IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 15, Issue 4 Ser. I (Jul. – Aug. 2020), PP 37-45
www.iosrjournals.org

Comparative Analysis between Biogas Yield of Human Waste, Kitchen Waste and Solar PV for the Generation of Power in A Remote Station

ADENLE, JOHNSON GBADEBO[1],
ADELEKE, ADEMOLAAJANI[2],AKANJI, SAIDU SUNBO[3]
[1,2](Department of Electrical Engineering , Kebbi State polytechnic, Nigeria)
[3](Department of Electrical Engineering , Karume Institute of Science and Technology , Zanzibar)

Abstract:
High cost of power and environmental hazards such as CO emission and noise pollution produced by diesel generators has made the use of renewable energy source very necessary. Biogas and solar power are renewable energy sources which can be utilized as a backup in case of power interruption. The present work focuses the ability of biogas production using both human and kitchen waste of a selected building to generate electricity. The expected biogas yield, power generated output, total component cost of the system and payback period is compared to total component cost of installing solar PV system for the same load.
The analysis enable us to ascertain the viability of biogas compared to other renewable energy resources. These data are used to determine the standalone component sizes, installation cost and the pay-back periods of both systems.
Each component part of both systems were sized according to the load and appropriate costing and its equivalent payback period of 8 years 5 months 8 days and 61 days for solar PV and biogas was obtained respectively. The results obtained were used to determine which of the system is economically friendly and cost effective. Analysis shows that it is cheap, profitable, economically friendly, cost effective and reliable when biogas plant is used as an alternative source of power supply compared to standalone solar PV system. However, the sizing and estimation perfectly meets the station energy requirement. Hence, biogas plant is recommended for this application due to its economic viability.

Keywords: Biogas plant, Sizing, PV modules, load, Estimation

Date of Submission: 14-07-2020 Date of Acceptance: 29-07-2020

I. INTRODUCTION

One of the key important factors that contribute to the sustainable development in any country is energy availability. Sustainable development is accompanied with greater levels of energy consumption. With the dominant dependency on non-renewable energy resource such as fossil fuels, the world has been faced with a lot of environmental threat such as air pollution, ozone layer depletion etc. [1] established that 60% of total greenhouse gas emission is caused by the use of non-renewable resources, it is therefore imperative to reduce carbon concentration in the atmosphere. This has made the use of renewable energy resources the best alternative for the actualization and realization of sustainable development goals not for only for the present but the future. In addition, renewable energy has been proven to be reliable, cost effective, affordable and capable of providing uninterrupted electricity every hour throughout the year compared to nuclear power and fossil fuels presently in use. In developing country like Nigeria, major sources of power are hydropower and fossil (gas) thermal power sources. Out of total installed generation capacity of 12,500MW, only 3,500MW to 5,000MW is typically available for the onward transmission to the final consumer. The drop in transmitted power has been attributed to recurrent challenges such as maintenance and repair requirements, trips, faults and leakages that make them unavailable for transmission to the national grid. Currently, 80% of energy is generated from hydropower which serves as a major source of electricity whereas, the country is blessed with abundance of renewable energy resources which are yet to be fully harnessed.

Biogas production has been identified as one of the ways of eliminating urban wastes [2] and the creation of wealth and employment. Human and kitchen waste generated in homes are economically feasible substrates for biogas production. The use of biogas system for the generation of power can replace the use of fossil fuels for electricity generation in developing countries while the by-product from the over-flow tank can be used as manure which is added to plants to aid germination. This possess no hazard to both plant and the environment [3]. The average composition of Biogas consist mainly 55-75% methane gas (CH_4) and 25-45% carbon dioxide (CO_2) while other matter include 0.3% carbon monoxide (CO), 1-5% Nitrogen (N_2), 0-3% Hydrogen (H_2), 0.1-0.5% Hydrogen sulphide (H_2S), and 0.1-0.8% of Oxygen (O_2) [5]. Soaps and other impurities needed to be eliminated before biogas can be effectively used for combustion. This is done via the process of purification.

