Review of Renewable Energy Sources in Nigeria – Security and Challenges

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DOI: https://doi.org/10.21590/ijtmh.2022090203

Abstract

Current trend of energy production and utilization in Nigeria are at the lowest level despite the abundance of primary sources of energy in the country. Facts from current work on the crisis in Nigeria energy sector have shown that it is not about resources but management, strategic investment and utilization. Past and contemporary works on this subject have identified areas of shortcoming but fall short of giving proper platform to the solution. Silent belief common to those literatures is that risk capacity is high and cannot be afforded in Nigeria. Indeed investment volume is high, but affordability is a subject of debate. Disputing the affordability is because nearly 16 billion US dollars spent between 1999 and 2007 on energy sector have not giventangible result. Thus, this work will assessenergy situation in Nigeria – security and challenges with a call to advocate for strategic investment in gasification of municipal solid waste.

Keywords: RE – Renewable Energy, Syngas – Synthesis gas, MSW – Municipal Solid Waste, Security – Ensuring stabilization in demand and supply.

1.0 Introduction

Energy is the ability to do work. Its use cannot be divorced from human life. It is the fulcrum of human life and technological advancement. In reality, it is an essential of all economic activity[1] and necessary in all form of services, transportation, health and activities that human being engaged in. In general, energy (whether in the form of oil, gasoline or electricity) can contribute to widening opportunities and empower people to exercise choices. The demand for energy today is far greater in this highly technological society. Historical facts have established that industrialization and growth rate of any country depend on energy available in that country, and also extent to which this energy is utilized [2].

The security of energy supply is a frequentconcept in national energy policies also at the Europeanand worldwidelevels [3]. Energy security cannot stand alone without input from energypolicy. Thus, it is difficult to discuss energy security without recourse to energy policy. Energy policy in its simplest explanation connotes planned action for tracking issues related to energy, supply, demand and development of energy related issues. In as much as the energy policy is easy to define, it is not stable. Analysis of energy policy could be complicated and difficult. Energy policy comprises several actors with different aims and objectives. In this sense, defining sets of rules and engagement in energy policy could further complicate the arising conflicts. Energy policy interacts among state (national or local), international and non-state elements e.g. NGOs. Besides, there are energy policy arrangements namely actors, power influence and coalitions. Actors are organizations or institutions that operate with a specified interest e.g. Power Holding Company of Nigeria, Nigeria National Petroleum Corporation, Energy Commission of Nigeria etc. Coalitions suggest when actors interacts together especially to defend their interest primarily related to governing rules or law, price, raw material etc. However, they may differ distinctively on competition and services.In policy arrangement, there are formal and informal rules.Formal rules to the extent as governed or dictated by laws as approved by the government. Informal rules are the views or perceptions of formal rules by the political class and ordinary people. The informal rules are difficult to put into perspective but yet go a long way to determine the final outlook of the formal rules. In all, policyarrangement is not universal.

According to Bazillian, Outhred, Millier and Kimble (2010), the objective of energy policy is to find sets of decisions and drivers that simultaneously optimizes numerous objectives functions that are non-linear, highly coupled (with significant tradeoffs), uncertain and subject challenging constraints. In energy policy, the key objectives to be addressed includes energy security, reduction in energy-related greenhouse gas emissions (and environment protection more widely), energyservice cost minimization (both for business and residential consumers) and energyservice accessibility [4]. The absence of such in Nigeria has robbed and will continue to hamper the country to attain desired goals in energy development.

Energy security generally refers to ensuring adequate and reliable energy supplies at reasonable prices in order to sustain economic growth [5].Several literatures available on the subject of energy security have identified that implementing strategy on energy security will achieve reducing the gap between energy demand and supply, improve energy efficiency, conservation by lowering energy resource intensity and achieving energy mix. Others includes diversification of energy sources, aggressive investment in energy infrastructure, encourage use of alternative and renewable sources and reducing energy pricefluctuation. Finally, sound governance is central to achieving those lofty ambitions sets herein [6].

2.0Review of Renewable in Nigeria

Nigerian renewable energy resource base is enormous. From north to south, east, and western part of Nigeria are found diverse kind of renewable energy sources. Annual average sunshine hours vary from 4 to 9 hours/day. There are seven river basins in the country, namely Sokoto, River Niger, Hadejia-Jama're, Chad, Upper Benue, Lower Benue and Cross River. Each of these has small-scale hydropower potentials estimated to be about 734.2 MW [7].

