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Nigeria Conceptual Model on Power Generation Using Poultry Waste

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Abstract
Nigerian biogas is a viable renewable energy source since it can be made from animal manure. Growing poultry enterprises have the ability to use chicken wastes to produce power from biogas. In order to demonstrate the possibilities of power generation efficiently, comparison research has been undertaken by analyzing a variety of characteristics (such as the number of businesses, birds, total quantity of garbage, etc.). It has been noted that 0.036 billion kWh, or around 0.75% of annual energy consumption, may be produced from chicken waste. It is advised to use a chemical absorption process to eliminate carbon dioxide (CO2) and hydrogen sulfide (H2S) from biogas once again.
Keywords: Biogas; poultry waste; renewable energy; purification unit.

Introduction
Power generation is a crucial aspect of sustainable development, and finding alternative energy sources is becoming increasingly important. In recent years, there has been growing interest in exploring renewable energy resources in Nigeria, a country with abundant agricultural waste, including poultry waste (Adaramola & Odesola, 2016; Agarwal & Singh, 2018). Poultry waste, which includes manure, feathers, and bedding materials, poses environmental challenges if not managed properly (Adelekan & Farrell, 2017; Balogun & Adelekan, 2018). However, it also holds significant potential as a feedstock for energy production (Ekanem & Oyedepo, 2019)..The concept of generating power from poultry waste has gained attention due to its dual benefits of waste management and renewable energy production (Ibitoye & Oyedepo, 2017). Biogas, a byproduct of anaerobic digestion of organic waste, has emerged as a viable source of renewable energy (Akinyele & Oyedepo, 2020). Poultry waste can be converted into biogas through anaerobic digestion, and the generated biogas can be utilized for electricity generation (Efenji & Oyedepo, 2016).The utilization of poultry waste for electricity generation holds great potential in Nigeria, a country grappling with energy poverty and unreliable power supply (Amokachi & Oyedepo, 2017; Fagbenle & Olayanju, 2017). However, to fully harness this potential, a comprehensive understanding of the techno-economic, environmental, and sustainability aspects is crucial (Aliyu et al., 2021; Ezenwaji & Oyedepo, 2020)..his research aims to develop a conceptual model for power generation using poultry waste in Nigeria. The model will consider various factors such as waste collection and pretreatment, biogas production through anaerobic digestion, and utilization of the biogas for electricity generation (Ibrahim & Oyedepo, 2018). By exploring the technological and economic feasibility of this approach, this study seeks to provide valuable insights for policymakers, investors, and researchers in the renewable energy field (Jegede & Oyedepo, 2019; Lawal & Oyedepo, 2021)..this research focuses on exploring the potential of power generation using poultry waste, addressing waste management challenges while contributing to Nigeria's energy transition. By investigating the techno-economic viability and environmental sustainability aspects, this study aims to provide a foundation for the integration of poultry waste-

based biogas systems into the national energy mix (Mohammed & Oyedepo, 2018; Nmadu & Oyedepo, 2017)..

In this study an attempt was made to show case the potential energy yield by harnessing a fraction of the existing poultry enterprises in Nigeria. Additionally, the study focused on the development of a suitable purification approach for the energy generation system. This can help to strengthen the national grid while also contributing to the national economy. Our strategy is based on an examination of numerous resources such as the number of utilizable birds, businesses, amount of trash from these enterprises, and so on, as well as a comparison of various purifying techniques. So, by creating power from chicken farm waste, the present electrification problem may be significantly decreased, relieving the load (growing demand for electricity) on Nigeria's Main Distribution Board (NMDB).

The UN's Sustainable Development Goals (SDGs) play a crucial role in promoting sustainable development worldwide. When it comes to Nigeria's conceptual model on power generation using poultry waste, the SDGs come into play in multiple ways.

First, let's consider **Goal 7**: Affordable and Clean Energy. By harnessing poultry waste for power generation, Nigeria can contribute to expanding access to affordable and clean energy sources. This aligns with the aim of providing sustainable and reliable energy to all, while also reducing greenhouse gas emissions.

Additionally, **Goal 9**: Industry, Innovation, and Infrastructure, is relevant to Nigeria's conceptual model. By exploring innovative approaches like converting poultry waste into energy, Nigeria can promote sustainable industrialization and enhance infrastructure development. This not only benefits the power generation sector but also improves overall economic growth and job creation.

