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Benchmarking and Multi-Criteria Decision Analysis Towards Developing a Sustainable Policy of Just in Time Production of Biogas in Nigeria

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ABSTRACT

Biogas is currently one of the most researched forms of renewable energy carried out by researchers because of its potential in replacing fossil fuel usage and aiding carbon-neutral energy production and consumption. Biogas Production has been successfully implemented in developed countries, which has generated sustainable energy for human comfort. Many developing nations that seek to engage in the production of biogas tend to struggle with the process. This paper aims to review the existing literature on benchmarking and multi-criteria decision analysis in developing a sustainable policy of biogas production in Nigeria. It is worthy of knowing that as of now, Nigeria as a nation does not have a policy governing the production of Biogas. The Government needs to apply some strategic steps to have the policy to guide the day-to-day running and develop a biogas production system, to improve the economic instability of energy generation in Nigeria. This research also discusses some significant ways to develop a sustainable policy for the just-in-time production of Biogas in Nigeria. After a thorough review of other literature, the study concluded that benchmarking and multi-criteria decision analysis is constructive in developing sustainable policy that will govern biogas plants and their production in Nigeria.

1. INTRODUCTION

Biogas is naturally produced fuels derived from the decomposition of organic waste materials in an anaerobic environment. Biogas mainly consists of methane and carbon dioxide [1]. The production of Biogas is an increasing interest in the area of energy science as it poses to be a viable replacement for fossil fuel usage to reduce fossil fuel carbon footprint in our atmosphere (Reducing the greenhouse effect of fossil fuel in our plants) [2-4]. Biogas production can be of two types which include dry and wet fermentation [5]. Biogas production is mainly done through wet fermentation [6]. The microbiological process in producing Biogas is very complex and involves different microorganisms. The production processes are done by decomposition waste through microbes in a controlled environment to produce the Biogas, which are rich in methane [7]. Aquinas et al. [8] paper review the production of Biogas from lignocellulosic waste to meet the increasing demand for energy and the same time, reduce the use of fossil fuel which is among the primary cause of greenhouse gases in our atmosphere.

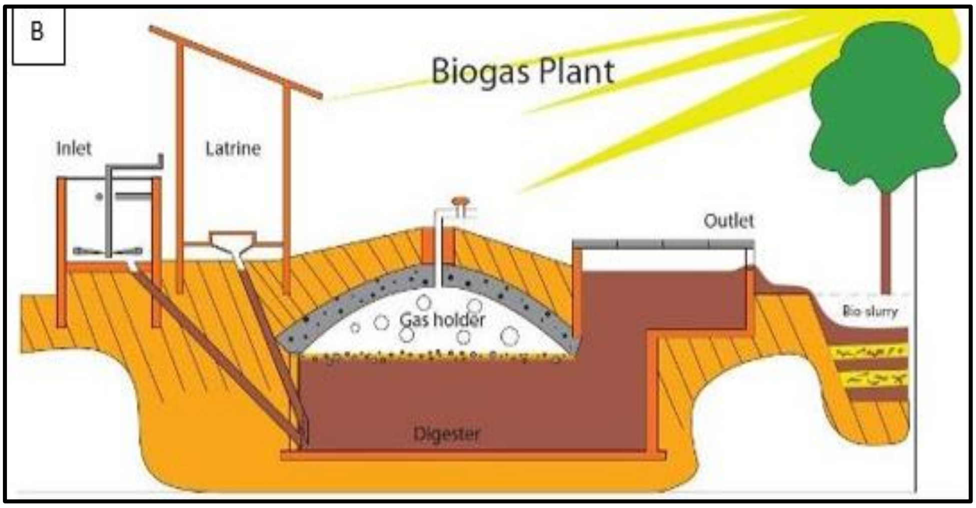
Biogas production ought to be a revolution in energy due to the high demand for energy and its high potential to help us combat climate change by switching to an alternative energy source (Biogas) from fossil fuel. However, the production process in making Biogas a viable competition to fossil fuel energy sources is met with various challenges. De Rosa et al. [9] highlighted the complexity in producing Biogas due to its different composition from different materials and requires energy to break down the materials and catalytic activation.

