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Techno-Economic assessment of biogas technology in Nigeria: a case study of northwest, kano state

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ABSTRACT

This survey research was conducted to assert the sustainability and financial and economic viability for any installed biogas plant. The study collected data through structural questionnaire from a total of twenty four families in six different wards which cut across two local government areas in two districts of kano state, Nigeria. The average family size of 15 members has 67% of the family size in the range of 10-19 members in a family and 61% of the family has cattle holding capacity of equal or less 50 herds of cattle to generate cow dung. Every family interviewed has reliable source of water supply. However, 58% of the families used fuel wood to meet their domestic energy requirement as against 34% who used convectional commercial kerosene for their energy consumption. 41.67% of the families didn't spent more than N 40,000 ($ 250.00) on energy consumption within a year. A 28% was determined as financial internal rate of return on a biogas plant with cost of installation of N 80,000 ($ 500.00) and economic viability base on intangible benefits of clean and less polluted environment and time saving in conversion of raw material into energy usage. Level of awareness of the biogas technology, initial high cost of installation and open rearing system are among identified constraints of the biogas utilization.

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INTRODUCTION

Global search for alternative and sustainable renewable energy is of great concern presently, most especially in Nigeria where uninterrupted access to reliable energy is a problem yet to be solved for both domestic and industrial applications. However, the incessant scarcity and rising cost of commercial energy source for household consumption make it inaccessible for most rural dwellers that make up about 70% of the country's population where their energy demands are met from renewable energy resource of mainly fuel wood. International Energy Agency [1], reported bio-fuel to account for 10 percent of global total primary energy demand while reliance on bio-fuel in Africa is 47 % and up to 20% in the developing countries around the world. It is therefore obvious that biomass resource is increasingly becoming a viable and sustainable alternative source of energy to replace the depleting fossil fuels energy. In order to reduce dependence on fossilfuel and reduce environmental pollution while creating a sustainable energy supply, Nigeria government has come up with Nigerian bio-fuel policy and incentives [2]. The policy framework of this programme is to integrate agricultural sector of the economy and other renewable energy sources in the country. To decrease reliance on fuel wood, use of biogas (a mixture of methane and carbon dioxide produced by decomposing organic matter) has been promoted for cooking fuel as well as many domestic activities[3]. Sandhya and Singh [4], stated that in developing countries biogas plants are being installed in villages to obtain biogas for use as anenergy source and at the same time obtain decomposed manure. Installation of biogas plants to meet demand of household energy could be a viable alternative to attaining sustainable energy supply and improvement on standard of living of rural population in Nigeria. Although, [5], reported biogas as the fourth largest source of energy in the world, it optimum potential has not been fully exploited in Nigeria.Orakwe et al [6], shows that Nigeria has about 180 million livestock with equivalent biogas production of over 100 million tones. However, many biogas plants were installed without adequate consideration of their sustainability.

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The Sokoto Energy Research center under Nigeria Energy Commission constructed and operated more than twenty [20] biogas plants of 10 to20 m^3 capacities using different feedstock such as cow dung, human excreta, piggery and poultry wastes but without sustain servicing. Also, the Raw Material Research and Development Council (RMRDC) funded the construction of a float drum type of biogas in Yobe, Jigawa and Kano states under the African low technology biogas system, but it has been observed that these biogas plants areunserviceable mainly because feedstock was suspended due to scarcity of water and paucity of continues supply of waste at the installed location, hence the potential of such biogas plants were not achieved. Furthermore, many biogas plants are rendered unserviceable because the rural dweller are not convince of the comparative cost advantage over the kerosene or firewood as energy source which they are accustom to and in many cases proximity to serviceable raw material for the biogas plant utilization. This is because people would adopt a new technology only if it is viewed from point of user benefit-cost ratio and believe it could have positive financial impact on their economic status. Therefore, an attempt to study the level of awareness of biogas utilization in meeting energy requirement amongst the rural dwellers in Kano state, northwest of Nigeria was conducted. It was aimed to ascertain the proximity and sustainability of feedstock materials to the biogas plant if installed and the constraints likely to be encountered in the efficient operations. Also, financial analysis of installation and maintaining a biogas plant of a family size was made base on the concept of financial internal rate of return (FIRR), using benefits and cost of biogas plant which vary depending on the use of inputs and output of a particular user.