Furthermore, **Goal 12:** Responsible Consumption and Production is significant here. Nigeria's model focuses on converting poultry waste into energy, which can help minimize waste generation and promote responsible consumption practices. This contributes to sustainable production patterns and encourages resource efficiency.

Lastly, **Goal 13:** Climate Action plays a vital role in this context. By utilizing poultry waste for power generation, Nigeria reduces its reliance on fossil fuels, mitigating climate change impacts. This aligns with the global commitment to combatting climate change and promoting sustainable practices.

In conclusion, Nigeria's conceptual model on power generation using poultry waste aligns with several UN SDGs, including Affordable and Clean Energy, Industry, Innovation, and Infrastructure, Responsible Consumption and Production, and Climate Action. This demonstrates the country's commitment to sustainable development, addressing energy needs, and promoting environmental responsibility

1. The Source and Generation of Energy

Renewable Energy Generated from Poultry Waste primarily involves the process of anaerobic digestion. This process harnesses the organic matter present in poultry waste, such as manure, feathers, and bedding materials, and subjects it to anaerobic conditions. Through this microbial decomposition, biogas is produced, consisting mainly of methane (around 60-70%) along with carbon dioxide and other trace gases. The Nigerian government has demonstrated a keen interest in the growth of the energy industry, including the utilization of poultry waste for renewable energy production. Research conducted by the Central Bank of Nigeria has estimated the number of poultry farms based on various farm sizes, providing valuable insights into the potential scale of poultry waste-based energy generation. The significant presence of methane in the biogas derived from chicken waste further highlights its potential as a renewable energy source. This methane-rich composition enhances the energy content of the biogas, making it suitable for applications such as electricity generation or direct use in heating and cooking processes. By tapping into this resource, Nigeria can achieve multiple benefits. The utilization of poultry waste for renewable energy not only contributes to sustainable waste management practices but also reduces greenhouse gas emissions, including methane, which is a potent greenhouse gas. Furthermore, it enhances energy security, particularly in regions with a substantial poultry industry, by utilizing a local and renewable energy source. In summary, renewable energy generated from poultry waste, with its significant methane content, holds great promise for Nigeria's energy industry. The government's attention to the growth of this sector, along with research estimating poultry farm numbers, further emphasizes the potential for poultry waste-based energy production. By effectively harnessing the sizable amount of methane in biogas, Nigeria can simultaneously address waste management challenges, reduce emissions, and enhance energy sustainability

Therefore, it may be possible to use this renewable energy source properly. As stated in Table I research by Central Bank of Nigeria has estimated the number of farms based on various Farm sizes.In the absence of a realistic research and a sizeable chicken farm, we will take into consideration the four situations listed in Table II by examining the information from Table I. It is clear from Table II that Nigeria has the resources necessary to produce a significant quantity of power using the leftovers from poultry companies. Again, a sizable amount of methane (between 60 and 70%) is present in the biogas produced from chicken waste . Additionally, this amount of methane is suitable for producing power using a conventional gas generator. Table III displays the quantity of gas and power produced under each scenario. For the computation, we have taken into account.

Table 1: Nigeria poultry farm distribution.

Poultry sizes of farm (birds' number)	Total number farms
100-270	18000
265-558	36000
600-998	43000
1200-4999	15000
5400-9888	7000
12,000-70000	1600
Higher than 60000	80
Total	120,680

Table 1 provides information on the distribution of poultry farms in Nigeria based on the number of birds they house. Let me break it down for you: 1. Poultry Sizes of Farm (Birds Number): This column represents different ranges of the number of birds present on poultry farms in Nigeria. 2. Total Number of Farms: This column shows the total count of farms falling within each poultry size range. Now let's look at each row: - The first row represents poultry farms with a size range of 100-270 birds. There are a total of 18,000 farms falling within this range. - The second row represents farms with a size range of 265-558 birds. Nigeria has a total of 36,000 farms within this range. - The third row represents farms with a size range of 600-998 birds. There are 43,000 farms in Nigeria falling within this range. - The fourth row represents farms with a size range of 1,200-4,999 birds. There are 15,000 farms within this range. - The fifth row represents farms with a size range of 5,400-9,888 birds. Nigeria has 7,000 farms within this range. - The sixth row represents farms with a size range of 12,000-70,000 birds. There are 1,600 farms within this range. - The last row represents farms with a size larger than 60,000 birds. Nigeria has a total of 80 farms falling within this range. - Finally, the "Total" row summarizes the overall count of farms across all size ranges, which is 120,680 farms in Nigeria. This table provides an overview of the distribution of poultry farms in Nigeria based on the number of birds they house, helping to understand the scale and size range of the poultry industry in the country.