Figure 1a shows the different sources of biomass used for the biogas production process, and Figure 1b shows the production system and the different stages at which the production process of biogas.

According to Rao et al. [10], biogas production processes have not improved since the production process began. The authors identified the lack of improvement in the biogas Production industries as the demand for energy consumption increases. This lack of improvement is a challenge due to the lack of sustainable policy in biogas production in Nigeria.

However, this research paper focuses on reviewing the impact of benchmarking and multi-criteria analysis as a sustainable tool for the biogas production industries and how it can help develop a policy that will guide and improve biogas production in Nigeria. The novelty of this paper is that the paper provides a valuable suggestion process that the Government needs to apply to develop a sustainable policy that will improve the just-in-time production of biogas in Nigeria, which will lead to improved energy supply and whereby create a sustainable economy for the nation.

(a) Different sources of Biomass materials used for Biogas production [1]



(b) The Biogas production process [1]

Figure 1. The application of Biogas materials in Biogas production plant

2. APPLICATION OF BENCHMARKING AND MULTI-CRITERIA DECISION ANALYSIS IN BIOGAS PRODUCTION

This section reviewed the effect of benchmarking and multi-criteria analysis in biogas Just in Time production in Nigeria.

2.1 Effect of benchmarking of biogas production

The existing biogas production plant to get energy generated from biogas in Nigeria, the local production system still needs improvement. Stürmer et al. [11] researched how to improve biogas production. The authors have researched on benchmarking of various biogas production industries. Results obtained from the comparison show that most biogas production plants are under some legal framework restricting their production, still on the issue of trying to reduce human carbon print in our atmosphere. De Arespacochaga et al. [12] carried out a study on the implementation of high-temperature fuel cells production on cogeneration with sewage biogas. Benchmarking against other options based on industrial-scale data.' try to avoid using greenhouse gas emissions from high-temperature fuel cells used in water treatment plants. A biogas-powered molten carbonate fuel cell was used. After comparison from various biogas production industries, biogas H2S 2500 and 250 pm were used in the study. The storage of biogas products is sometimes difficult.

Gruber-Brunhumer et al. [13] use benchmarking to select a suitable storage cell wall for biogas. Furthermore, this was a microalga with a resistance cell wall. In order to improve biogas production and usage, a constant comparison is needed between renewable and non-renewable energy sources and renewable and renewable energy sources. Lindkvist et al. [14], paper on, "Methodology for analyzing energy demand in biogas production plants—A comparative study of two biogas plants," compared via benchmarking two biogas production firms. The authors worked on this to analyze the efficiency and energy consumption, and production. This is to obtain information about the production process of the better firm, which will increase biogas production effectiveness.

Biogas production has not been adequately utilized in some regions and this most of the time is due to underlying law preventing the use of biogas. Poeschl et al. [15] were able to identify in their paper Prospects for expanded utilization of biogas in Germany.' Via benchmarking for the deployment of biogas as an environmentally friendly renewable energy source compared to other renewable energy like natural gas. In terms of job creation, increasing employment availability from fossil fuel sources to biogas fuel sources would help combat greenhouse effects by putting more concentration on the biogas industry. Dvořák et al. [16] proposed in their paper how benchmarking can be used to increase the employment rate in the biogas industry firms in the Czech Republic. The illustration of the domestic electricity consumption in the Czech Republic is shown in Figure 2.

