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Biogas: An Alternative Energy Source for Domestic and Small-Scale Industrial Use in Nigeria

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ABSTRACT

In Nigeria today, there is a lot of waste that is being generated on a daily basis. From Domestic wastes to kitchen wastes, poultry and livestock not excluded. Due to the current energy crisis and climate change, the country could benefit greatly from an alternative energy source which is eco-friendly, renewable, sustainable and efficient. This alternative energy source is called "Biogas". Biogas is formed by anaerobic digestion of organic materials. Biogas can be produced from kitchen wastes, cow dungs, poultry, pig faeces, etc. These wastes from the Bio-digester can later be treated as a by-product to give a nutrient rich organic fertilizer that can be used in farmlands and gardens. This paper outlines the benefits of organic waste and its potentials for domestic as well as industrial use when compared to other conventional fuels. The selected organic wastes that were thoroughly analyzed in this research work are; Human excreta, Pig excreta, sheep and goat excreta, abattoir waste, poultry excreta, cattle excreta, crop residue and municipal waste. Using computational techniques based on standard measurement. It was deduced that Nigeria generates about 591 million tons of the selected organic waste per annum. The results obtained from the research work shows that biogas has the potential of yielding about 32.29 billion m3 of biogas equivalent to 178 894 587.6 MWh. This estimated biogas yield will completely displace use of kerosene and coal for domestic cooking hereby reducing the consumption of wood fuel by 70%. The research also gives a recommendation for government and also the NGOs to encourage waste to energy mobilization and support its implementation in rural areas of the country.

INTRODUCTION

Nigeria generates approximately 4000MW of electricity which is not adequate for its population of over 200 million energy demands.(Okeniyi, *et al.* 2012) The world is in need of a green, efficient, carbon-neutral energy source to replace fossil fuels.

One of the reasons for Nigeria's decline in economy is due to the inability to meet the growing demand of energy for both domestic and industrial usage. Leading to the energy crisis we are currently facing in Nigeria.

The search for energy alternatives involving locally and renewable resource is of utmost priority to government, scientists and business people in the globe.(Report, 2014) Hence the justification of this research, in order to pour more insight into prospects of conversion of organic wastes to energy also to meet local and global demands. This article looks extensively at the sources of biogas energy in the surroundings, utilization of it for domestic use and its applications. The study also presents discussion of findings and observations followed by the conclusion and some key recommendations.

LITERATURE REVIEW

Currently, electricity supply in Nigeria relied significantly on hydropower, and this has resulted in frequent outages of electricity due to underinvestment in other sources of energy (Oke, *et al.* 2013). The average calorific value of Nigerian waste was estimated to be about 9.6MJ/kg based on the waste profile obtained. If all waste generated could be successfully collected and incinerated in a modern waste-to-energy facility, more than 5000 MW of electricity could be generated by the year 2022.(Atta, *et al.* 2016) Most electricity in generation in Nigeria comes from the hydropower and thermal with minimal electrical energy produced from renewable energy sources. This is the primary source of electricity in Nigeria's power sector without considering renewable energy options with much energy potentials.(Oyedepo, 2012)

Considering the volume of wastes generated in Nigeria through Human undertakings and their toxic effects on the ecosystem and human health, triggered the need to embrace other technical schemes for safe discard of wastes.(Amoo & Fagbenle, 2013)

Biogas energy sources such as organic wastes materials from the community wastes, livestock biogas. According to Researchers. Conversion of wastes into electricity reduces the volume of greenhouse gases, displacement of the high cost of conventional energy sources and costs of waste management and disposal.(Review, 2018.)

Nigeria has significant biomass resources to meet both traditional and modern energy uses, including electricity generation. The situation in the rural areas of the country is that most end users depend on fuel wood. Fuel wood is used by 70% of Nigerians living in the rural areas. Nigeria consumes over 50 million tons of fuel wood annually.(Oyedepo, 2012) The major energy-consuming activities in Nigeria's households are cooking, lighting and use of electrical appliances. Cooking accounts for a staggering 91% of household energy consumption.(Akuru, *et al.* 2010) Hence the need for biogas cannot

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be over-emphasized because it presents an alternative energy sources for Domestic use such as cooking and heating. it also provides a cheaper option when compared to LPG which is quite more expensive to use. Anaerobic digestion which yields biogas that can be utilized as fuel for domestic incineration gadgets serves as a very useful technique for conversion of waste resources to energy (Ufua & Olujobi, 2021).