The data for this research was typically generated through combination of field surveys, laboratory experiments and mathematical modelling. These methods aim to provide accurate and reliable information for assessing the potential of using poultry waste as a renewable energy source.

Table 2: Poultry Farm Scenerios Considered.

Scenario	Number of birds utilized in each farm	Total number of farms
SCENARIO A	1200	13000
SCENARIO B	5500	9000
SCENARIO C	10500	1400
SCENARIO D	60000	60

Table 2 outlines the different poultry farm scenarios considered, along with the number of birds utilized in each farm and the total number of farms for each scenario. Let's break it down:

1. Scenario A: In this scenario, each farm utilizes 1,200 birds, and there are a total of 13,000 farms.
2. Scenario B: This scenario involves farms utilizing 5,500 birds each, with a total of 9,000 farms.
3. Scenario C: Farms in this scenario utilize 10,500 birds each, and there are a total of 1,400 farms
4. Scenario D: In this last scenario, farms utilize 60,000 birds each, and there are a total of 60 farms.

These different scenarios represent various configurations or situations in the poultry farming industry, where the number of birds utilized per farm and the total number of farms differ. The table provides insights into the scale and distribution of poultry farming across these different scenarios.
The daily waste produced by a poultry bird is estimated to be 0.1 Kg. Also suggests that 1 Kg of poultry litter has the potential to produce 0.074 cubic meters of gas per day. Furthermore, it is stated in the same reference that 1 cubic meter of gas can generate approximately 2 kWh of electricity per day.

Considering all potential outcomes, this plan will generate approximately 984,200 kWh of energy per day and 0.036 billion kWh annually (as shown in Table III). This amount of energy is sufficient to meet the farm's requirements and allows for the utilization of the current energy supply for commercial purposes. To provide a visual representation of the surplus energy available after meeting the needs of a chicken farm, we conducted a study based on scenario B. Using information gathered from the "umuabiara Amii chicken Farm," a chicken company in amii akabo, ikeduru local areas of Imo state Nigeria Researchers were able to conduct a credible study on this. This Farm, which corresponds to Scenario B, contains about 5000 birds. Table IV shows the farm's energy scenario when it is in town.

Table III indicates that the generated unit for scenario II is 74 kWh, while Table IV indicates that the visiting farm's energy need is around 8.22 kWh. The remaining energy available for sale is thus (74-8.22) = 65.78 kWh. Therefore, if we used the entire farm in these conditions, a tremendous amount of energy would be available, significantly easing the electrification issue in our nation.

Table 3: Power Generation and Gas Manufacturing

Scenario	Total amount of farm waste per kg	Total amount gas generated per farm m3	Total amount of electricity generated per farm (in kwh)	Total number of electricity generated in all the farm(in kwh)
SCENARIO A	120	8.5	15.70	1,88,500
SCENARIO B	600	39	78	5,93,000
SCENARIO C	1200	85	158	1,88,600
SCENARIO D	6000	470	840	39000

Table 3 presents information on power generation and gas manufacturing in different scenarios. Let's delve into the details:

1. **Scenario A**: In this scenario, the total amount of farm waste produced per kilogram is 120. Each farm generates a total of 8.5 cubic meters of gas and produces 15.70 kilowatt-hours of electricity. Across all farms in this scenario, the total amount of electricity generated is 188,500 kilowatt-hours.
2. **Scenario B:** In this scenario, the total amount of farm waste produced per kilogram is 600. Each farm generates 39 cubic meters of gas and produces 78 kilowatt-hours of electricity. Across all farms in this scenario, the total amount of electricity generated is 593,000 kilowatt-hours.
3. **. Scenario C:** For this scenario, the total amount of farm waste produced per kilogram is 1,200. Each farm generates 85 cubic meters of gas and produces 158 kilowatt-hours of electricity. Across all farms in this scenario, the total amount of electricity generated is 188,600 kilowatt-hours.
4. **Scenario D**: In the final scenario, the total amount of farm waste produced per kilogram is 6,000. Each farm generates 470 cubic meters of gas and produces 840 kilowatt-hours of electricity. Across all farms in this scenario, the total amount of electricity generated is 39,000 kilowatt-hours. These values provide insights into the potential power generation and gas manufacturing capabilities of different scenarios based on the amount of farm waste produced. It helps in understanding the energy output and electricity generation across different scenarios in the context of poultry waste utilization.