Nigeria is blessed with more than enough quantities of water resources especially in the southern and mid-belt. Annual rainfall decreases 3400mm depth in the south central shores, of the Niger Delta to 500mm over the northern boundaries of the country, with a perched increase to 1400mm over the central Jos Plateau region [8, 25].Power Holding Company of Nigeria (PHCN) has of recent estimated that, the country's outstanding, total exploitable hydro potential currently stands at 12,220 MW [25].In Nigeria, 1939 MW of hydropower is already in use, adding this to 12, 220 MW would provide about 14,150

MW.Current hydropower generation is about 14% of the nation's hydropower potential and represents some 30% of installed grid connected electricity generation capacity of the country [7].

The amount of solar energy intercepted by the planet earth is 170 trillion kW [9]. The applicability and popularity of solar energy technology has widening in this present dispensation of renewable energy awareness due to its simplicity and environmental friendliness. Solar resources in Nigeria could be considered from required area to generate the total national energy consumption.Thus, the PCHN total electricity generation of 14.68 TWh in the year 2000 could have been provided by the average solar energy intensity of 1934.5 kWh/m²-yr (6898.5 MJ/m²-yr) falling on an area of 7.66 km² if a 100% efficient conversion device were used, or an area of less than 1 km² if a conversion device having efficiency of only 10% employed [8, 10].

Earlier work by Fagbenle[11], reveals that the mean annual temperature for most localities in Nigeria is about 27ºC with the mean annual solar radiation about equal to that of several cities in a temperate climate.This assertion was confirmed by Sambo and Doyle [12]who calculated the average yearly incidence of solar energy on the ground to be 2300 kWh/m² giving total incident energy of about 2100 exp12 kWh per year for Nigeria. These studies reveal that there is a preponderanceof solar energy irradiation in Nigeria. Its average solar insolation is greater than the world's averages. Therefore, there is a greater accessibility and availability ofsolar energy for Nigeria to develop her solar energy technology [13].

In reality and excluding the covered surface area with residential building and agricultural material, the minimum available land mass to solar radiation could be approximately 339 km² in Nigeria. Besides, several studies relevant to the availability of solar energy resources in Nigeria have indicated to its viability for practical use. However, and as with other renewable resources in Nigeria, solar resources havenot received adequate attention due of lack of necessary investment, political will and necessary research from institution saddle with such responsibility.

The biomass energy resources of the country are144 million tons per yearapproximately. Nigeria is currently consuming about 43.4 x 109 Kg of fuel-wood annually. The average daily consumption is about 0.5 to 1.0 kg of dry fuel wood per person [10]. Biomass dominated Nigeria's energy landscape. It remains a leading source of energy for Nigeria contributing 37 per cent of total energy demand, and energy of choice for the vast majority of rural dwellers and the urban poor [14, 15]. The 37 per centpiece attributed to biomass resulted through off griduse and mainly for those that resides in the rural areas.

Renewable energy use in Nigeria is split essentially between hydroelectricity and traditionalfuel wood. Akinbami (1997) indicated that a comparison between historical consumption and supplypattern reveals that the demand for wood (especially fuel wood) outstrips the natural regeneration of the forestry stock. At the present rate, the nation's forestry may as well be depleted within 50 years if the trends are allowed to continue [16]. Clearly, Nigeria forestry reserved is in danger and combustion of biomass should be not encouraged at this point in Nigeria's history. Instead, effort should be made to focus on how to de-emphasized, discourage the use of wood as fuel and increased information on efficient use of biomass.

Although there are wind energy resources in Nigeria, its use has been insignificant. Studies conducted by different experts, collated by the Nigeria Metrological Services has shown that total actual exploitable wind energy reserve at 10m height, may vary from 8 MWh/yr in Yola to 51 MWh/yr in the mountain areas of Jos Plateau and it is as high as 97 MWh/yr in Sokoto [7].Table 2.0 provides information about primary energy sources in Nigeria.