Globally, researches on biogas production using several waste materials has been done. Kevin et al (2017) [4] compared biogas yield of selected animal and non-animal waste in a typical modified house digester. In his study, 34.7 liters of biogas was generated per every 20kg of water hyacinth plant which made the substrate a viable gas source due to its availability along costal wasters. Similarly, [5] also researched on biogas utilization from biomass and kitchen waste and its impacts on energy cost on a university campus. Recent studies include the work on cost-benefits analysis of a small-scale biogas plant and electric energy production [6]; Design of standalone hybrid biomass and PV system of an off-grid house in a Remote area [7] and many more researches on biogas technology.

The present work focuses the ability of biogas production using both human and kitchen waste of a selected building to generate electricity. The expected biogas yield, power generated output, total component cost of the system and payback period is compared to total component cost of installing solar PV system for the same load. The analysis enable us to ascertain the viability of biogas compared to other renewable energy resources. Human and kitchen waste are collected and both fed into the digester. The Human waste is fed directly from the water closet straight into the mixing tank while the kitchen waste is fed from inlet chamber, which is at angle, for easier flowability into the digester. High cost of power has deprived many house owners the full utilization of power whereas waste products from both Human and kitchen lays in abundance. Finding an alternative use of these waste is much recommended for developing countries in terms of cost savings.

II. Materials And Methods

Currently, however, there has been almost no itemized data for planners, installers and shoppers of PV frame work about the best module to use for their application and site, or which PV vitality yield prescient execution apparatus will give an exact estimation of vitality yield or the proposed frame work and furthermore relying upon their interest. Biomass power rely upon plant and animals waste of the area under consideration.

The main aim of this segment is to generate the appropriate sizing method for PV and Biogas system, economic feasibility of biogas and PV, their output, return on investment, profit estimation and payback period.

Sizing a typical PV system

1. **Power consumption estimation**: To design a solar PV system, it is imperative to estimate the total power and energy consumption of all loads that need to be supplied by the solar PV system.
2. **Estimate total Watt-hours per day for each appliance used**: Add the Watt-hours needed for all appliances together to get the total Watt-hours per day which must be delivered to the appliances.
3. **Estimate total Watt-hours per day needed from the PV modules**: Multiply the total appliances Watt-hours per day times 1.3 (the energy lost in the system) to get the total Watt-hours per day which must be provided by the panels. This is the expected panel output.

a. PV modules sizing

Different size of PV modules will produce different amount of vitality (power). To estimate the sizing of PV module, the total peak watt produced must be calculated. The peak watt (w_p) produced depends on size of the PV module and climate of site location. We have to consider panel generation factor which is different in each site location. For Nigeria, the panel generation factor is 3.40. To determine the sizing of PV modules, the following needs to be calculated:

1. **Calculate the total Watt-peak rating needed for PV modules**: This is calculated by dividing the total Watt-hours per day (Wh) needed from the PV modules by 3.40(generation factor) to get the total Watt-peak rating (w_p) needed for the PV panels needed to operate the appliances.
2. **Estimation of total PV panels required for the system**: The total number of PV panels required for the system can be calculated by simply dividing the total Watt-peak rating needed for PV modules by the rated output Watt-peak of the PV modules available. Approximation to the next whole figure can be made to give the number of PV modules required. The Result of the calculation is the minimum number of PV panels.

b. Estimating the size of Inverter

For stand-alone PV systems, the inverter must be large enough to handle the total amount of power (Watts) needed. The inverter size should be 25-30% bigger than total Watts of appliances. In the event of large machines like blowers, the inverter size should be multiple times the capacity of those machines in other to handle high current flow during starting.

c. Estimation of Battery size

Deep cycle battery is the battery type suggested for using in solar PV system. This battery has high productivity, explicitly intended to quickly recharge after being discharged to low energy levels and also very durable. The battery ought to be sufficiently enormous to store adequate energy which will be used to operate the appliances at night and cloudy days. To adequately estimate the size of battery, the following steps should be taken:

1. Calculate total Watt-hours per day used by appliances.
2. Divide the total Watt-hours per day used by 0.85 for battery loss(efficiency)
3. Divide the answer obtained above by 0.6 for depth of discharge.
4. Divide the answer obtained above by the nominal battery voltage.
5. Multiply the answer obtained above by the days of autonomy (the number of days that you need the system to operate when there is no power produced by PV panels) to get the required Ampere-hour capacity of deep-cycle battery.

$$battery\ Capacity\ (Ah) = \frac{Total\ Watt-hours\ per\ day\ \left(\frac{Wh}{day}\right) used\ by\ appliances\ *Days\ of\ autonomy}{(0.85\ x\ 0.6\ x\ nominal\ \ battery\ \ voltage\ )}\ (Ah)$$

d. **Solar charge controller sizing**

The solar charge controller is is normally evaluated against Amperage and Voltage limits. Solar charge controller is chosen to coordinate the voltage of PV arrays and batteries. For the series charge controller type, the sizing of controller relies upon the absolute PV input current which is conveyed to the controller and furthermore relies upon PV board design (series or parallel configuration).

According to standard practice, the sizing of solar charge controller is to take the short circuit current (I_{sc}) of the PV array, and multiply it by 1.3(this factor accounts for the loss in the system) [8]

$$Charge\ controller = I_{sc} * 1.3 \quad (Amps)$$

Sizing a typical biogas plant

Among the following are different components involved in producing gas and electricity from biomass. They are:

1. Digester: This is where slurry is fermented
2. Hydraulic chamber: Here, slurry is moved to the digester via inlet pipe.
3. Gas purification unit: To remove impurities
4. Pipe Line: This transport the gas to various points of usage such as lamps, cooking gas etc.

Gas generator: an internal combustion gas engine that convert biogas energy into useful electrical energy. The receiving tank houses the mixture of water and waste. This is converted to solid waste which is sent to the digester for fermentation. Fermentation process and generation of gas occurs in the digester. With no-air entering, the generated methane gas [9] is collected in the upper portion of the digester known as the chamber. When gas is produced, pressure is exerted on the waste which causes it to rise. These waste goes out via the outlet into the overflow tank. Impurities such as chemicals from soaps and moisture are removed through the gas purification chamber and finally, the gas is sent to the gas generator. The gas generator internally burns the gas and converts it to mechanical rotation which is then converted to electrical energy.

Worksheet estimating the amount of biogas produced by a biogas system

In this work, generation of biogas will focus on two sources namely: Human waste and Kitchen waste.

Generation of biogas from Human excrete

If average waste per day by one person = 0.5kg [10], then at ordinary temperature i.e.30^0c, biogas obtained from solid human waste = $0.365m^3/Kg$ which is 20% of total solid waste (TS). If, for example, we have x number of people, then, Biogas obtained from x people will be: $(0.5 * x * 0.2 * 0.365)m^3$

Generation of biogas from Kitchen waste

If average kitchen waste per day by one person = 0.1kg (estimated), then at ordinary temperature i.e.30^0c, biogas obtained from kitchen waste is $0.949m^3\ TS.$ The total solid of kitchen waste is 52%

Therefore if 20% =0.365

$$52\% = \frac{0.365*0.52}{0.2} = 0.949m^3/kg$$

If, for example, we have y number of people visits the kitchen daily, then, Biogas obtained from y people will be: $(0.1 * x * 0.2 * 0.949)m^3$

Worksheet estimating the amount of power that can be generated from biogas

[10] states that $19MJ\ of\ energy\ can\ be\ generated\ from\ 1m^3\ of\ biogas$

Then, from human excrete, $(0.5 * x * 0.2 * 0.365 * 19)MJ$ and from kitchen waste, $(0.5 * y * 0.52 * 0.949 *$ $19MJ$ is generated

The total power = Power obtain from Human waste + power obtain from Kitchen waste

$$= [(0.5 * x * 0.2 * 0.365 * 19) + (0.1 * y * 0.52 * 0.949 * 19)]MJ.$$

Total Power (In Kwh) = $\frac{Total\ Power\ (MJ)}{3.6}$

III. Case Study and Results

Case Study

In this project, requisition to satisfy the basic needs of demand of middle class families living in a 5-story apartment was estimated. The table 1 gives the household electrical appliances and their daily usage in hours from 00:00hr-23:59hr (24hours).