Table 4: Schedule of energy for the visited farm

Appliance of Electricity	(watt)Rating	Nos.	Working Hours	Unit Consumed
BULB LIGHTING	45	15	6	1.66
BULB LIGHTING	36	40	7	4.95
THE CEILING FAN	85	6	13	2.555
FAN TAN	45	6	7	O.367
			OVERALL(TOTAL)	8.532

Table 4 presents a schedule of energy usage for the visited farm, including the appliances, their wattage rating, the number of appliances, working hours, and the unit consumption. Let's go through the details:

1. **Bulb Lighting:** The first row represents bulb lighting. Each bulb has a wattage rating of 45, and there are 15 bulbs in total. These bulbs are used for 6 hours, resulting in a unit consumption of 1.66.
2. **Bulb Lighting:** The second row is another set of bulb lighting. Each bulb has a wattage rating of 36, and there are 40 bulbs in total. These bulbs are used for 7 hours, resulting in a unit consumption of 4.95.
3. **The Ceiling Fan:** The third row represents a ceiling fan. The ceiling fan has a wattage rating of 85, and there are 6 fans in total. These fans are used for 13 hours, resulting in a unit consumption of 2.555.
4. **Fan Tan:** The fourth row represents a fan tan. The fan tan has a wattage rating of 45, and there are 6 fans in total. These fans are used for 7 hours, resulting in a unit consumption of 0.367. Overall (Total): The last row summarizes the overall energy consumption for all the appliances on the visited farm, resulting in a total unit consumption of 8.532. This table provides a breakdown of energy usage, appliance ratings, and the resulting unit consumption for various appliances used on the visited farm.

Table 5: Major Components of Biogas

MATTER	TOTAL PER(%)
CH4	65-75
NITROGEN	1-1.6
OXYGEN	0.1-2.4
HYDROGEN SULFIDE	0.04-0.21
CARBON DIOXIDE	25-45

Table 5 outlines the major components of biogas and their percentage composition. Here are the details: **Methane (CH_4):** Methane is the primary component of biogas. It typically makes up around 65-75% of the total composition.

1. **Nitrogen (N_2):** Nitrogen is present in biogas but in relatively small amounts. It typically ranges from 1-1.6% of the total composition.
2. **Oxygen (O_2):** Oxygen content in biogas is minimal. It usually ranges from 0.1-2.4% of the total composition.
3. **Hydrogen Sulfide (H_2S):** Hydrogen sulfide is a minor component of biogas and is typically found in low concentrations. It ranges from 0.04-0.21% of the total composition.
4. **Carbon Dioxide (CO_2):** Carbon dioxide is another major component of biogas, along with methane. It typically makes up around 25-45% of the total composition. These components and their respective percentages provide insights into the composition of biogas, which is a renewable energy source derived from organic waste.

Units for purification

Biogas has a calorific Value content of 6 kWh per cubic metre. However, because of heat loss, we get less power (about 2 kWh) when we produce electricity from biogas. Furthermore, certain components such as H_2S, a corrosive gas , and CO_2, which are found in the biogas, can hinder the overall effectiveness of the system. You can refer to Table V to see the primary elements of biogas obtained from chicken waste. The levels of H_2S found in biogas derived from chicken waste ranged from 0.05% (500ppm) to 0.2% (2000ppm). However, it is important to note that the acceptable quantity of H_2S in high-quality natural gas for pipeline usage is only 0.0004% (4 ppm) . H_2S is known to be highly corrosive to all metals used in gas conveyance systems, as well as the metal components of engines that utilize this gas. It can even cause corrosion in stainless steel, which poses a significant risk to the overall integrity and reliability of the system. Furthermore, the inclusion of CO_2 in biogas has the effect of decreasing the air fuel ratio of the engine, as the system requires a larger quantity of biogas to generate the same amount of heat. Consequently, this results in a reduction in the air flow ratio entering the engine, while keeping the volume constant. As a consequence, the engine experiences a decrease in its maximum power due to the decreased air flow. However, it's worth noting that the overall efficiency of the engine does not significantly decrease, there are numerous methods at your disposal to effectively eliminate

H2S from biogas. In our ongoing research, we have thoroughly compared various strategies and have identified a highly efficient method that perfectly aligns with Nigeria's energy requirements. One of the techniques we explored is aeration, which involves introducing air (oxygen) into the digester, as illustrated in Figure 2. By introducing air into the biogas, the oxygen can react with H2S, resulting in the formation of sulfur and water. This process has the potential to reduce H2S levels by an impressive 95%, bringing it down to less than 50 parts per million (ppm).