Table 2: Primary Energy by Type in Nigeria [8]

Resources	**Reserves (MW)**	**% Fossil**
Crude Oil	618,899 (exp) 7	31.1
Natural gas	4502.4 billion m^3(159 trillion scf)	26.7
Coal and Lignite	358,652 (exp) 6	13.0

Tar Sands	575,813.78 (exp) 7	29.2
Sub-Total (Fossil Fuels)		100
Hydropower, large scale	10,000	
Hydropower, small scale	734	
Fuel-wood	13,071,464 has (forest land 1981)	
Animal waste	80,985.2	
Solar Radiation	3.5-7.0kWh/m²-day	
Wind	2-4 m/s (annual average)	

2.1Electrification and Economic outlook in Nigeria

International Energy Agency data for 2008 indicated that electrification rates for Nigeria were 47 percent for the country as a whole. In urban areas, only 69 percent of the population had access to electricity compared to rural areas where electrification rates were 26 percent. Approximately 81 million people do not have access to electricity in Nigeria. According to the Nigerian Energy Policy report from 2003, it is estimated that the population connected to the grid system is short of power supply over 60percent of all time [8]. Additionally, less than 40percent of the population is connected to the grid. Iwayemi (2008) noted that, between 1970 and 2000, approximately 5000 MW of electricity was generated in Nigeria [17].

According to the Renewable energy master plan, expected level in energy generation was supposed to be 42 percent for the entire population of 169 million as at 2005. This should increase to 60 percent by 2015 while the expected access should rise to 75 percent by 2025. Theoretically expectation that could serve the population is put at 192 000 MW using growth reference by 2030. As it stands, plans have remains on paperlargely. Implementations have been disappointing. For instance, as at the end of 2011, energy generation for the revised population of Nigeria is well below 6000 MW. Implication of this scenario is that, investment in the energy sector of Nigeria is not consistent. In fact, the more the investment is inconsistent, the more Nigeria state is getting far from attaining sets of objectives contained in the renewable energy master plan (see the Fig.1 below for expected energy level scenarios).

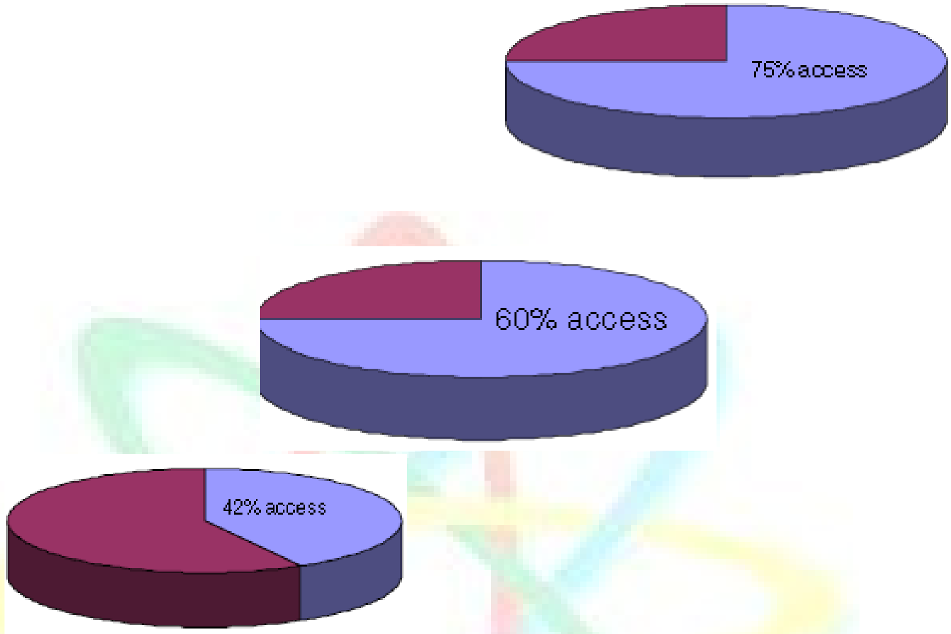

Figure 1: Source [8]

3.0Gasification of Municipal Solid Waste

Thermo-chemical conversion based on gasification is a proven technology and robustconcept. Gasification is capable of employing a variety of feedstock while consistently generating functional and useful syngas that can be converted into energy fuels, and other value added chemicals [18]. Thermal process of combustion can be identified in five distinct entities namely plasma arc gasification, conventional gasification, pyrolysis gasification, pyrolysis and mass burning (Incineration). Priority will be accorded conventional gasification due to the fact it has been around for a long.

Gasification is a form of pyrolysis, carried out at high temperaturesin order to optimize the gas production. Gasification is a process that chemically and physically changes biomass through the addition of heat in an oxygen-starved environment.The resulting gas, known as producer gas, is a mixture of carbon monoxide, hydrogen and methane, together with carbon dioxide and nitrogen. Conventional gasification is a thermal process which converts carbonaceous materials, such as biomass and municipals solid waste into combustible gases (e.g. H2, CO, CO2 and CH4) with specific heating values using a limited quantity oxygen or suitable oxidant such as steam and carbon dioxide [19,22]. In conventional gasification operating conditions are in most cases between 787 and 1650°C. Steam is injected into conventional gasification reactor to promote CO and H2 formation [19]. Gasification is more environmentally friendly because of the lower emissions of toxic gas into the atmosphere and more versatileusage of the solid by-products.