Karmaker *et al.* (2020) found the use of biogas for electric vehicles charging in Bangladesh most useful. They proposed for the establishment of electric vehicles charging station which can save $16.31- $29.46 monthly and also the proposed charging station can reduce 65.61% CO_2 omissions than a grid-based charging station. Regarding the present status of the depletion of the electricity from national power grid in Bangladesh, set up of the biogas plant will be an excellent idea for both economically and environmentally.

Shaibur *et al.* (2020) found the conversion of the cow dung residues into the renewable energy and nutrient rich organic fertilizer in the form of biogas plant in Satkhira, Bangladesh was successful and the system also reduced the chemical fertilizer cost for plant owners, which they have studied in 2014.

MATERIALS AND METHODOLOGY

This study adopts primary sources, personal observation and secondary sources such as articles, textbooks, magazines, households and business energy surveys etc. Five different methodologies have been summarized for calculating and estimating bio-gas production and consumption. However, for the purpose of this research work, three methodologies have been extensively examined. Estimates can be based on plant capacity; gadgets use or feedstock use or by comparing fuel use in households with and without a biogas plant (the fuel substitution method). Biogas production may also be measured directly. Bio-gas is often measured in cubic meters over a period of time. But it is quite appropriate to convert it into energy unit in Joules. This is achieved by first converting it into methane production then energy production (MJ). The methane content of biogas should be about 65% and 1 m^3 of methane contains 34 MJ of energy, so 1 m^3 of biogas should contain about 22 MJ of energy.(Renewable & Agency, 2016)

Each cubic meter of biogas contains the equivalent of 6 kWh of heat energy

Conversion Factors

- 1m^3 of bio-gas = 0.65 m^3 of methane
- 1m^3 of methane = 34 MJ of energy
- 1m^3 of bio-gas = 22 MJ of energy
- 1m^3/day of bio-gas = 8060 MJ/year

Table 1: Summary of the different methods to estimate bio-gas production

Estimation methodology	Advantages	Disadvantages
Plant capacity: Estimate production from capacity data using a Capacity utilization figure.	Useful to make estimates from administrative data or simple surveys of plant capacity. Can be used to produce annual estimates of production in between biogas surveys.	The accuracy of estimates will depend on how much is known about capacity utilization. This method may be difficult to use if many different types and sizes of biogas plants exist.
Gadgets use: Collect data on biogas devices usage (hours per day and gas per hour) and use this to estimate consumption.	This requires a small number of questions that can be integrated into existing household surveys. It can be used to produce detailed estimates of consumption as part of larger surveys or as a relatively small energy survey.	Biogas users may not know how much they use biogas appliances. There may be a difference between biogas consumption and production.
Feedstock use: Collect data on digester size, technology and feedstock use and calculate the expected level of gas production.	This method calculates production based on feedstock use rather than assumptions about capacity utilization. It is most suitable for including in detailed household energy surveys. Results can also be used to calculate capacity utilization figures.	Data collection requires a detailed set of questions and more complex calculations to produce results. Estimates of feedstock inputs may not be accurate, but errors may be lower than in other methods.
Fuel substitution: Collect data on fuel use in households with/without or before/after connection to biogas and estimate consumption from the use of other fuels.	This requires a small number of questions that can be integrated into existing household surveys. This approach is particularly useful for project monitoring and for examining socio-economic and environmental aspects of fuel switching.	More complex analysis is required to adjust for household characteristics in the comparison of fuel use. Total energy use may also differ between households using or not using biogas.

Direct measurement: Biogas production is recorded over a period of time by mechanical devices (flow meters).	This method will give the most accurate and detailed measurements of biogas production. It is only likely to be cost effective for large-scale production or for detailed research into the design and operation of biogas plants.	Measuring devices are expensive and may require specialized training to use. It may also still be necessary to estimate annual production from measurements taken over a short time period.

Source: (Renewable & Agency, 2016)

Plant Capacity

The strategy used by this technique is quite simple and straightforward. The data on plant capacity is used to compute the theoretical level. In this instance, the measurement was derived from administrative data and findings from capacity surveys.

