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Evaluation of the Feasibility of Biogas-To-Electricity Plant in Mai Idris Alooma Polytechnic Geidam, Yobe State, Nigeria

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Abstract: *There are uncertainties over insufficient supply of electricity to the local populace of Mai Idris Alooma Polytechnic, Geidam Yobe State Nigeria. Constantly increasing population has led to a wider gap between supply and demand of energy, leading to the independent power generation with the use of internal combustion engines which are not environmental friendly and comes with high cost of operation and maintenance. Fluctuating fossil fuel prices has further increased the need to assess the available renewable energy (RE) resources. Municipal solid waste (MSW) is generally accepted to be a RE resource with wide availability, however, it has not been harnessed in Nigeria. This work will present an economic evaluation of the feasibility of investing in biogas-to-electricity projects that can process MSW generated in Mai Idris Alooma Polytechnic, Geidam Yobe State Nigeria and its environments, thereby improving the supply of electricity within the local community. The assessment will be carried out for energy generation by a biochemical process (Anaerobic Digestion) based on Primary and secondary data. It will also incorporate all the plants' output (digestate, recyclables, electricity and heat) as co-products which can be marketable. Results obtained indicates the investment would be feasible on retail electricity distribution basis. However, trading directly to end users will pay back the investment cost of the project faster at 2 years and 361 days, at an NPV of $57,944,603.13. Thus, the project will help in increasing the amount of power available in the community. Hence, the BTE project will have a positive effect on the power sector, thereby contributing to the improvement of the economy of the local populace.*

Keywords: *Biogas, Electricity, Anaerobic digester, Municipal solid waste*

Introduction

Access to energy is said to be an unavoidable prerequisite to sustainable development and economic growth of any nation. However, Nigeria, like any other African country, has a potential for growth in energy demand driven by population growth, yet, about 60 per cent of Nigeria's population has no access to electricity (90 per cent in rural areas). However, the population growth has also resulted in a significant increase of uncontrolled amount of waste, thus, creating environmental, social and economic problems that need urgent attention (Gajibo, 2016).

The success of a biogas-to-electricity (BTE) project is dependent on the need of the local populace, since no profit will be made if there is no market for the BTE plant, resulting in a loss of the investor's capital. Nigeria is one of the major victims of shortage in global energy amongst other sub-Saharan African countries. This shortage has led to a significant overdependence of households on traditional energy source, like forest-wood and the charcoal derived from it for its primary energy consumption (Mohammed *et al,* 2020). A likely reason for this energy shortage is a lack of access to modern energy supply, with only about 46% of households having access to electricity (Dassapa, 2011; Sambo, 2009). Figures from The World Bank (2013) shows a 2 percent increase in the percentage of households without access to electricity from the year 2010 to 2013 due to an increase in population. The subject of electricity generation, distribution and transmission has been a major issue in Nigeria and has been the centre of previous research over the years (Akinbulire *et al.,* 2008; Mohammed *et al.,* 2013; Ogujor and Orobor. 2010 ; Oseni, 2011 and Sambo, 2009) due to the inadequacy of supply to the citizens of the nation. This has resulted in self-generation of electricity through the use of small personal generators that have low efficiencies and high CO_2 emissions. This is very expensive to generate. Furthermore, it is harmful to the environment as a result of the high CO_2 emissions from the machines utilised for self-generation.

The use of biogas, produced from the processing of municipal solid waste as a renewable and sustainable energy source, could be the solution to the recurrent energy challenges of the country. Biogas is a gas that comprises methane, carbon dioxide and other constituents; it is produced through the process of anaerobic digestion of biomass. Since the proposed study area (Mai Idris Alooma Polytechnic, Geidam, Yobe state Nigeria) has a significant amount of waste generation capacity than it has the ability to handle, this could also be a feasible approach to power generation, as well as waste management.

This work investigates the use of biogas produced from anaerobic digestion of municipal solid waste (MSW) generated is an economically feasible substitute for power generation in the study area. The most important issues and the key objective of this work are:

- To estimate the amount of MSW generated and collected which will be used to determine the potential biogas yield, total electrical, digestate and recyclables output (revenue generating output).
- To perform a cash flow analysis to determine its economic feasibility and competitiveness.

Methodology

Similar work has been carried out by Mohammed *et al* (2020). The methodology used will be adopted for the purpose of this study. The procedures that will be used in actualising the objectives of this study are involves collection of primary data from the waste generated within the location. Also, a variety of secondary data collected from literatures both qualitative and quantitative, and used to generate the required figures for the economic model to be carried out successfully. Location specific data will be obtained from various sources and collated.