3.1 Waste Characterization

It is necessary to understand the waste composition and rate of their generation before embarking on its gasification. This is essential in order to be confident that the feed stock will be not short in supply. Typically, MSW is uniform globally especially in the cities. However, compositions could differ significantly where technological sophistication play a leading role. More so, in some instances waste compositions are site specific.

It has not been possible to perform site inspections to most waste dump sites in Nigeria. However, data from existing literatures provided some information upon which extrapolation could be performed. In comparison with existing literature, MSW composition in Lagos state, Nigeria comprise compostable paper, magazines, mixed recyclable paper, newsprints, non-recyclable paper, plastics containers. Others could include aluminum containers, ferrous food and beverage containers, aluminum materials, metals, glasses, yard waste, treated wood, demolition/renovation debris, cells phones and charger, computer monitors and TV's, textiles and leathers, rubber, diapers, organic waste and others. It is possible to categorize these wastes into exact composition and quantities where adequate data for statistical analysis is available.

The high heating value of the MSW can be determined from the proximate analysis using the equation below [20]:

HHV (MJ/kg) = (34.91 x C) + (117.83 x H) – (10.34 x O) – (1.51 x N) + (10.05 x S) – (2.11x Ash)

Where HHV is the high heating value and C, H, O, N, S and Ash are the mass fractions of the element from the ultimate and proximate analyses.

Ultimate analysis indicated the following composition for, H, O, N, S and Ash respectively [21]:

C = 37.42 weight by % of the dry matter

H = 5.14 weight by % of the dry matter

O = 29.91 weight by % of the dry matter

N = 1.19 weight by % of the dry matter

S = 0.13 weight by % of the dry matter

Ash = 25.56 weight by % of the dry matter

In comparison, coal has the following ultimateanalysis:

C = 71.72 weight by % of the dry matter

H = 5.06 weight by % of the dry matter

O = 7.75 weight by % of the dry matter

S = 2.82 weight by % of the dry matter

It can be assumed that coal is a better fuel, but observing the sulfur content in the ultimate analysis of coal is high, MSW then stands a better chance. The best way to solve the resulting environmental issue in this regard is to think of co-combustion. Besides, an accurate heating value of MSW can be determined using calorimeter bomb experiment in a laboratory setting.

In term of quantity and in the absence of reliable data for adequate determination of amount of municipal waste generated in Lagos, it is safe to juxtapose among different cities within the same population range. For instance, New York has a population of approximately 15 million and her MSW per is year is around 7 million tons. In the same way, Los Angeles has a population of 13 million with MSW output of 6 million tons annually. Chicago and Philadelphia haveapproximately 8 million and 4.9 million population respectively. Their MSW output annually is 3.7 and 2.3 million tons per year. Lagos population as of 2006 was approximately 9 million. It must be noted that technological pattern and development contribute largely to the composition of MSW. In term of technology and economic power, Lagos might not be able to compete with cities mentioned earlier. However, given the increased level of awareness in technology use in the Lagos city its economic power, it can be assumed that her MSW could be approximated to 5 million tons annually.

It is possible to translate 5 million tons of MSW generated in Lagos State into tangible amount of electricity possible. Assuming 70percent of MSW gasified (remaining 30% reduced due to volume and moisture content), theoretically approximately 4646.68 MW of energy is possible.If 25percent of4646.68 MWis used in a power plant, approximately 1161.67 MW of electricity are theoretically possible.

3.2Economic Implication and Justification for use in Nigeria

Gasification as a technology has been used commercially in different parts of the world.For instance, in the 1990, China built more than 70 biomass gasification system for the household cooking gas. Each of the system has an average gas delivery of 200 – 400m³/h to some 800 to 1600 families [22]. In India, gasification is a choicemethod for electricity generation [23] while in Finland; the Kymijarvi power plant of LadhenLampovoimaOy produces electric power (167MWe) and district heat (240MW) using gasification techniques. The Lathigasifier started commercial operation in 1998 and initially used biofuels such as bark, wood chips, sawdust and uncontaminated wood waste. Recently, other fuels have also been tested, and this includes in-origin classified waste fuel (REF), railway sleepers and shredded tyre. In all, the plant has operated well with varying fuel mixes [24].