Calculations

The biogas capacity was recorded as the rated gas produced from biogas plants daily, hence the total biogas production was calculated by multiplying the plant capacity by 8,060 (to convert from m^3/day to MJ/year). The total plant volume is the sum of two components: the digester volume and the gas storage volume, measured in meter cube. The digester volume is the maximum amount of slurry that the plant can hold, while the gas storage volume is the amount of gas it can hold when full of slurry. The latter is usually a proportion of the former. The digester volume may also include a safety margin or "dead zone volume", which is used to prevent waste overflow on days when biogas production is higher than normal or biogas use is unusually low.

Table 2: Proportions and multiplication factors to convert total plant volume and rated daily gas production into digester volume and gas storage volume.

Biogas plant type	**Digester and gas storage volumes as a share of total plant volume**			**Multiplication factors to convert gas production to plant volume**		
	Digester volume	**Gas storage volume**	**Total volume**	**Digester volume**	**Gas storage volume**	**Total volume**
Fixed dome plant	80%	20%	100%	2.4	0.6	3.0
Floating drum plant	70%	30%	100%	1.4	0.6	2.0
Balloon/bagdigester	75%	25%	100%	1.8	0.6	2.4

Source:(Renewable & Agency, 2016)

Table 3: Standard sizes (models) of fixed dome biogas plants used in Bangladesh

Rated daily gas production (m^3/day)	**Effective digester volume (m^3)**	
	Cow	**Poultry**
1.2	3.0	2.3
1.6	3.8	3.0
2.0	4.8	3.9
2.4	5.8	4.5
3.2	7.8	6.0
4.8	11.8	9.3

Source: (Neupane, et al. 2013)

For example, Table 2 shows that the total plant volume of fixed dome plants should be about twice the daily volume of biogas production, so total plant volume (in m^3) divided by two (2) will give an estimate of total daily gas production (in m^3/day). This can then be multiplied by 8,060 to get a figure for biogas energy in MJ/year. The result of these calculations is the maximum theoretical or potential level of gas production in a country, but this assumes that all biogas plants are operated under optimal conditions (e.g., with the correct preparation of feed stocks, ideal operating temperatures, etc.). Real operating conditions are unlikely to be ideal, so this figure should be multiplied by a capacity utilization factor (%) to take this into account. The main advantage of this methodology is that plant capacity data can be converted into estimates of biogas production with simple calculations. The main problem is that the results of these calculations should be adjusted for capacity utilization, which will often be unknown and could be as low as 40-60%.(Neupane *et al.*, 2013) To solve this problem, capacity utilization may be estimated from local expert knowledge or from a more detailed survey of sample of biogas plant owners (comparing rated and actual production levels). This information may also be obtained gradually over time as more biogas data is collected in a country.(Renewable & Agency, 2016)

Direct Measurement

Low efficiency is usually compounded by regular gas leakages and clogging of pipelines and appliances. Due to problems such as these, the most accurate way to measure biogas consumption is directly through the use of flow meters (Task, 2018).

However, the use of flow meters presents its own set of

Figure 1: Biogas Flowmeter

challenges including the variable structure of biogas due to differing waste inputs; the relatively low gas pressures; and the high moisture and particulate content('Guide to Biogas From production to use', 2019).

Thermal mass flow meters are often used to measure biogas flow rates in industrial settings because of their ability to operate at low pressures and flow rates. Nevertheless, these devices tend to be fabricated into the system limiting their application for portable and small scale use. Such instruments are calibrated for low flow rates between 0-4 m^3/hr and take both gas flow measurements as well as cumulative flow also, these flow meters are often able to measure methane concentration.

Measurement

To measure the biogas flow it is necessary to attach a flow meter somewhere along the gas pipe, so that the cumulative flow can be measured over a period of time. The meter can then be read and removed at the end of this period.

Calculation

Gas consumption per day can be derived by dividing the cumulative gas flow by the number of days that the meter was in place. This can then be converted into MJ/year as described previously. While this approach will give very accurate measurements, it is likely to require technical expertise to attach these devices and the cost of flow meters may make this a very expensive exercise. Therefore, it is only likely to be justified for the measurement of gas production in large communal digesters or in situations where very detailed data is required for analysis.

Gadgets Use

One of the most efficient method to estimate biogas production is to gather more information about the use of biogas powered devices such as lamps and stoves. This then can be computed to derive the consumption of biogas of households annually.

