measuring energy sustainability can be observed at several stages based on the level at which assessments are carried out and from different measure of relevance. The measuring criterion may also be different in the magnitude of measurement, and the duration of application [6]. Assessing the environmental consideration of renewable energy in Nigeria, Lawrence [15], emphasizes that the following attributes should be considered for evaluating Energy use in a sustainable manner: Land-use, Land cover change, Soil and water/air integrity, Habitat fragmentation and Selective exploitation of species.

New technologies and innovations time and again have cruel effects apart from their societal benefits and the advantage of creating economic growth. Most cases of these cruel effects are resulting from the impact of technology on the nature and its resources. Technology have a mixed blessing, it can inflict environmental pressure while on the other hand, technologies can also promote a more ingenious utilization of resources, less pressure on the environment and even protection of the environment [16]. Thus, technology romances with the environment in a complex and paradoxical sense that require management in order to make the technological change sustainable. Studies revealed that formulating and implementation of the required managerial practices has been an issue in many national environmental policy programs in Nigeria [17].

Recognizing the complexity of interaction in use of technology and the environment, leads to Innovation system approach that is to control the pace and trend of technological evolution in the society [18]. The work of Hekkert and colleagues (2007) identified the weakness of the innovation systems and proposed a frame work called the function of innovation systems. The approach study the pattern of technological change evolving within the innovation system, focusing specifically on the most important processes that most be executed to successfully achieve technology development and diffusion. Their work is highly relevant for policy makers especially when policy initiatives drives and direct the technological change.

Unruh [19] studied the work of [20-22] on new technological development in specialized niches. He added that the niche strategy become visible to suit in to component level continuity strategies, but argued that it is apparently a difficult task finding a “niche” that can suit a whole system. The limitation of the niche strategies is the wider time frame the system required for perfect conditions to emerge. The risk occurs when degradation progresses to the peak before the perfect conditions of the evolution emerges, Thus, rendering the strategy inadequate for addressing environmental problems.

Government policy is important in inducing change in technological system, but for such changes to occur there must be a change in institutional priority, which is frequently a gradual process. Social changes often precede institutional changes in democratic societies. The reflecting question is “at what point does societal recognition of environmental degradation leads to action” [19] by implication, the strategy is lagging behind focusing event before implementing new policy frameworks.

However, while a new Techno-Institutional Complex (TIC) poses the ability to mitigate environmental challenges, it should be noted that by doing so it undoubtedly creates new problems in the future.

Therefore, individuals in charge of policy making and management should be conscious of the likelihood of future inconveniences and distress into account and

formulate policy regimes that will allow for future development. This implies that all new technological innovation should not be concluded to be the solution for the environmental challenges at hand, rather should be taken as a further step in the development corridor which requires a careful design and implementation.

## 2.0 METHODOLOGY OF THE STUDY

The focusing initiation of this study is to propagate the idea for assessment of technological change and innovation on systematic mapping of all the activities that make up the system, so as to adequately manage the system precincts and select adequate mechanisms for the development by manipulating sustainable resources and combining forces across divisions and disciplines.

Data for the study was collected through secondary and primary sources which include a structured interview with energy consultants, community leaders, system developers and managers of energy development organizations. The content analysis of the data was done and results are presented accordingly. However, the following questions were answered during the literature review and the semi-structured interview:

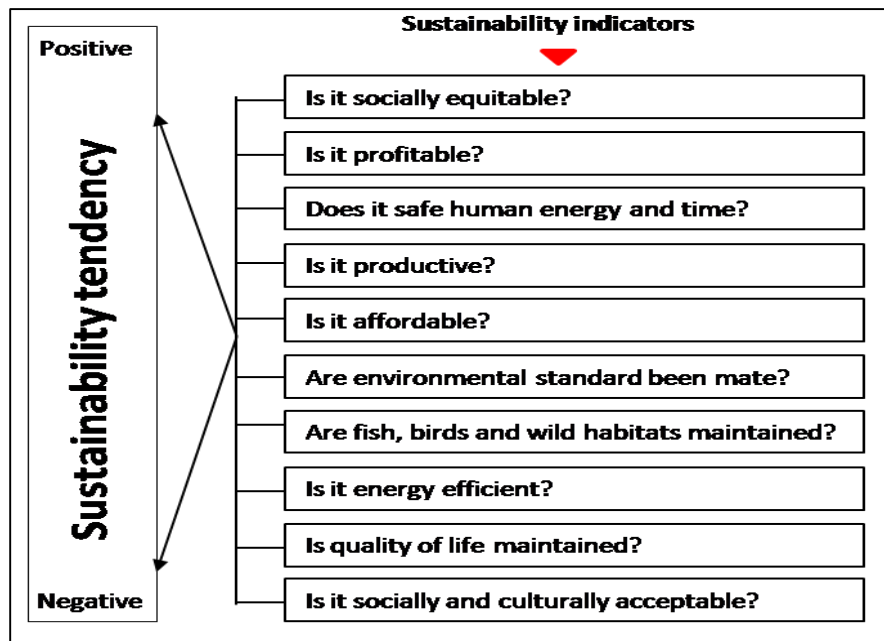


Figure 1 Measurable indicators for Energy sources sustainability assessment

1. What are the predominant renewable energy sources in Nigeria?
2. What are the effects of renewable energy sources to sustainable development in Nigeria?
3. How did you define sustainability of renewable energy source?
4. What strategies should be used to manage the renewable energy sources in a sustainable way?

### 2.1 Proposed Assessment Method

Reviewed literatures established that Sustainability indicators are far the most dynamic method of sustainability assessment. Such criteria according to [6] includes; multiple attributes that can be measured qualitatively and quantitatively. Thus, the paper propose that, approach to energy resource sustainability assessment should be dependable with translating sustainability as the medium for addressing all components of the system believed to influence sustainability and development. In tune with the aforementioned, the study proposes the following measurable indicators as in figure 2. Assigning weights and/or rating the indicators based on specific restraints generate a figure of merit. A positive or negative change in the collective indicators, suggests that the system is sustainable or vice-versa.

## 3.0 RENEWABLE ENERGY RESOURCES AND THEIR POTENTIALS IN NIGERIA

Nigeria is endowed with sufficient renewable energy (RE) resources to meet its present and future development requirements [2]. Interest in RE growth and development in Nigeria was steered by factors which include, the hike in oil prices just as we recently experienced, and the ecliptic supply of electricity to majority of the people. This regrettable situation was hinged to the high cost of generation and energy losses connected with grid transmission [23]. In energy terms, Nigeria has about 75% potential of RE over that of fossil energy resources [24]. The result obtained from the study identified the predominant RE sources in Nigeria, which include: Hydro, solar, biomass and wind. The sources, capacity and potential of each RE resource is shown in Table 1.

### 3.1 Biomass Energy Resources

Nigeria as an agro-based country has quite a large number of people that are engaged in rural agriculture, farm animals and poultry farming that has great economic impact to the country. biomass resources are organic matters such as fuel wood or aquatic vegetation that have significant amount of calorific content for cooking, and other heating activities [25]. Table 2 shows different biomass resources and their estimated quantities in Nigeria.

**Table 1** Dominant renewable energy sources in Nigeria and their usage

Energy source	Energy usage
Hydropower	Power generation
Biomass	Torrefaction, pyrolysis, co-pyrolysis, coal, liquefaction, gasification, heat and power generation, digestion.
Wind	Wind turbines, windmills, power generation
Solar	Solar hydrogen technologies, CSP, thin films, thermal power generators, water pumps, photovoltaic
Tidal	offshore turbines and vertical-axis turbines

**Table 2** Biomass resources and their estimated quantities in Nigeria [21]

Resources	Quantity (million ton)	Energy value (000 MJ/kg)
Fuel wood	39.1	531.
Agro-waste	11.244	147.7
Saw dust	1.8	31.433
Municipal solid waste	4.075	-

A study by Akinbami [26] revealed that urban refuse, industrial waste, sewages and a large chunk of agricultural residues such as cassava leave are identified feedstock substrate for an economically feasible biogas program in Nigeria. Biogas production from waste have some comparative advantage over other biofuel concept [27], advantages tied to biogas include that of reducing the menace and nuisance of urban wastes in many communities by transforming the waste in to electricity generation with appropriate technology. It utilizes less space of land, requires no irrigation and the slurry sludge is utilized for fertilizer. Mondal and Denich [28] Emphasizes direct combustion and gasification (Syngas) as suitable methods for processing biogas for electricity generation.

### 3.2 Hydro Power Energy Resources

The world hydropower capacity in 2004 was 2810 TWh [29]. The greatest contribution of global hydropower development projects is coming from Asia at 84,000MW [29]. The contribution from other regions of the world includes: South America 14,800MW, North and Central America 1236 MW, Europe 2211MW and Africa 2403 MW [30]. The potential of hydropower sources in Nigeria totals to about 14,750 MW [26]. Surprisingly, only approximately 14%, (1930 MW) of that is currently being generated [31]. The situation clearly demonstrated that despite its high potential, hydroelectric energy in Nigeria is grossly underexploited. Nevertheless, there is a rapid consideration of small hydropower (SHP) by both the

developed and developing economies of the world. Laghari, Mokhlis [32] described that Africa and Asia has the most unrealized potentials of SHP. The growth of Mini hydropower generators has witnessed an increase in growth rate of about 28% in the last Five years, and the global capacity of small hydro reached 85 GW. Presently in Malaysia, mini-hydropower plants are gaining popularity with a long term plan to supply 470 MW by the year 2020 [33]. In Nigeria, the SHP

potential is estimated at 734.2 MW [34]. Out of the total capacity of 734.2 MW, only 32 MW were developed while 702.2 MW are yet to be developed. Thus, there is a vital need to develop these on time in order to extend electricity provision to rural and remote areas [2]. Table 3 showed the survey of small hydropower potentials in Nigeria.