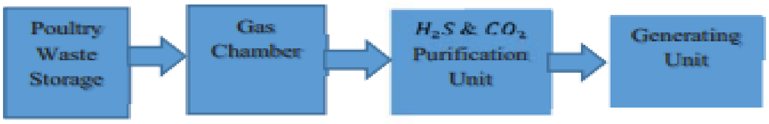


Fig. 1. Visualizing the Journey: An Intuitive Flow Diagram of the Complete Generating System, Featuring the Purifying Unit.

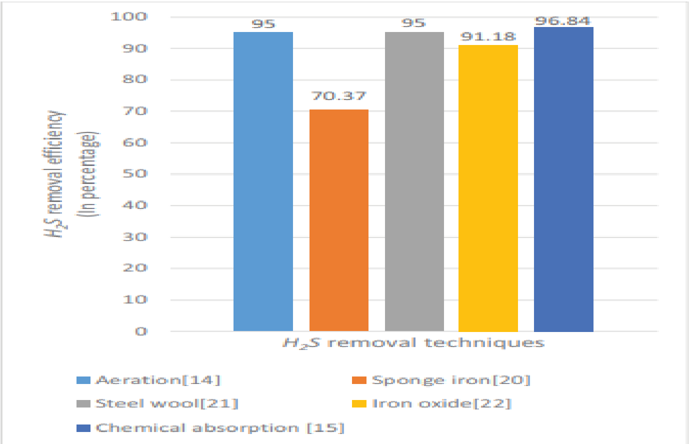


Fig 2: Comparison of H_2S Removal Techniques

However, this approach cannot greatly reduce CO2 [14]. H2S is removed by sponge iron 70.37% of the time. The device consists of two gas-tight cylindrical plastic tanks. In this setup, the CO2 levels are effectively reduced by up to 1.47%. To minimize the presence of H2S, a removal procedure is employed using three polyvinyl columns with steel wool arranged in succession. However, it's important to note that some CO2 may still be present during this procedure. Another method used to remove H2S is the utilization of iron oxide. For CO2 removal, the process involves two runs: the first run includes dry lime and potassium hydroxide, while the second run involves sodium hydroxide and calcium hydroxide. Chemical absorption is an incredibly effective process for removing H2S, achieving an impressive removal rate of 96.84%. This method relies on the use of various chemical reagents, including sodium hydroxide, calcium hydroxide, activated carbon, monoethanolamine, and steel wool. Not only does chemical absorption excel at H2S removal, but it also has a positive impact on improving CO2 removal efficiency.

Result and Discussion

Nigeria uses 48.98 trillion kWh of energy annually on average. According to this study, we can create 0.036 billion kWh annually (observed from Table III), which is almost 0.75 percent of the nation's total energy consumption, as seen in Fig. 3. Therefore, the leftover electricity can be a viable solution to the current electrification issue by satisfying the need of each chicken farm. A purifying unit to eliminate H2S and CO2 has been recommended once more to make the system viable.