Measurement

A Survey was conducted to obtain data about the types of household gadgets making use of biogas and the amount of consumed in each household, primarily its power rating and the average number of hours each appliance is used every day. For instance, if a household has one lamp that uses 60 litres/hour of biogas an hour and another that uses 100 litres/hour, the average power rating of the biogas lamps would be 80 litres/hour. Similarly, if a biogas stove has two burners and a total power rating of 5,000 watts, the power rating of each burner would be 2,500 watts.

It is worthy of note that surveyors should ask about these power ratings, but should also check the answers by looking at technical manuals or on any labels on gadgets (if available). They should also be very careful to record the power rating of each lamp and burner and not the total power rating of all lamps and burners. In countries where the power ratings of biogas lamps and stoves are standardized, it may also be possible to collect this data using a limited choice of answers rather than asking about the exact power rating of appliances.

Procedures

Step 1:

The readings obtained from the power rating of the gadgets are expressed in a unit of m^3/hour. After which Measurements in litres per hour are divided by 1,000. The data recorded in watts are hereby divided by 6,100. That means that 6100 watt-hours is equivalent to 1 m^3 of biogas contained in 22 MJ.

Step 2:

In calculating for the set of power rating measurements, national minimum standards for appliances have been used for this research work. The table below shows some examples of minimum standards for bio-gas burners and estimate of bio-gas use in lamps.

Table 4: Examples of appliance power ratings

Biogas lamps (average)	
Cambodia	0.049 m^3/hr
Ethiopia	0.048 m^3/hr
India	0.093 m^3/hr
Biogas stove burners (minimum standards)	
China	0.380 m^3/hr
India	0.450 m^3/hr
Kenya	0.500 m^3/hr

Sources: (Khandelwal K.C., 2009)

Step 3

The daily bio-gas consumption (in m^3) for flaring, lighting and cooking in each household is gotten by finding the average daily bio-gas consumption of each household. This is done by multiplying the average power rating of biogas lamps (m^3/hr) by the total number of hours they are used. The same procedure is applied to the burners. By multiplying the power rating of the burners by the total number of hours they are used for cooking and flaring.

Step 4

Finally, the results obtained from the above steps are hereby multiplied by 8,060 to convert the figures directly to MJ/year household. With appropriate multiplication factors to convert the sample results to population estimates, the figures obtained can be used to produce regional and national estimates.

It should be noted the bio-gas used for flaring should be recorded as losses, while bio-gas used for cooking and lighting are recorded as final consumption in the end-users applications. Hence the three uses are regarded as primary energy supply.

RESULTS AND DISCUSSION

4.0 Performance Criteria

In this chapter we have use the following criteria as a measure of the performance of bio-gas in comparison with other conventional cooking methods. The criteria for evaluation include: Efficiency/Fuel Use, Indoor Emissions, Total Emissions, and Safety For households without access to grid-based electricity or gas for cooking, cook stove options include a range of technologies with varying degrees of efficiency to burn traditional biomass such as charcoal and fuelwood, LPG, kerosene, ethanol, pellets, briquettes and biogas. Bio-gas offers a superior

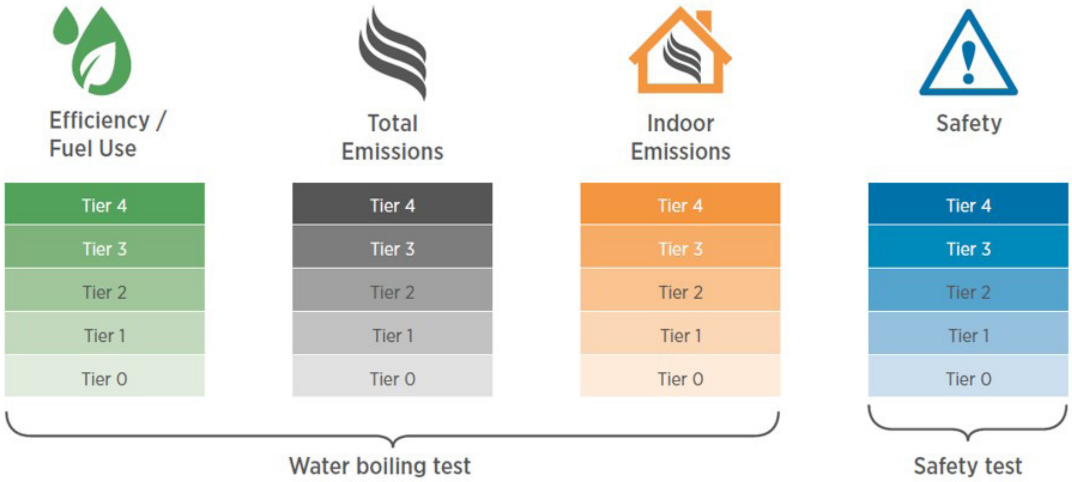

Figure 2: Water boiling and safety test

performance compared to these fuels by a number of measures, as elaborated below.(Renewable & Agency, 2017)