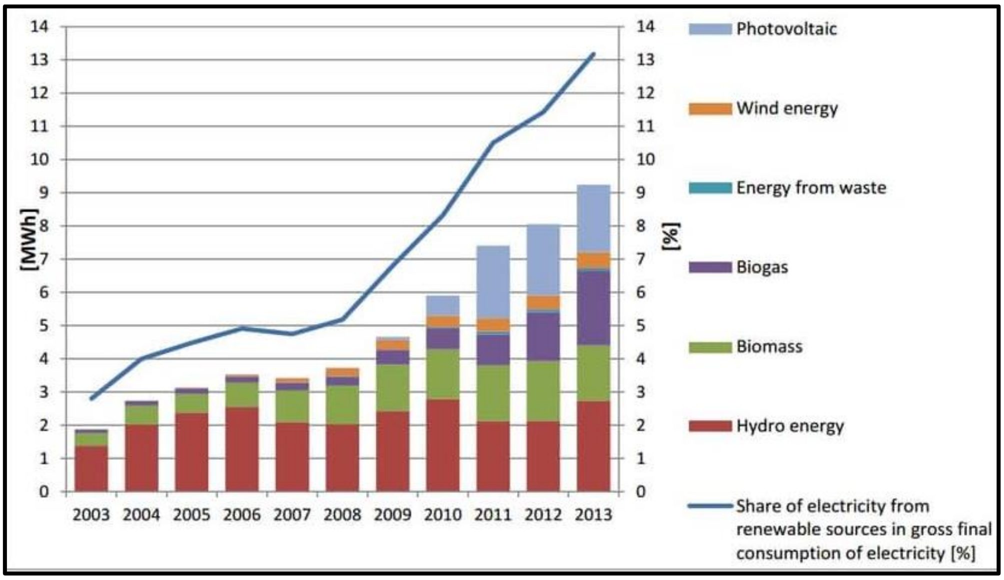


Figure 2. Domestic electricity consumption in the Czech Republic [16]

Tuner [17] Reviewed benchmarking of alternative fuels in conventional and advanced engine concepts with emphasis on efficiency, CO_2, and regulated emissions (No. 2016-01-0882) used benchmarking to find alternative fuel sources. The author's analysis was made through various available fuel sources: methanol, ethanol, and biogas. The research aimed to identify the best alternative fuel sources with fewer carbon emissions. Biogas was proved to be one of the safe alternative fuel sources because of its carbonate neutrality.

Flores-Alsina et al. [18] worked on including greenhouse gas emissions during benchmarking of wastewater treatment plant strategies." using benchmarking has the best biogas heat treatment process for wastewater tanks as shown in Figure 3. The aim is to identify those with fewer carbon emissions footprints as the demand for energy increases and greenhouse effects on our planet rise. The need for the use of renewable energy is currently on the increase. Hahn [19] paper benchmarks the environmental and economic performance of biogas plants. How they supply energy, and the cost of supplying energy is averaging the cost of biogas production.

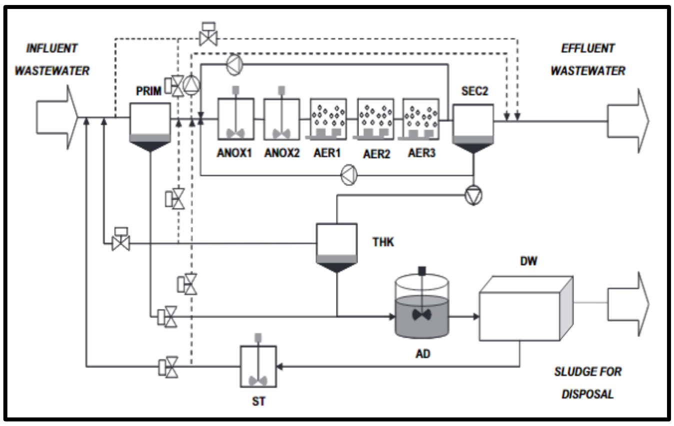


Figure 3. Process chart of a biogas treatment plant [18]

Blumberga et al. [20] studied the "Benchmarking method for estimation of biogas upgrading schemes" proposed a new approach to benchmarking biogas. The method has been developed to compare the indicators of alternative biogas purification and upgrading solutions and their threshold values. The chosen indicators cover both economic and ecological aspects of these solutions, e.g., the prime cost of biogas purification and storage and greenhouse gas emission reduction and cost-efficiency. It also proposed comparing the effectiveness of purifying biogas by benchmarking various purification and upgrading methods. The parameters considered were its effects on cost and climate (greenhouse effect). The best purification method was chosen by Hasan and Ammenberg [21], paper on "Biogas potential from municipal and agricultural biomass for producing power in Hazaribagh," focused on the use of benchmarking the find the optimal means of producing biogas energy due to the increasing demand of energy in Hazaribagh and also intending to eliminate fossil fuel consumption within the state. From the research, the authors observed that biogas production from municipal and agricultural biomass is possible.