MATERIALS AND METHODS

The study was conducted in Kano state, North West region of Nigeria. The state has over 12 million populations with three senatorial districts via; north, south and central districts. Both north and south senatorial districts are predominately rural areas, hence their choice as the study areas. The state lies in Sahel savannah between 11^o 58' North of latitude and 08^o 03' East of longitude. The study areas are kiru Local government area in Kano south senatorial district (11^0 42' N and 08^o 08' E) and Shanono local government area in kano north senatorial district (12^0 03' N, 7^0 59'E). The survey was conducted through in depth case studies of three wards in each of the local government areas of the two senatorial districts. The wards studied in Kiru local government area are; Kiru, Zuwo and Maraku while that of Shanono local government are Farin-ruwa, Shakogi and Gidan-fulani. In each of the wards studied, a survey sheet was designed to collect the required information from four different families through structured questionnaire and personal interviews to gather information on energy source, energy consumption patterns and it cost, family daily income, family size, awareness level of biogas, cattle holding and proximity to raw materials. The financial and economical internal rate of return of the biogas plant was determined based on the concept that if the internal rate of return (IRR) of the biogas plant exceeds the user required rate of return, then the biogas is desirable. In order to evaluate the IRR, it was assume that the biogas plant is a fixed dome type with economic life of 6 years and the cost of installation as reported by [7]to be between US $300-500 (N48, 600- N80, 000). The annual income from the plant is assumed to be the saving on commercial convectional fuel sources the user would have bought to meet his energy needs while the operation and maintenance cost is taken to be the amount spent by user on the plant within the year. Based on all these assumed parameters of both expenditure and saving on the biogas plant, the net savings on yearly basis were determined for period of ten years and Microsoft excel software was executed to calculate the internal rate of return (IRR).

RESULTS AND DISCUSSION

The data collected from the twenty-four [24] different families in the two local government areas through structural questionnaire were analyzed. Table 1 shows the mean family size of all the families interviewed to be 15 with the corresponding cattle holding capacity of 90 while all the families have reliable sources of water either as borehole or dung well and in a close proximity of not more than 50 metres from their houses. However, no family was observed to be using biogas plant as the source of energy consumption because all the families are either using firewood or kerosene to meet their energy requirements. In this survey, the results for the family size showed that 67% are within the family size range of 10-19 members, 28% are within the family size of 1-9 members and 20-29 members had the lowest of 5%, table 2. On the energy consumption pattern, 58% of all the families surveyed used firewood/fuel wood while 34% were using commercial kerosene for their energy need and 8% combined both kerosene and firewood depending on the availability of the source. A total of 2,036 cattle were enumerated to be the cumulative cattle holding capacities in the six wards of the twenty-

four families surveyed. This results show that 61% of the families interviewed have minimum of 50 herds of cattle while 28% have between 100 and 150 herds and 11% have more than 150 herds of cattle. It could be inferred from this results that every family in the surveyed area would be able to sustain a family size biogas plant through the dung generated from their herd of cows. It has been pointed out that in villages, support of minimum number of cattle (at least 5) is necessary to run a small home digester plant [8]. Hence a family biogas plant could be continuously sustained by most families in the studied areas.

Table 3 shows the main sources of income, income per annual and cost of energy usage of the data collected through the questionnaires base on the local government areas surveyed. It was observed that 54.17% of the families interviewed in Kiru local government area are mainly farmers (crop and animal husbandry) while 62.5% are farmers in shanono L.G.A. 25.0% and 16.67 % are engaged in both farming and trading in Kiru and Shanono local government areas respectively.The information on table 3 depicts the income per year of the families interviewed. It was noticed that higher percentage of the families interviewed in Shanono were in in the range of high income per annual than that of Kiru local government area. This might not be unconnected to higher percentage of the families engaged in farming and also farming and trading in Shanono local government area. In Kiru, 33.33% of the families earned between N 280,000 and N400, 000 equivalent to($1,750- $2,500), 41.67% earned N420, 000-N580, 000($2,625-$3,625), 16.67% earned 600,000-N720,000 ($3,750-$4,500) and 8.33% earned between N740,000 and N 900,000 equivalent to($4,625-$5,625).The amount expended by all the families on energy consumption in the two local government areas is presented in table 3.In kiru local government area, 41.67% of the families spent less or amount equal to N 40,000 to meet their energy demands for both cooking and lighting in a year while 20.83% of the families spent same amount in Shanono. 25.0, 20.83, and 12.50 % families in kiru spent between N45,000 and N 55,000, N60,000 –N70,000 and N 75,000 –N85,000 respectively on energy used per annual while 20.83, 37.50,25.0 and 16.67 % spent the same amount respectively in Shanono local government area.Table 4 shows the calculation for an equivalent of a3m^3 daily gas production of a biogas plant. The calculated financial internal rate of return (FIRR) value for the biogas plant base on the $300-$500 as cost of installation was found to be 28%. This implies that the return of investing on the biogas plant would be above the opportunity cost of using either kerosene or firewood. Similarly the benefit- cost ratio exceeds 1which implies that the installation of biogas plant is financial viable. On the economic analysis, the major constraint is the numerical quantifying of the benefit of the biogas plant. However, benefits such as clean environment, protection of forest, reduction in release of carbon, saving time of fetching firewood are intangible. Therefore, it could be assumed that biogas plants also economically viable.

Table1: Family size, assessment of biomass resources and energy sources within the family unit ofKiru and Shanono L.G.A of Kano state.