A distinct advantage of bio-gas is the use of organic wastes and by-products for energy production, reducing the waste volume and associated disposal challenges. (World Bioenergy, 2020) Post-treatment bio-gas effluent can provide high-quality organic fertilizer feed additives, pesticides, seed-soaking and topdressings, which can

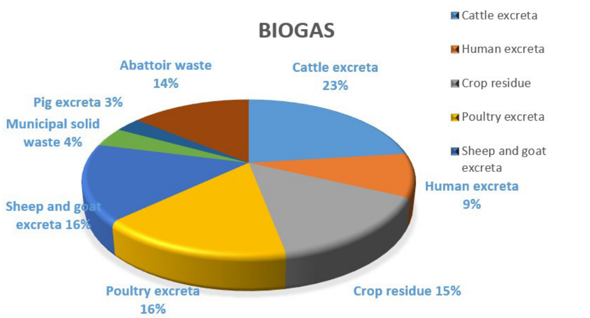

Figure 3: Sector tonnage distribution of biomass generated in Nigeria

substitute the import or production of synthetic nitrogen fertilizers. Compared to other cooking fuels and technologies, biogas stoves are highly rated in terms of health and climate impacts.

Figure 3 shows that a total of 71% of bio waste is generated from livestock wastes (pig, poultry, sheep and goat, abattoir). While human excreta, Municipal Solid Waste and Crop wastes accounts for 9%, 6% and 14% respectively. From the Table 5 the total tonnage of bio waste generated per annum was calculated to be about 591 million. The estimated potential biogas that can be generated per annum is 32.24 billion m^3 biogas with 72% (23.37 billion m^3) coming from livestock waste alone, while the remaining 15%, 4% and 9% comes from Crop residue, Municipal solid waste and human excreta respectively.

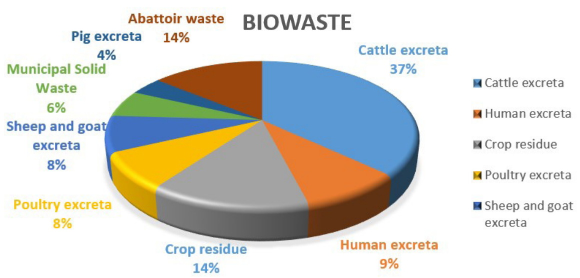

Figure 4: Distribution of potential biogas obtainable from biomass generated in Nigeria

Table 6 shows the biomethane potentials (BMP) of biogas from different organic wastes and their corresponding values of energy potentials. A total estimated BMP of 19.29 billion m^3 per annum has a corresponding energy value of 644, 020 TJ; with livestock wastes contributing 13.75 billion m^3 which is approximately 71% of the total

Table 5: Potential biogas derived from biomass generated in Nigeria

Organic Waste(Biomass)	Number of units (millions)	Biomass Generated (million tons per year)	Estimated biogas potential (billion m^3 $year^{-1}$)
Cattle excreta	25	220	8.5
Human Excreta	130	52	2.6
Crop residue	-	83	4.98
Poultry Excreta	160	45.7	5.2
Sheep and Goat Excreta	120	45.4	4.3
Municipal Solid Waste		39.1	1.29
Pig excreta	10	22.5	0.95
Abattoir waste		83.3	4.42
Total		**591**	**32.24**

Source; (Energy Commission of Nigeria)

Table 6: Potential biogas derived from biomass generated in Nigeria

Organic Waste(Biomass)	Estimated biogas potential (billion m^3 year-^{1})	Bio-methane potential (BMP) of Biogas (billion m^3 $year^{-1}$)	Energy Potential of Biogas (TJ) Per annum
Cattle excreta	8.5	4.52	150 500
Human excreta	2.6	1.69	65 910
Crop residue	4.98	3.0	117 000
Poultry excreta	5.2	3.1	74 350
Sheep and Goat excreta	4.3	2.9	72 450
Municipal Solid Waste	1.29	0.85	33 150
Pig excreta	0.95	0.58	27 310
Abattoir waste	4.42	2.65	103 350
Total	**32.24**	**19.29**	**644 020**

Source; (Energy Commission of Nigeria)

potential bio-energy generated from bio-waste. The remaining 28.7% constitutes crop residue, Municipal Solid Waste and human excreta.