De Clercq et al. [22] paper on "Machine learning-powered software for accurate prediction of biogas production: A case study on industrial-scale Chinese production data" used artificial intelligence in the benchmarking process to predict the optimal biogas digester for biogas production. It involves implementing artificial intelligence to two biogas production plants in China and obtaining the most optimal biogas producing plant through an artificial intelligence predictive model. Municipal fecal waste was the input that yielded the most biogas.

2.1.1 Effects of Benchmarking in Just in Time Biogas Production in Nigeria

In order to reduce Solid waste and open dumping of waste in Lagos, Nigeria. Suberu et al. [23] paper on "Renewable power generation opportunity from municipal solid waste: a case study of Lagos metropolis (Nigeria)" focuses on waste to energy in the city of Lagos. This was done by benchmarking the approximate population dumped refuse daily to determine the possible number of MSW available for biogas production, thereby freeing land for other uses. Alabi and Diji [24] Researched how to provide power supply for indigenes of a rural community in Edo state. Benchmarking was carried out on three scenarios, including fossil fuel usage for powering the community, biogas, and sending biogas residuals to the power grid.

2.2 Multi-criteria analysis in producing biogas

One of the significant issues in biogas production is the materials. Determining the suitable waste to use in the production process is sometimes difficult. Feiz & Ammenberg [25] Proposed in the paper 'Assessment of feedstocks for biogas production, part I—A multi-criteria approach' how researchers can use multi-criteria decision-making tool to determine the suitable decision animal waste to be used for the production of biogas and biofertilizer. The authors achieved the production of biogas from different materials via a multi-criteria decision-making tool. Rao et al. [10] proposed in their paper 'Multi-criteria analysis of alternative biogas technologies' how multi-criteria analysis helps produce biomass from various materials. The method employed was the Analytical Hierarchy Process tool. Low energy consumption in the villages and rural environment in Kenya required the development of alternative renewable, cheap energy sources and biogas, which are relatively cheap and capable of reducing poor energy supply in rural areas. Nzila et al. [26] paper focused on biogas production in Kenya regarding power generation sustainability. The paper used multi-criteria analysis of various biogas production alternatives to provide a means of decision-making for biogas production companies in the county.