Average per capita waste generation will be obtained from taking the average of different locations in within the study area. These locations represent the academic, commercial, industrial and residential areas, this is because waste generation varies significantly, thus, will yield errors if the average is not taken.

Table 1: Important Data Utilised in the Research

S/N	DATA	USE OF DATA	SOURCE
1	Population	To assess the amount of waste generated	National Population Commission (2006)
2	Population Growth Rate	To assess the quantity of waste that can be generated over a number of years	UNFPA Nigeria (2014)
3	Waste Generation per person	To estimate how much waste can be generated by a person per day	Babatunde *et al.* (2013)
4	MSW Properties	General properties of waste generated in Borno state such as organic fraction of waste, carbon-nitrogen ratio and biodegradability of waste generated	Abubakar *et al.* (2013)
5	Waste Collection	To estimate how much waste can be made available for processing	Ogwueleka (2009)
6	Price of Electricity, Fees Payable, taxes and incentives, Licences	To estimate revenue that can be generated from sale of electricity, and power regulations and incentives offered	National Electricity Regulatory Commission (2010, 2012 and 2013) and KPMG (2013)
7	Energy Recovery Potential	To calculate the energy recoverable from the biochemical conversion of waste to energy	MUDGI (2013:15)
8	Plant costs	To estimate the costs of building municipal solid waste to energy plant	EIA (2013)

Source; Adopted from Mohammed *et al* (2020)

Population and per capita waste generation were used to calculate the total waste generated per day; this was converted to waste generated per year.

$$Total\ Waste\ Generated\ per\ day(Tonnes/day) = Population\ (hd) \times Average\ per\ capita\ Waste\ Generation\ (kg/hd/day) \quad (1)$$

This was according to calculations made by the Anderson centre, and GMU (2001). Future generated waste projections were made using the population growth rate of the state. The percentage quantity of total generated waste that can be collected was assumed to be 70% (Mattocks,1984). The MUDGI biochemical conversion model was modified according to the location specific data and used to calculate the biogas yield, net power generation and energy recovery potential of the biogas plant. Using MUDIG (2013:15) energy recovery potential as shown below;

Total Waste Quantity: W (tonnes)

Total Organic/ Volatile Solids: VS (50%)

$$Organic\ biodegradable\ fraction(66\%\ of\ VS) = 0.33 \times W \quad (2)$$

Typical Digestion Efficiency (60%)

$$Typical\ Biogas\ Yield\ (m^3) = 0.80m^3/kg\ of\ VS\ destroyed \quad (3)$$

$$0.80 \times 0.60 \times 0.33 \times W \times 1000 = 158.4 \times W \quad (4)$$

Calorific Value of biogas = 5000kcal/m³ (typical)

$$Energy\ Recovery\ Potential(kWh) = B \times 5000/860 = 921 \times W \quad (5)$$

$$Power\ Generation\ Potential(kW) = 1339.53 \times W/24 = 38.4 \times W \quad (6)$$

Typical Conversion Efficiency (30%)

$$\boldsymbol{Net\ Power\ Generation\ Potential(KW) = 11.5 \times W} \quad (7)$$

$$Potential\ Energy\ Income\ (\$) = Net\ Energy\ Generated\ (kWh) \times Price\ /kWh \quad (8)$$

Percentage plant consumption (15%) and energy loss due to down time (10%) was subtracted from total energy generated in order to get the net energy generation. The capital cost and the operation and maintenance (O&M) cost of the proposed plant was calculated based on estimates of municipal solid waste power plant costs established by EIA (2013). The cost was given as 8,312 ($/kW) and 392.82 ($/kW-year) for capital and O&M costs respectively. These figures were given for plants with nominal capacity of 5.5 MW. This formed the basis for the cost estimation for this study.

A discounted cash flow for economic analysis will be constructed for a ten-year MSW to electricity generation project. Ten years was selected because the licences for power projects are only valid for ten years in Nigeria after which it can be renewed. The variables required for the project analysis are capital investment, operation and maintenance costs, cash flows, present values (PV), net present value (NPV), internal rate of return (IRR), payback period (PP) and benefit-cost ratio (BCR).

Results and discussion

The waste generated per year was calculated using the amount of waste collected through a period of three months within the study area. Only 70% of total waste generated is collected, thus yielding a total waste generation of 244,900 Tonnes/year of MSW in the first year and 316,758 Tonnes/year of MSW in the tenth year. Also, the amount of recyclable waste saleable was calculated to be 50% of the inorganic waste collected after pre-treatment and is shown in Table 2.

These results were used to calculate the amounts of all required outputs to be generated as stated in the methods section. These outputs include the biogas yield, electrical energy generated, digestate output after digestion and the amount of saleable recyclables gathered. The amounts generated as shown in Table 2 was used to calculate the income generating potential of the BTE project.