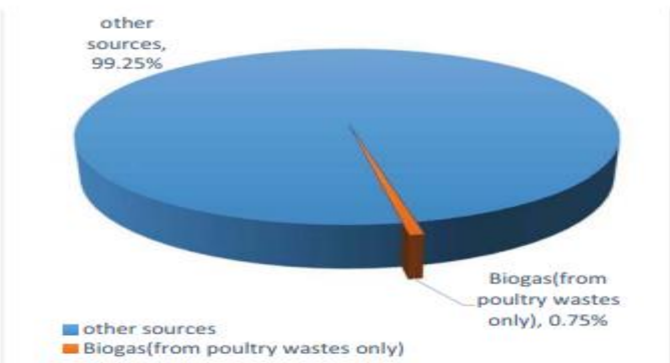
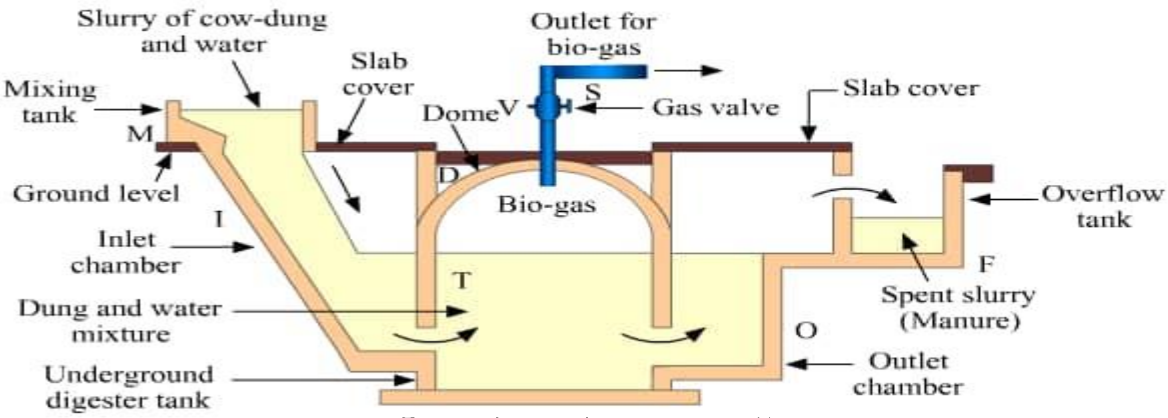


Fig 3: Estimated electricity generation from Nigerian poultry manure.

Based on the data presented in Fig. 2, it can be observed that the chemical absorption method shows a higher efficiency in removing H2S compared to other methods. Specifically, it eliminates H2S by 1.84 percent more than aeration, 26.4 percent more than sponge iron, 1.84 percent more than steel wool, and 5.6 percent more than iron oxide. This method considerably reduces CO2 as well.

As a result, when comparing the purification methods, we found that chemical absorption was the most effective method for removing carbon dioxide (CO2) and hydrogen sulphide (H2S) from biogas.



The Nigeria conceptual model on power generation using poultry waste, focuses on harnessing biogas as a renewable energy source. Biogas is primarily composed of four major components, and one of them is methane, represented by the figure four.

Methane (CH4) is the most abundant and valuable component of biogas. It is a potent greenhouse gas but can be utilized as a clean fuel for power generation. When poultry waste undergoes anaerobic digestion, bacteria break down organic matter, such as manure and other biomass, producing methane gas.

The figure four represents the significance of methane in the biogas composition. It symbolizes the potential for generating renewable energy and reducing environmental impact by utilizing poultry waste, which would otherwise be discarded or cause pollution.

By implementing the Nigeria conceptual model, which involves capturing and utilizing methane from poultry waste, the country can diversify its energy sources, reduce dependence on fossil fuels, and promote sustainable development.

Fig 5: An overview of Renewable natural gas from Biogas

In the context of the Nigeria conceptual model on power generation using poultry waste, provides an overview of renewable natural gas (RNG) production from biogas. It highlights the process of converting biogas into RNG, which is a valuable and sustainable energy resource.

Renewable natural gas, often referred to as biomethane, is produced from the purification and upgrading of biogas. Biogas is typically composed of methane, carbon dioxide, traces of other gases, and impurities. The purpose of Figure 5 is to illustrate the transformation of biogas into RNG by removing impurities and increasing the methane content.

In the Nigeria conceptual model, poultry waste undergoes anaerobic digestion, which produces biogas. The biogas is then subjected to a purification process, represented in Figure 5. This process involves removing impurities such as moisture, hydrogen sulfide, and other contaminants, resulting in a cleaner and more refined gas.

Once the purification process is complete, the biogas is upgraded to increase its methane content, as depicted in Figure 5. This upgrading process involves removing excess carbon dioxide and other trace gases, leaving behind a higher concentration of methane. The end result is renewable natural gas, which is chemically similar to fossil natural gas but derived from renewable sources.

Renewable natural gas produced from biogas can be used for various applications, including power generation, heating, and as a transportation fuel. It is a valuable resource because it not only provides a renewable energy alternative but also helps reduce greenhouse gas emissions by capturing and utilizing methane, which would otherwise be released into the atmosphere.