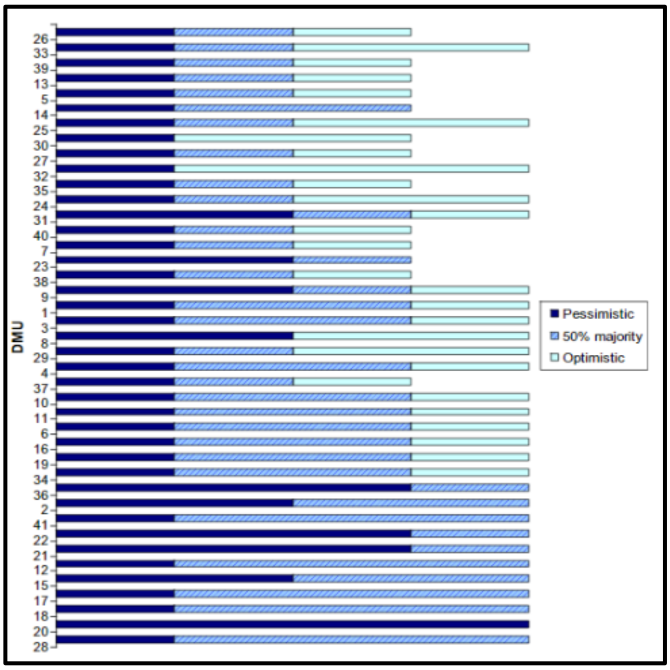


Figure 4. Result from DMU according to DEA with GHG emission

Biogas production is mainly from livestock feedstock. However, Vindiš et al. [27] paper proposed the use of energy crops for biogas production. Multi-criteria analysis was Carried out on the different energy crops alongside simulations. Findings determined that maize was the best energy crop for biogas production. Still on energy crops, Madlener et al. [28] assessed the performance of biogas plants with multi-criteria and data envelopment analysis, which assessed various energy crops in Austria to determine their performance. The research was based on data envelopment analysis (DEA) and multi-criteria analysis. Multi-criteria decision analysis together with IRIS yield better results compared to the DEA approach. The results in Figure 4 are carried out with the decision-making units (DMU) ranking according to the DEA score for efficiency along with the greenhouse gas (GHG) emission.

There is different biomass that can be used for the production of biogas. Each has its characteristics. Seabra Júnior et al. [29] worked on "Biomass selection method to produce biogas with a multi-criteria approach." The study developed a mathematical model via multi-criteria analysis to determine which biomass is required to produce high-quality biogas. Biogas cannot be produced if there is not a favorable environment to site the biogas digester plant. Silva et al. [30] study focused on determining a suitable environment for establishing a biogas plant via multi-criteria decision analysis. The multi-criteria decision-making considers various factors, among which are economic factors, safety factors. The study observed that the MCDA was very good in determining real-world problems looking for suitable land for biogas. Nzila et al. [31] carried out "Multi-Criteria sustainability of biogas production in Kenya," focused on the use of multi-criteria decision analysis in the production of biogas digester to provide sustainable electricity within rural areas in Kenya. The analysis focused on the sustainability of the technical, economic, and environment. The research observed that a tabular and fixed dome digester were the most sustainable after carrying out multi-criteria analysis.

Robert et al. [32] studied the "Technology selection and siting of a biogas plant for the organic fraction of municipal solid waste (OFMSW) via multi-criteria decision analysis." The study focused on the use of multi-criteria analysis to select a biogas digester and to determine the location for installing a biogas plant within the University of Johannesburg's Doornfontein campus in South Africa. Fourteen biogas digesters were considered and three site locations using a simple multi-attribute rating technique (SMART) and analytic hierarchy process (AHP). The research work shows that the Puxin digester was the best near a female hostel at the Doorbfontein campus within the school premises.

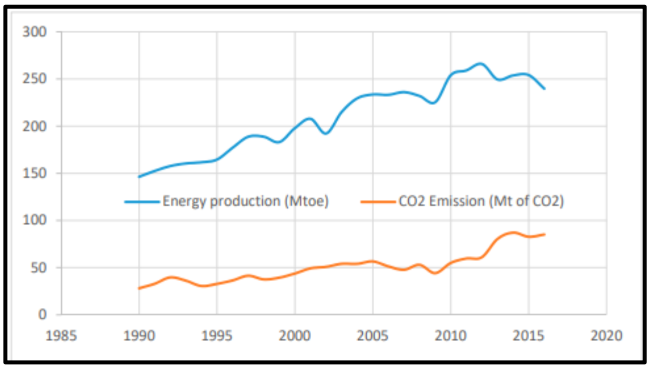


Figure 5. Carbon emission from fossil fuel [33]

2.2.1 Effect of multi-criteria analysis in biogas production in Nigeria

Northern Nigeria has the highest livestock farmers in the country, and waste from livestock in the northern part tends to be a significant issue as it mostly leads to pollution. In a country where energy consumption needs are high and supply is low with high CO_2 emissions, Figure 5. There is every need to find an alternative power supply with a cheap and readily available source. Audu et al. [33] paper focused on using multi-criteria analysis on livestock waste for either fuel source or fertilizer. The authors find out that the application of converting waste products to electricity will be more profitable than fossil fuels. Also, the study concluded that there is a high need for public and policy support for biomass production into biogas for efficient and sufficient energy supply. However, in Nigeria, no policy guides the biogas production process.