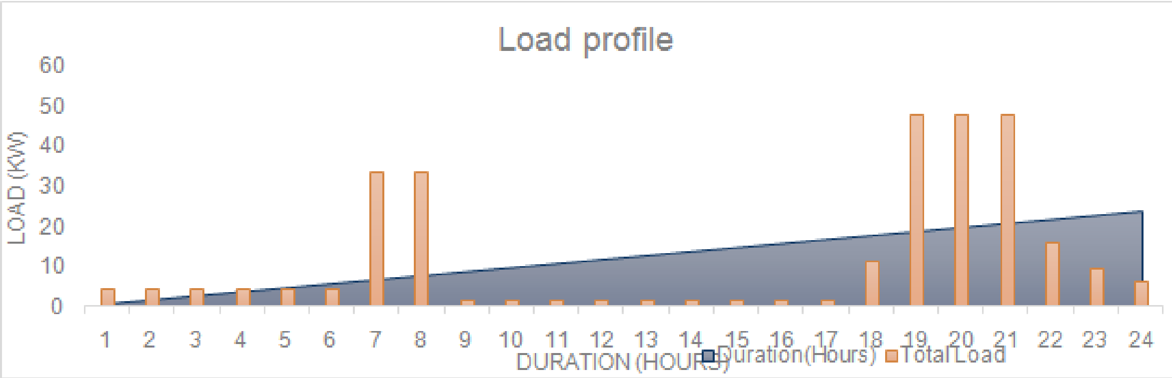
Table 1: Remote residential building daily load demand

S/No	Mostly used appliances	Power rating (Watts)	Quantity	Load (Watt*Qty)	Load (KW)	On-Time(Time in use)	Total Hours in Use (Hrs)	Estimated Load /day (KWh)
1	Fans	15	56	840	0.840	(18:00hr-06:00hr)	12	10.08
2	Refrigerator	50	32	1600	1.6	(06:00hr-23:59hr)	18	28.8
3	Lightings	8	400	3200	3.2	(18:00hr-23:59hr)	6	19.2
4	Television	150	38	5700	5.7	(17:00hr-22:00hr)	5	28.5
5	Laptops	45	18	810	0.810	(17:00hr-22:00hr)	6	4.86
6	Cooker	1000	32	32000	32.0	(06:00hr-07:00hr)& (18:00hr-21:00hr)	5	160
7	Decoders	8	38	304	0.304	(17:00hr-22:00hr)	5	1.52
8	Air conditioners	750	5	3750	3.750	(18:00hr-06:00hr)	12	45
9	Security Lighting	15	6	90	0.09	(18:00hr-06:00hr)	12	1.08
TOTAL				**48294**	**48.294**			**299.04**

Table 2: Load distribution

Table no 2 gives an approximate estimation of energy usage of the residential building under consideration and the daily load profile of a 5 story residential building