**Table 3** Small hydro potentials in Nigeria - Energy Master plan [1, 2]

Selected state	River basin	Total sites	Potential capacity (MW)	Developed capacity (MW)	Under developed Capacity (MW)
Sokoto	Sokoto-Rima	22	30.6	8	22.6
Katsina	Sokoto-Rima	11	234.34	-	234.34
Adamawa	Upper Benue	3	28.600	-	28.600
Niger	Niger	30	117.6	-	117.6
Kaduna	Niger	19	59.2	-	59.2
Ogun	Niger	13	15.610	-	15.610
Kwara	Niger	12	38.8	-	38.8
Kano	Hadeija-Jamare	28	46.2	6	40.2
Bauchi	Upper Benue	20	42.6	-	42.6
Gombe	Upper Benue	2	35.099	-	35.099
Taraba	Upper Benue	9	134.720	-	134.720
Plateau	Lower Benue	32	110.4	18	92.4
Benue	Lower Benue	19	69.2	-	69.2
Cross rivers	Cross rivers	18	28.1	-	28.1
Total		238	991.069	32	959.069

### 3.3 Solar Energy Resources

Nigeria has good radiation sites that can boost the development of solar energy, and supply an economical and abundant energy for populace living in remote areas that are practically isolated from the national grid because of their geographical location or their proximity to the grid connection spot [2]. Based on the Nigerian land size of 923,768km<sup>2</sup>, the country received the average of 1.804\_1015 kWh of incident solar irradiation per annum, an average of 166kWh/m<sup>2</sup>/month.

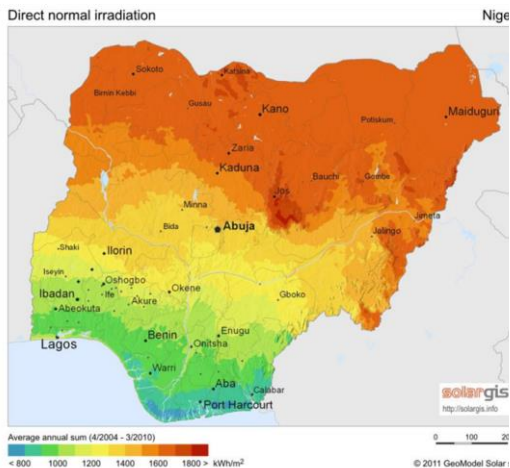
The average sun shine per day in Nigeria is about 6-7 h/day, while the solar energy irradiation per annum was value to 27 times higher the country's total fossil energy resources in energy units. Furthermore, the solar energy irradiation per annum was estimated

115,000 times more than the electrical power produced per annum [35]. Figure 1, shows the average solar radiation in Nigeria from 2004 to 2010. Analysis of the figure shows that cities like Maiduguri, Pofiskum, Kano, Katsina, Sokoto, Birnin-kebbi, Gusau and Zaria, which are situated at the far northern Nigeria has the average of more than 1800KWh/m<sup>2</sup> while cities like Warri, Aba, Calabar and Port-Harcourt has an average incident solar energy of less than 800KWh/m<sup>2</sup>.

### 3.4 Wind Energy Resources

At the end of the year 2006, the estimation of the world wind capacity was about 72,000 MW. The developed in wind energy has been at the forefront in the industrialized world for sustainability of the

environmental, nevertheless wind energy resources are receiving attention in the developing countries owing to its advantage of quick installation for urgent electricity need. The early use of wind energy in Nigeria can be traced back to the northern regions of Sokoto and Garo, windmills were used there to pump water for schools, house hold utilization and for drinking [36]. The application of wind resources for energy in Nigeria has not been an appealing alternative because of varying potential for wind energy across the nation as shown in Table 4.



**Figure 2** Average solar radiation in Nigeria - Global solar model (2011).

A review of renewable studies by Ajayi [37] described and identified that the North central and Southeast of Nigeria has the highest possession of wind energy potential. He further states that the potential wind speed in the northern region is about a high of 8.70 m/s. Hence, the North would be the best strategic location to start an initiative towards harnessing wind energy in Nigeria.