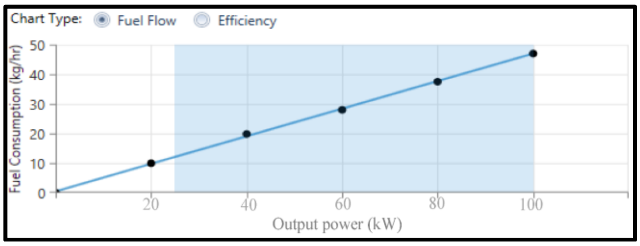


Figure 6. Biogas power out per fuel consumption [34]

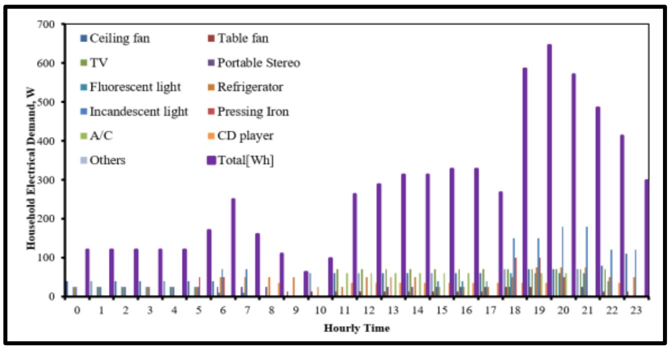


Figure 7. Household electrical component for daily energy consumption [35]

Ukoba et al. [34]] work on "Composite multi-criteria decision analysis for optimization of hybrid renewable energy systems for geopolitical zones in Nigeria." The study focuses on improving renewable energy sources by considering eight different hybrid renewable energy systems to improve energy consumption in various households in Lagos, as shown in Figure 6. All eight renewable energy systems were subjected to multi-criteria decision analysis, and the biogas hybrid system performed best. Diemuodeke et al. [35] carried an estimate on the household component that consumed energy on a coastline solar energy of a rural area community. The analysis of the results is shown in Figure 7. The study shows a need for a renewable energy generation process that will assist rural area communities.

3. BIOGAS PRODUCTION IN NIGERIA CHALLENGES AND WAY FORWARD

The significant challenges in biogas production in Nigeria lie in the Governments governing the operations and production. The industry can get Biogas from most waste products, which will highly assist in reducing environmental pollutions. It is worthy to note that there are no available sustainable policies that guide the production process of biomass to Biogas in Nigeria, and Biogas from the literature has proven to be a potential source for energy generation. The significance of research in the sustainable development of economic growth and policy can not be quantified [36-39].

The way forward is that the Government needs to develop a firm policy that will assist manufacturing companies to efficiently carry out the production process of Biogas with standard principles.

3.1 Benchmarking process for Policy Development of Biogas Production in Nigeria

Benchmarking is a distinguished process that guides a system to develop policy via five various steps. There are three significant types of policy from literature: regulatory, distributive, and redistributive policy [40-43]. The system or the Government can develop the policy in two different ways, bottom-up and top-down methods.

The top-down process is a straightforward procedure for studying the yearly report on the biogas process and is used as an end product. These two methods are essential techniques that need many vows from the decision-makers on the safety regulation of the policy governing the production of Biogas in Nation. Nevertheless, the benchmarking procedure comprises five steps, i.e., the planning process, data investigation, incorporation of the findings, implementation, assessment of the benchmarking process, implement decision policy for the implementations of biogas production in Nigeria, shown in Figure 8.