Time	Appliance	Fans	Refrigerator	Lighting		TV	Laptops	Cooker	Decoder	AC	Security lighting	Total (watts)	Total (KW)
(00:00hr-01:00hr)		840								3750	90	4680	4.68
(01:00hr-02:00hr)		840								3750	90	4680	4.68
(02:00hr-03:00hr)		840								3750	90	4680	4.68
(03:00hr-04:00hr)		840								3750	90	4680	4.68
(04:00hr-05:00hr)		840								3750	90	4680	4.68
(05:00hr-06:00hr)		840								3750	90	4680	4.68
(06:00hr-07:00hr)			1600					32000				33600	33.6
(07:00hr-08:00hr)			1600					32000				33600	33.6
(08:00hr-09:00hr)			1600									1600	1.6
(09:00hr-10:00hr)			1600									1600	1.6
(10:00hr-11:00hr)			1600									1600	1.6
(11:00hr-12:00hr)			1600									1600	1.6
(12:00hr-13:00hr)			1600									1600	1.6
(13:00hr-14:00hr)			1600									1600	1.6
(14:00hr-15:00hr)			1600									1600	1.6
(15:00hr-16:00hr)			1600									1600	1.6
(16:00hr-17:00hr)			1600									1600	1.6
(17:00hr-18:00hr)			1600			5700	810		304			11614	11.61
(18:00hr-19:00hr)		840	1600	3200		5700	810	32000	304	3750	90	48294	48.29
(19:00hr-20:00hr)		840	1600	3200		5700	810	32000	304	3750	90	48294	48.29
(20:00hr-21:00hr)		840	1600	3200		5700	810	32000	304	3750	90	48294	48.29
(21:00hr-22:00hr)		840	1600	3200		5700	810		304	3750	90	16294	16.29
(22:00hr-23:00hr)		840	1600	3200						3750	90	9480	9.48
(23:00hr-00:00hr)		840	1600	3200						3750	90	6280	6.28
TOTAL													299.04



From the information above, it is observed that from 00:00hrs to 05:59hrs the load demand is 4.68KW. The load demand increased sharply to 33.6KW between 06:00hrs-07:59hs and crashed to 1.6KW at 08:00hs which is due to the fact that people are off to work and most of the home appliances are switched off except the refrigerators. Maximum load was reached between 18:00hr-21:59hr due to several activities like cooking, watching TV etc. during the evening period. As occupants goes to bed, the load demand reduces as many appliances were turned off between 21:00hrs and 23:59hrs.

Analysis and result presentation

The feasibility study of both solar PV and biogas power generation for this paper entails designing a biogas plant from human and kitchen waste of a 5-floor story building and also a solar PV energy system that will provide power during the mid-night hours when grid power is unreliable.

Biogas generation estimation

Using the population information in Table 3, we will design a biogas plant that will be fed with waste materials from the building.

Table 3: Population Information

S/No		Floor	Floor No	Occupants/flat	Population(approx.)
1		Floor 1	10	4	40
2		Floor 2	10	4	40
3		Floor 3	10	4	40
4		Floor 4	10	4	40
5		Floor 5	10	4	40
6		Ground Floor	10	4	40
					TOTAL:240

The analysis of the design is as follows:

If average of 240 people stay in a building, then the amount of biogas and generation of electricity can be calculated as follows:

- **Average human waste** = $0.5kg/person$
- For 240 persons, total human waste = $0.5 * 240 = 120kg$
- But at 30^0c, $0.365m^3/kgTS$ is obtained from human waste. Where TS is the total solid which is 20% or 0.2
- Biogas from 240 persons = $(0.5 * 240 * 0.2 * 0.365) = 8.76m^3$
- **Average kitchen waste** = $0.1kg/person$
- If 240 $person$ $(assumed)$ were served from the kitchen, then, total kitchen waste = $(240 * 0.1) = 24kg$
- But at 30^0c(room temperature), biogas obtained from TS value of 52% is $0.949m^3/kg$ i.e. $if\ 20\% = 0.365kg\ then$

$$52\% = \frac{0.52 * 0.365}{0.2} = 0.949m^3/kg$$

In summary, Total Biogas from kitchen waste = $(240 * 0.1 * 0.52 * 0.949) = 11.84m^3$

Bringing the total generated biogas from the residential building to be:

$$Total\ Biogas = Biogas\ from\ Human\ waste + Biogas\ from\ kitchen\ waste$$
$$= (11.84 + 8.76)\ m^3$$
$$= 20.60m^3$$