Wards Name	Family No	Family size	Cattle holding	Water source	Energy source
Kiru	1	18	47	Available	Fuel-wood
	2	9	33	Available	Fuel-wood
	3	16	50	Available	Kerosene
	4	7	34	Available	Fuel-wood
Maraku	5	15	103	Available	Fuel-wood
	6	10	43	Available	Fuel-wood
	7	8	39	Available	Kerosene
	8	19	125	Available	Fuel- wood
Zuwo	9	20	158	Available	Fuel-wood
	10	19	112	Available	Fuel wood
	11	15	40	Available	Fuel-wood
	12	9	35	Available	Kerosene/wood
Farin-ruwa	13	15	39	Available	Fuel-wood
	14	12	35	Available	Kerosene
	15	18	109	Available	Fuel-wood
	16	13	50	Available	Fuel wood
Gidanfulani	17	25	129	Available	Fuel-wood
	18	11	46	Available	Kerosene/wood
	19	15	173	Available	kerosene
	20	18	121	Available	kerosene
Shakogi	21	8	47	Available	Kerosene
	22	17	116	Available	Kerosene
	23	14	45	Available	Kerosene
	24	22	160	Available	Fuel-wood
	MEAN	15	90		

Table 2: Percentage distribution of the family size range, energy source and cattle holding capacity of the families in the two local government areas

Family size range	%	Energy source	%	Cattle holding capacity	%
1-9	28	Kerosene	34	≤ 50	61
10-19	67	Fire-wood	58	≥100≤150	28
20-29	5	Kerosene/firewood	8	≥150	11

Table 3: Source of income, income per annual and cost of domestic energy consumption of the family units in the two local government areas

	Kiru Local government area		Shanono Local government area	
Parameters	Frequency	%	Frequency	%
Source of income				
Farming only	13	54.17	15	62.5
Trading only	3	12.50	2	8.33
Farming &Trading	6	25.0	4	12.50
Civil servant (Government work)	2	8.33	3	16.67
Income/annual(' 000') : $1=N 160				
≥ N 280≤ N 400	8	33.33	2	8.33
≥N 420≤N 580	10	41.67	12	50.0
≥N 600≤N 720	4	16.67	6	25.0
≥N 740≤N 900	2	8.33	4	16.67
Cost of domestic energy used/annual(' 000') : $1=N 160				
≤N 40	10	41.67	5	20.83
≥N45 ≤N55	6	25.0	9	37.5
≥N 60≤N 70	5	20.83	6	25.0
≥N 75≤N 85	3	12.50	4	16.67

Table 4: FIRR calculation for a $3m^3$ biogas plant

Items	Amount
1) Installation cost	N 80,000
2) Annual maintenance cost	N 8,000
3) Annual salvage value	N 20,000- 1st year 25% of installed cost N 16,000-2nd year 20% of installed cost N 12,000- 3rd year 15% of installed cost N 12,000- 4th year 15% of installed cost N 12,000- 5th year 15% of installed cost N 8,000- 6th year 10% of installed cost
4) Annual saving on energy	N 21,500

Year	1	2	3	4	5	6
Expenditure	N 28,000	N 24,000	N 20,000	N 20,000	N 20,000	N 16,000
Saving on energy used	N 21,500	N 21,500	N 21,500	N 21,500	N21,500	N 21,500
Net saving	-N 6,500	-N 2,500	N 1,500	N1,500	N 1,500	N 5,500
FIRR	28%					

The following are Identified constraints of biogas technology:

Awareness level:

85.60% of the families interviewed are not aware of the biogas technology and it praticability. It's only when people are aware of this alternative to conventional sources of energy supply that the technology would have it place in the rural area.

Initial cost of installation:

One major limiting factor of the practicality of biogas technology is the relatively high installation cost of the biogas digester [9]. In this survey, 46.8% of the family respondents signified intension to finance the installation of the biogas digester on their own while 52.3% said they would not be able to finance without subsidy from government.

Technical know-how

The study showed that 14.40% of the family respondents who are aware of the biogas plant to meet their energy demands obviously know nothing about the operation and maintenance of the biogas plant. Hence a train on biogas operation would be required for the success of the usage.

Open rearing system:

The type of animal rearing practiced in the area surveyed does not make room for the economic recovery of animal waste. The system in which animal are left to wander from place to place in search of pasture is not a good practice for the operation of biogas technology. Apart from this, 90% of the families that keep livestock do not have an intensive system where the animal are housed, fed and given medical attention. It is only in such housed practice that the economic recovery of waste is possible.

Conclusion:

This studyassessed the availability of biomass materials so as to establish if servicingany installed biogas plants could be sustained in the two senatorial districts of Kano state surveyed. Six wards were selected in which twenty- four families were interacted with for information on family size, source of energy and it consumption patterns, cattle holding capacity and available source of water. It was observed that the mean family size is 15 members with corresponding 90 herds of cattle as the cattle holding capacity. 58% of the families use fuel wood as the main source of energy consumption .About 61% of the families sampled has cattle holding less or equal 50 herds with reliable source of water throughout the year. This shows that servicing and utilization of biogas plant could be sustained if installed.Also determined is the financial internal rate of return of any installed biogas plant in the survey area which was found to be 28%.The intangible of clean environment and time saving in energy usage make the biogas plant economical viable in the survey area. The identified constraints of low level of awareness, high cost of biogas plant installation, open rearing of livestock and technical know-how are the major factors militating against adaptation and sustainability of this time and resource saving energy utilization technology.

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