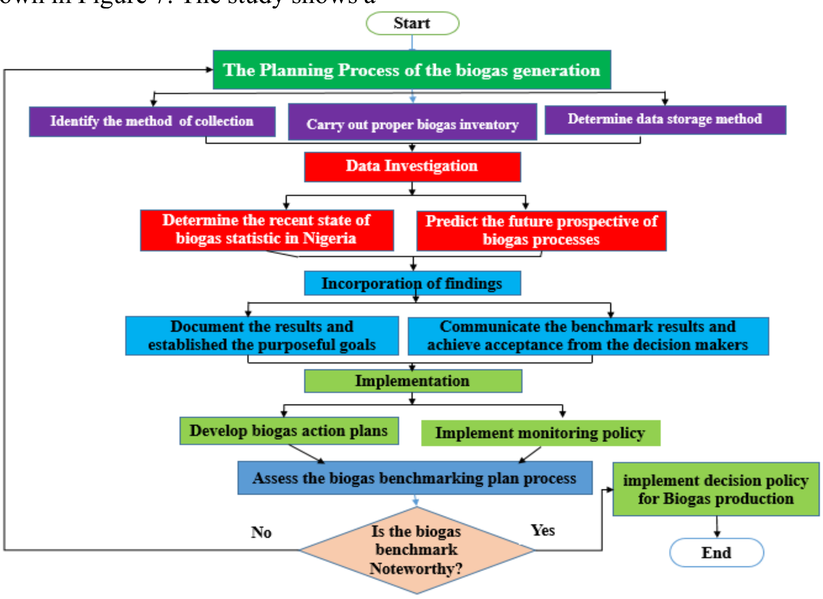


Figure 8. Benchmarking process policy for developing sustainable Biogas production in Nigeria

Step one: The biogas planning process should comprise a team set of seven (7) by the Government with the required knowledge in the biogas production process. This team will map out the design plan, location of a standard production plant for biogas production, employed professionals to carry an inventory of different sites where biomass can be primarily obtained, and device mix for a sustainable collection process and possible storage methods.

Step Two: from the first step, the data collected should be analyzed using the professional process to determine the current state of the art of the available biomass and order waste materials employed to produce biogas. The data analyst can also use data to predict the life span of the availability of this waste material for sustainable biogas production. Predicting the waist product efficiency of the biogas production in Nigeria will enhance the production process and assist the economic viability in the Nation.

Step Three: Incorporating the finding into the design process is two-level, such as the adequate documentation of all investigations carried out and communicating the research findings from the benchmarking to the decision-makers and the communities to gain acceptance.

Step Four: the implementation of the policy is a very significant stage. The action plan that is developed will be put into work. The processing standard of the biogas lies in the implementation process of the developed policy. At this point, the government policy will be stated on the step-by-step procedure to avoid impurity in the biogas and improve the efficiency of the developed biogas.

Step Five: The team, decision-makers, and the communities need to agree on a proper process to evaluate the benchmarking process used for the policy development. If suitable and economically viable, the decision-makers should abduct the policy plan and implement it. Furthermore, to obtain a smooth running policy, the Government should establish a body to govern the process with quality checks from a specific time and periods; with this, the running and the operation of biogas production will be efficient and serve the Nation wisely.

3.2 Multi-Criteria Decision Analysis Steps to Achieve Sustainable Development Policy

The multi-criterial decision analysis (MCDA) is majorly a selection process. However, the method can select the appropriate site for the biogas production plant and laboratory installation [44-46]. This MCDA is made up of different designs such as Aggregated Indices Randomization Method (AIRM), Analytic hierarchy process (AHP) Analytic network process (ANP), gives an excellent understanding to the production of the biogas as it relates to the economic perception of biogas to this country. The MCDA can also be used to carry out further analysis of biomass use for biogas production. Several researchers have engaged the implementation of MCDA in the selection process and making concrete decision processes for sustainable development [47-52].

4. CONCLUSION

The research focuses on the effects of benchmarking and multi-criteria decision analysis on the biogas production process. The main area of concentration is on the effects of benchmarking and multi-criteria decision analysis towards sustainable policy development for biogas production and implementation in Nigeria. From rigorous literature review carried out in the study shows standard policy can be successfully developed for a better production process for the just-in-time biogas production in Nigeria. Also, it has the following conclusion:

- Multi-criteria decision analysis can be applied to determine the best fuel required for biogas production and possibly also to determine the exact energy crop that produced the best biogas when applied
- Also, the study sufficiently recommended a standard procedure for developing sustainable policy via the benchmarking tool with the five steps

The study will recommend further works on the hybrid formulation of benchmarking process with multi-criteria decision analysis to produce sustainable policy that the Government of Nigeria will apply. In order to increase the nation's economic value via biogas production and implementation policy.

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