## 4.0 KEY FINDINGS

### 4.1 Ecological Impacts

- Documented trend estimates that over 300,000 hectares of deforestation occur per year in Nigeria due to a combination of rapid growth in the timber industry and domestic firewood dependency [38]. Study within the whole of Africa estimated a loss of 64 million hectares of forest between 1990 and 2005. The following were among the findings of the study on the effect of renewable energy processing on eco system:
- Massive land-use in the case of solar, death of birds/bats resulting from wind turbine, death of fish resulting from hydro turbines and dams are leading to wildlife extinction.

- Incomplete combustion of biomass in the traditional cooking stove released carbon monoxide, polycyclic aromatic hydrocarbons and particles containing elements of carbon and other organic compounds [39].
- The effect of corrosion and hydrogen aging are few among many drawbacks in biomass conversion to fuel. Other notable limitations include non-total solid conversion and production of tars in biomass to hydrogen fuel Process.

### 4.3 Economic Impacts

- Solar energy source is free of charge and environmentally friendly. In many cases, the technology appliances required less maintenance, thus making it a very attractive innovation for communities and sites whose locations made access to national grid and adequate maintenance services very difficult. Nevertheless, it is found that the high cost of setting the system is the utmost factor against its acceptability in Nigeria. Others include:

The technology involved in the fabrication of the cells used in photovoltaic is, however, high and so are the initial capital costs of the system [40]. Wind turbines and generators also have moving parts that require maintenance for efficiency at high costs.

- In biomass to hydrogen as fuel, its seasonal availability and high costs of handling poses a great economical sustainability challenge.
- The construction cost of hydropower is high, but respondents argued that the zero fuel cost make hydro generation a gung ho investment.

### 4.2 Social Impacts

- The study found a wide variety of crops, such as cassava, soybean, palm, rapeseed, cotton seed, sunflower and groundnut among others are used for biofuel productions which most of the respondents argued to have cause rise in food prices. Other findings include:
- There is a high dependency on food crops for consumption in Nigeria; the intricacy of the food concern in the case of biofuel is frequently overlooked, as such high prices of food is constantly associated with the production of biofuels. This is because the energy market for crops tends to be a more lucrative option for farmers.
- Death of fish resulting from hydro turbines and dams, as well as the killing of wild life creatures and birds by the wind turbine blades while they generate electricity are social sustainability concerns often recorded during the study.
- The humming noise of the turbine blades as they cut in the air, is a nuisance to the people who dwell near them, other respondents are of the view that

the wind turbine and its stall are ugly and its existence spoils the surroundings

- Land ownership issue is a serious social concern in Nigeria and the sub-Saharan Africa, Solar and Wind power systems regularly consume acres of land

which some respondents attributes to be sources of communal disagreement with energy developers which in some places leads to vandalize of installed plants

**Table 4** Wind energy potentials in Nigeria (preliminary report, 2011)

Studied state	Area (Km <sup>2</sup> )	Windy (%)	Area Effective (Km <sup>2</sup> )	Wind Potential capacity (MW)	Potential Generation (MW)
Adamawa	37,957	44	170,80	854	2244
Bauchi	48,197	50	24,098	1204	3166
Borno	72,767	100	72,767	3638	9561
Gombe	17,428	100	17,428	871	2290
Jigawa	23,415	100	23,415	1170	3076
Kaduna	44,217	60	26,580	1326	3486
Kano	20,389	90	18,350	917	2411
Katsina	23,822	100	23,822	1191	3130
Kebbi	36,320	25	9080	454	1193
Plateau	26,539	90	23,885	1194	3138
Sokoto	32,146	90	28931	1446	3801
Taraba	58,180	40	23,672	1183	3110
Yobe	44,880	100	44,880	2244	5897
Zamfara	33,667	80	26,933	1346	3539
Total				19,043	50,046

## 4.0 CONCLUSION

This paper has shown that the sustainability of any source of energy depends on its adaptability to the society in line with ecological, economical and social sustainability indicators. It has been suggested that careful evaluation of a proposed energy source in terms of the indicators discussed here will help all stake holders in Nigerian energy sector to ensure that only sustainable energy sources are utilized in the quest for sustainable energy development.

Nigeria has good reasons to diversify its supply of energy and to better exploit its energy sources. Meanwhile, the few examples in this study are enough to substantiate the imperative of assessing the sustainability of any source of energy by making use of sustainability indicators in order to achieve the philosophy of sustainability while adopting renewable energy technologies. The measures for selecting convenient sustainable technology such as availability, financial capability to incur cost

(maintenance and repairs), ability to operate by consuming less energy and time; competence to meeting the needs of the society fairly; resource consumption and environmental advantage, must be assessed and scored based on the proposed measurable indicators as in Figure 2. A certain education of the influence of social change mandate on institutional change, and the significance of government at national, state and local level to formulate policy in bringing about changes in technological systems is probably also necessary in order to make technological change sustainable.

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