On the economic perceptive, Gary C. Young performed a preliminary analysis for five different thermal processes. Parameters used for the economic analysis includes capital investment (average of 20 years), plant capacity (tons MSW/day) and energy production (kWh/tons MSW). Others include operation and maintenance (capital budget/disposal), tipping fee (US$/ton MSW), green tags (revenue), production energy sales (revenue), by-product and residue (tons/ton MSW). Table 3.0 below shed light on the findings.

Table 3.0 [20]

Thermal Process/Typical Range Operations	
Plasma Arc Gasification	3982.2- 6648.8°C
Conventional Gasification	760 - 1537.7°C
Pyrolysis Gasification	760- 1537.7°C
Pyrolysis	648.8 - 1537.7°C
Mass Burn (Incineration)	537.7- 1204.4°C

Analysis showed that a mass burn gives negative net annual revenue (before taxes) while pyrolysis, pyrolysis gasification, conventional gasification and plasma arc gasification indicate positive net annual revenue (before taxes) [21]. The plasma arc gasification process has the highest net revenue followed closely by conventional gasification. Environmentally plasma arc gasification process, produced vitrified slag, conventional gasification produced slag while incineration produced ash [22]. Of the three processes, plasma arc gasification by-product is the most environmental friendly while incineration is the most damaging.

Conclusively, in gasification processes, MSW is a feedstock for high temperature chemical conversion process. Thus, apart from utilizing syngas in power plant, resulting energy gas from gasification process can be utilized in biochemical and chemical production. It is an all inclusive solution compare to incineration process. Besides, gasification of MSW makes it is possible to breakdowntotallylargemolecules of plastics and other related material into syngas.Above all, syngas, from gasification of MSW has several applications especially in the production of fuel (electricity), chemicals and fertilizers.

3.3 Conclusion

Energy mix is essential in the 21st century, and there cannot be any pretence about it. It is one means to achieve energy security. Energy security can only be achieved through adequate investment that are coherent and consistent. In order to address challenges that Nigeria is facing, and those ahead in term of energy security, adequate attention has to be paid to renewable energy resources and diversification in fuel resources.

Notable observation during the course of this work, is that institutions in Nigeria are lacking in capacities. Impacts of thesecould be seen in the quality of research output, framework and absence of advocacy coming from the established institutions. It is vital for Nigeria government to give full support to research institutions in the country. Research institutions and universities have the capacity to birth inventions and innovations that can transform the present level of decay to phenomenon growth and development. This can be achieved through adequate disbursement of research grants and creating an enabling environment for the university dons and academica to optimize their potentials.

Attempts to utilize reneable energy sources to Nigeria have been directed mostly at rural areas and commounities.These were courteous and encouraging especially when such efforts are from biomass and fuel wood standpoint. However, such efforts can also be directed towards large cities where more than 100 MW can be achieved through conscious and delibrate effort. In fact, several housing and industrial estates can provide a ready market for the utilization of heat and electricityproduce from such effort.

Pathway to developments cannot be premised on luck or potential it must be achieve through deliberate effort.This work is advocating for thecreative approachneededto solve Nigeria energy crisis through gasification of MSW. The utilization of gasification technology offers clearthe advantage. It willopen up space for technological development (as the approach can be sourced locally). It promotesustainabilityconcept as there would be anopportunity to save for the future. This in turn, will address the environmental problem at least asconern MSW and other related wastes. Gasification of municipal solid waste is recommended in this work. However, its technical details and economic viability is beyond the scope of this work.. Integral solution to the energy crisis in Nigeria can be formulated through effort as this. Thus, it will be beneficial to channelinvestment resources for research and development of gasification of municipal solid waste in Nigeria. Through this kind of effort, it will be possible to understand the perculiar nature of gasification project in Nigeria's environment. Alternatively, Nigeria can seekpartnership especially from those countries who have understood the art and technology of gasification in details. Such a partnership could readily come from countries like Finland, Sweden, Austria and United States of America.

Overall, reality of energy security must be dawn on Nigeria political leaders, academicinstitution and other relevant government agencies to as a matter of urgency put in place mechanisms necessary for attainment of short, medium and long term plans on energy generation utilization in Nigeria. National Beruea of Stastistics data indicated that more than 100 million people in Nigeria lives below the poverty line of 1 US dollar per day. The connection here is that, many business opportunities will thrive when there is an adequate supply of electricity. This can only be guaranteed when breakthrough in academic research is meeting with political will.

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