Table 7 shows the tonnage equivalents of wood fuel, coal, kerosene, liquefied petroleum gas, and liquefied natural gas. 23.37 billion m^3 of biogas is gotten from livestock waste alone is equivalent to 33.78 million tons of wood fuel, 22.47 million tons of coal, 15.25 million tons of kerosene, 14.32 million tons of liquefied petroleum gas, 13.64 million tons of liquefied natural gas respectively per annum.

Table 7: Potential biogas derived from biomass generated in Nigeria

Organic waste (biomass)	Estimated biogas Potential per annum (billion m^3)	Wood fuel equivalent per Annum (million tons)	Coal equivalent Per annum (million tons)	Kerosene equivalent Per annum (million tons)	Liquified petroleum gas equivalent per annum (million tons)	Liquified natural gas equivalent per annum (million tons)
Cattle excreta	8.5	10.52	7.32	5.5	5.21	5.10
Human excreta	2.6	4.48	2.62	1.53	1.42	1.46
Crop residue	4.98	7.96	4.66	2.72	2.52	2.59
Poultry excreta	5.2	8.23	5.55	3.90	3.72	3.21
Sheep and Goat excreta	4.3	6.52	4.6	2.88	2.65	2.54
Municipal	1.29	2.26	1.32	0.77	0.71	0.73
Solid Waste (MSW)	0.95	1.48	0.89	0.57	0.51	0.50
Pig excreta	4.42	7.03	4.11	2.40	2.23	2.29
Total	**32.24**	**48.48**	**31.07**	**20.27**	**18.97**	**18.42**

Source: (Energy Commission of Nigeria)

Economic and Social Performance

Key performance indicators for biogas and other cooking fuels are compared in table 8 below.

It can be observed from the table above that biogas offers a top environmental performance, hereby making it a sustainable method for cooking, besides its positive environmental impact it is also efficient in fuel savings with zero health risk and it saves time leading to a corresponding decrease in cooking time. Overdependence on fossil-based fuels can be a huge barrier in climate

Table 8: Various performance metrics by stove type, where there is a classification between, ICS, modern fuel stoves and renewable cooking stoves

		Affordability	Fit w/ Custom	Life/Durability	Safety	Fuel Savings	Cooking Time	Environment	Health	Employment
ICS	Legacy Stoves	●	●	◔	◔	◔	○	○	○	◔
	Basic Efficient Stoves	◕	●	○	◑	◔	◔	◔	◔	◕
	Chimney Rocket	◕	◑	◕	◕	◕	◑	◑	◑	◑
	Portable Rocket	◑	◕	◑	◕	◑	◔	◑	◔	◔
	Advanced Charcoal	◔	◕	◑	◕	◕	◑	◑	◑	◔
	Natural Draft Gasifier	◑	◔	◑	◕	◑	◕	●	◕	◑
	Fan Gasifier/Jet	◔	◔	◑	◕	◑	●	●	●	◔
Modern	LPG	◑	◑	●	◑		●	◕	●	◔
	Electricity	○	◑	●	●		◕	◕	●	○
	Kerosene	◑	◑	◕	◑		◕	◕	◑	◕
Renewable	Ethanol	◑	◔	●	◑		◕	◕	◕	◑
	Biogas	◔	◔	◕	◕	◕	●	●	●	◑
	Solar	◑	◔	◑	●	◔	○	●	●	◔
	Briquettes/Pellets	◕	◑		●	◑		●		◕
	Retained Heat Devices		◔	◑	●	◑	○	●	●	◔

Source:(Venkata, et al. 2015)

change mitigation. Also countries where LPG is not subsidized suffers from the outcome too. Biogas offers a sustainable solution to the lack of access to clean cooking. Air pollution poses the most significant environmental health risk globally. Currently, the most significant source of air pollution is from the use of fossil fuels, which includes emissions from power generation, industry, traffic and residential energy use, the burning of solid biofuels for cooking, in many parts of the world, is a huge contributor to household air pollution.