Table 2: Results Obtained for Revenue Generating Outputs

Year	Population	Total Waste Collected (Ton/year)	Organic Fraction of Waste Available for Digestion (Ton/year)	Biogas Yield (M^3/Year)	Solid Digestate Output (Ton/Year)	Amount of Saleable Recyclables (Ton/Year)	Net Energy Generated (kWh)
1	244,900	110,205	36,368	17,456,472	49,592	39,673,800	4,231,872
2	252,002	113,401	37,422	17,962,710	51,030	40,824,340	4,354,596
3	259,310	116,690	38,508	18,483,628	52,510	42,008,246	4,480,880
4	266,830	120,074	39,624	19,019,653	54,033	43,226,485	4,610,825
5	274,568	123,556	40,773	19,571,223	55,600	44,480,053	4,744,539
6	282,531	127,139	41,956	20,138,789	57,212	45,769,975	4,882,131
7	290,724	130,826	43,173	20,722,814	58,872	47,097,304	5,023,712
8	299,155	134,620	44,425	21,323,775	60,579	48,463,126	5,169,400

9	307,831	138,524	45,713	21,942,165	62,336	49,868,557	5,319,313
10	316,758	142,541	47,039	22,578,488	64,143	51,314,745	5,473,573

Cost Estimates

For the plants, the capital cost for the tenth year was used for the purpose of the analysis as this was the point with the highest energy generation. It was calculated using the capital cost criteria stated in the methods section, and is given as $**46,324,574.90**. The total capital investment comprises of the capital cost, and applicable licence fees required. For project alternative one, the licences for generation, transmission, distribution, systems operations and trading are included in the capital investment.

Table 3: Total Capital Investment

License Category	($)
Generation	30,916.20
Transmission	306,107.99
System operations	306,107.99
Distribution	81,107.99
Trading	81,107.99
Capital cost	45,600,335
TOTAL CAPITAL INVESTMENT	**46,324,574.90**

**Not Applicable*

The operating cost was also calculated according to the criteria stated in the methods section of this study. Table 4 presents the operating costs for the project In utilising the converted biogas, the project details a total investment in the project, from generation of electricity to trading directly to the end users. Retail prices were used to calculate the income from electricity and kept constant over the ten year licences' validity period. Table 4 below shows the criteria for which the profit indicators used for the economic analysis of the project's viability will be acceptable. Outside of these criteria, the project will not make any profit and will therefore fail.

Table 4: Acceptability Criteria of Profit Indicators

Economic Profit Indicator	Criteria for Acceptability
NPV ($)	NPV > 0
DISCOUNT RATE (%)	Discount Rate < IRR
CBR	CBR >1

Table 6 shows the results of the profit indicators used in this project, obtained from the discounted cash flow analysis was $57,944,603.13, which was higher than zero, indicating that the project has a high profit potential. To strengthen this result, the IRR was 44%, indicating that the project could be profitable. The BCR was obtained to be 1.78 which is greater than 1; hence for every $1 invested, the wholesale electricity distribution project option will deliver $1.82. Therefore, the project could recover its costs in about two years and 361 days, and still make further profits as high as $0.78 for every dollar spent.

Table 5: Economic Profit Indicator Results from Discounted Cash Flow analysis

Economic Profit Indicator	Alternative one
NPV ($)	57,944,603.13
IRR (%)	44.00
BCR	1.78

As can be seen from Table 5 above, installing biogas plant will yield profits when the energy generated is sold on a retail. Therefore, the cash flow analysis of BTE plants shows economic viability of the project when all outputs (Digestate, Electricity, and Recyclables) are able to generate revenue.

Conclusion

From the discounted cash flow model adopted in this research, results obtained indicated that investing in Nigeria, and selling all of the plant's output (electricity, digestate, and recyclables) at current market prices, with a discount rate of 14.60%, will yield an economically viable investment. The results obtained and presented from the economic analysis of BTE plants in Geidam, reveals that the argument posed in the introduction section of this work, which states that "the use of biogas produced from anaerobic digestion of municipal solid waste (MSW) streams is an economically feasible alternative for electricity production in Nigeria" is true and can be accepted. However, this argument can only be fully accepted if all plant outputs and benefits such as waste processing, reduction of landfill tax, reduction in carbon emission, digestate, electricity, and recyclables are inputted into the revenue generating stream.

Competition in the electricity market by new entrants in generation and retail supply will help in reducing the price of electricity, and also allow consumers to choose their suppliers, thus improving their confidence and reliability in the energy sector. This will also reduce the amount of self-generation of electricity in the state, thereby reducing cost, noise pollution and CO_2 emissions into the atmosphere.

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