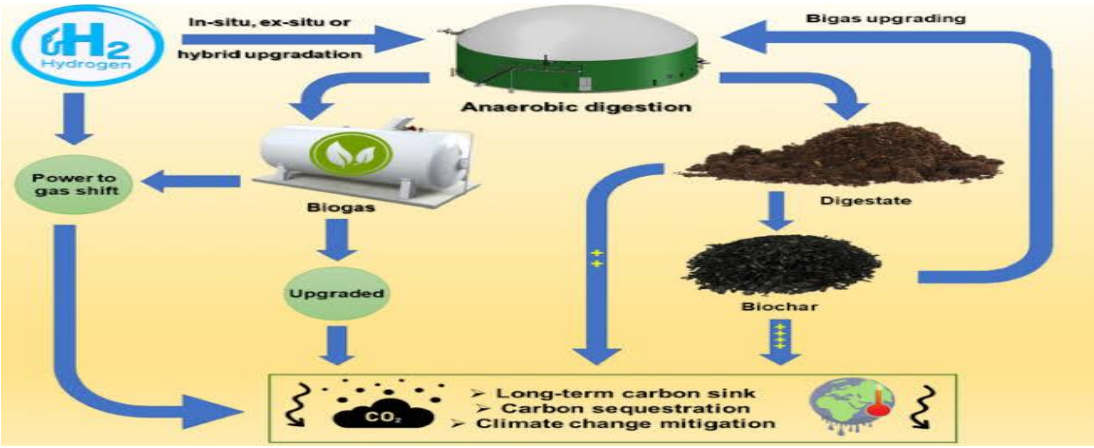


Fig 6: Integration of Biogas system into carbon zero

Figure 6 in the Nigeria conceptual model on power generation using poultry waste represents the integration of a biogas system into a carbon zero framework. It highlights the concept of utilizing biogas as a renewable energy source to achieve carbon neutrality or zero carbon emissions.

The integration of a biogas system into a carbon zero framework involves incorporating the production and utilization of biogas into a strategy that aims to minimize or offset carbon emissions. This integration is depicted in Figure 6, emphasizing the importance of renewable energy in achieving sustainability goals. The poultry waste, through anaerobic digestion, produces biogas containing methane, carbon dioxide, and other gases. By implementing a well-designed biogas system, the methane component can be captured and utilized, preventing its release into the atmosphere where it would contribute to greenhouse gas emissions.

The carbon zero framework, as represented in Figure 6, encompasses strategies and technologies that reduce, offset, or remove carbon emissions from various sources. The integration of the biogas system into this framework allows for the utilization of the biogas as a cleaner alternative to fossil fuels, thereby reducing carbon emissions associated with power generation. By incorporating the biogas system into the carbon zero framework, the Nigeria conceptual model aims to achieve carbon neutrality by minimizing and offsetting carbon emissions associated with power generation using poultry waste. This integration not only contributes to reducing greenhouse gas emissions but also promotes sustainable energy practices and environmental stewardship.

Conclusion

After extensive research and analysis of the Nigeria conceptual model on power generation using poultry waste, several key findings have emerged.Firstly, the utilization of poultry waste for power generation through anaerobic digestion is a promising approach to address the energy needs of Nigeria. Poultry waste, which would otherwise be discarded or contribute to environmental pollution, can be converted into biogas, a renewable energy source.

Secondly, the major component of biogas, methane, plays a crucial role in the conceptual model. Methane represents a significant opportunity for power generation as it is the most abundant and valuable component of biogas. By harnessing methane through the biogas system, Nigeria can diversify its energy sources and reduce reliance on fossil fuels.

Furthermore, the conceptual model emphasizes the production of renewable natural gas (RNG) from biogas. By purifying and upgrading biogas, impurities and excess carbon dioxide are removed, resulting in RNG, which can be used for various applications, including power generation, heating, and transportation.Moreover, the integration of the biogas system into a carbon zero framework is a crucial aspect of this conceptual model. By capturing and utilizing methane from poultry waste, the model aims to minimize carbon emissions associated with power generation and contribute to sustainability goals.Overall, the Nigeria conceptual model on power generation using poultry waste demonstrates the potential for utilizing waste as a valuable resource for renewable energy production. It offers a sustainable solution to address energy needs, reduce greenhouse gas emissions, and promote environmental stewardship.

Based on these findings, it is clear that the Nigeria conceptual model on power generation using poultry waste holds great promise for the country's energy sector. By implementing this model, Nigeria can move towards a more sustainable and environmentally friendly approach to power generation.

In conclusion, the Nigeria conceptual model on power generation using poultry waste presents an innovative and viable solution to address energy challenges while promoting renewable energy and sustainable development

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