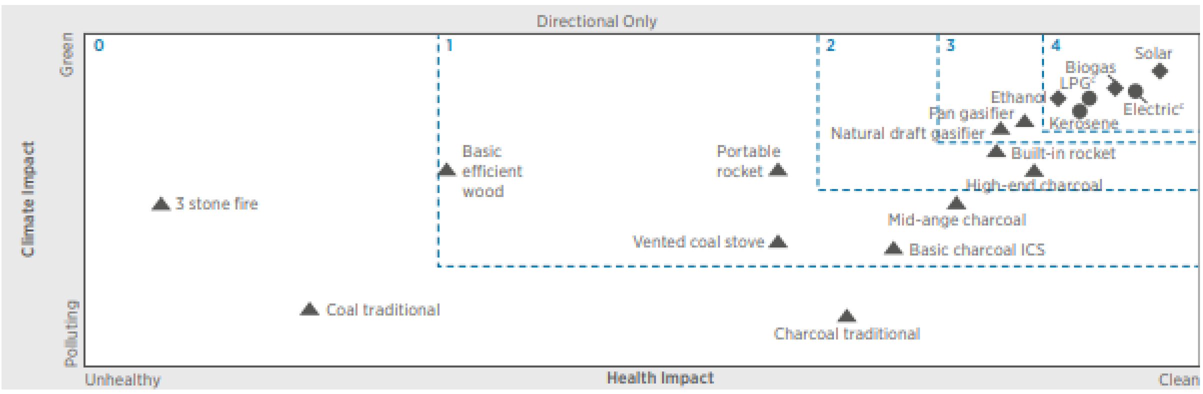

Figure 5: Indicative health and climate impact by stove type, including the tiers categorization, indoor emissions and safety, Source: (Venkata, *et al.* 2015)

From the chart above it can be seen that Biogas has tier 4 performance level in climate impact and health impact, due to the fact that it has low or no Indoor Emissions.

A report on "Plant for 64000 biogas plants" by Ariful Islam (2021) said that the government of Bangladesh took the initiative to set up biogas plants in integrated farms, to produce biogas as an alternative fuel, in order to create smokeless, comfortable, healthy, and timely cooking opportunities, generate electricity, create odorless and pollution-free hygienic environments in cattle and poultry farms. A total of 4,038 plots were set up in 10 upazilas from July 2006 to June 2011 through a first phase project titled Innovative Management of Resources for Probability Elevation through Comprehensive Technology (IMPACT) funded by the Government of Japan. In addition, 31,000 biogas plants have been successfully set up in 66 upazilas of 61 districts of the country by the Government's Implementation, Monitoring and Evaluation Department (IMED) Impact (Phase-I) project from January 2014 to June 2019 for massive technology-based integrated resource management (II). As part of its move, the Ministry of Youth and Sports the government has taken initiative to set up 64,000 biogas plants in 64 districts of the country in order to create huge employment for poverty alleviation under a project titled "Integrated Resource Management Phase III based on massive technology for poverty alleviation".

The report showed that the project could provide employment to the rural youth by setting up cattle and poultry farms and biogas plants and to meet the demand for protein through production of milk, eggs, meat and so on in the country. Proper use of biodegradable waste in biogas plants will enable development of sewerage and health systems and production of micro-nutrient rich organic manure for use in agricultural land, they mentioned.

CONCLUSION AND RECOMMENDATION

From the above results and discussion, it is evident that Nigeria has a lot of potentials for a sustainable biogas implementation.

Replacing polluting, open fires or inefficient cookstoves with clean cooking technologies reduces exposure to household air pollution, lowering the burden of associated diseases. Biogas is strongly recommended here based on the results obtained from this research work.

The estimated potential of 644 020 TJ per annum from organic waste is equivalent to 178, 894 587.6 MWh. About 18% (5.80 billion m^3) of the 32.24 billion m^3 total estimated biogas potential is required to totally displace kerosene and coal as the domestic cooking fuel and reduce wood fuel consumption by 70%.

The limitations of this study are the unavailability of results for increasing the specific calorific values of the Bio-gas being produced. This study is open to researchers to come up with various techniques for Bio-gas purification and increasing its specific calorific value.

Government is hereby implored to invest in scaling up biogas production here in Nigeria. As a good number of Nigerians in rural areas still lack access to affordable energy for cooking and other domestic use. Also, international agencies and NGOs here in Nigeria can help with the installations of biogas units at a very subsidized rate to enable rural communities here in Nigeria to be beneficiaries.

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