Electricity generated for the available biogas
Electricity from human and kitchen waste is calculated as follows:
Since $19MJ$ electricity can be generated from each cubic meter i.e.$1m^3$,$therefore$

$$20.60m^3\ of\ biogas\ will\ generate\ (20.60\ *\ 19)\ =\ 391.4MJ$$

Conversion to Electrical Energy
Total Energy in (Kwh) = $\frac{391.4}{3.6}$ = 108.72Kwh
But 65% of energy is lost as heat and other mechanical losses as used by electrical generator.
Therefore, available electrical energy = 108.72 * 35% = 38.04Kwh
From table 2, it can be concluded that with energy from biogas, Lighting, Fans, security Lighting and Laptops can operate efficiently. This is described in the table below;

Table 4: Renewable energy Distribution

	Time of Usage	Wattage	Energy (Kwh)
Load A(Lighting)	18:00-23:59	3200	19.2
Load B(Fan)	00:00-06:00 18:00-23.59	840	10.08
Load C (Security L.)	00:00-06:00 18:00-23.59	90	1.08
Load D(Laptops)	18:00-23:59	810	4.86
Total			35.22Kwh

Cost analysis of the biogas plant

➢ Using hydraulic retention time (HRT) of $40days$ at 30^0c room temperature and $0.5kg$ waste produced per person, Total discharge of human waste

$$=\ (0.5*240)\ =\ 120kg$$

➢ TS of this fresh discharge = $20\%\ of\ 120kg$

$$=\ 24kg$$

If 8% of TS is required to mix $100kg$ of influent, then 20% of solid waste will require $(\frac{20*100}{8})kg =$ $250kg\ of\ additional\ water\ (influent)$
i.e. $250kg$ of additional water is needed to mix $24kg$ of Total solid waste in the digester
Therefore the influent can be represented as T_{inf}

A. **Digester volume** = $HRT\ *\ T_{inf}$
= 40 * 250kg
= $10m^3$

➢ But Digester = 80% of Total volume (Geometric assumption)

Therefore, $Total\ volume\ of\ the\ Digester\ =\ \frac{Digester\ \ Volume}{0.8}\ =\ \frac{10}{0.8} = 12.5m^3$

➢ But $1m^3$ = $35.315ft^3$

$$Therefore,\ 12.5m^3\ = 12.5\ *\ 35.314$$
$$=\ 441.425ft^3$$

B. **Hydraulic chamber** = $2\ *\ Recharge\ per\ day$

$$=\ 2\ *\ T_{inf}$$
$$=\ 2\ * 250kg$$
$$=\ 2\ *\ 0.25\ =\ 0.5m^3$$

But $1m^3$ = $35.31ft^3$
$0.5m^3$ = $17.655ft^3$

C. **Over flow tank**: This is usually half of the volume of main digester

$$=\ \frac{10m^3}{2} = 5m^3$$

D. **Biogas generator**: A standard 10KVA biogas generator from market survey shall cost #550,000
E. **Gas purification unit:** A standard purification plant suitable for this project shall cost #39,000
Excluding generator and Gas Purification unit, the approximate total construction cost of constructing a fixed dome biogas plant according to market survey is #59,000.00

Profit and payback period
Payback period can be calculated as follows:
Assuming biogas plant is used to supply load A-D, then, per day, 38.05Kwh or units of energy can be saved
As at June 2019, electricity tariff in Nigeria = #25.731/KWh or $0.071USD for single phase [11]
Thus, profit made from Biogas = 38.05 * 25.731 = #979.26.
The total cost (in Naira) of the proposed biogas system to satisfy the load of 38.05KWh is **#59,000**
Payback Period $=\frac{Cost\ of\ Biogas\ plant}{Total\ savings}$
$= \frac{59{,}000}{979.06} = 61\text{days}$
The payback of biogas capital cost is 61days (approximate) or 2 month 1 days
If the life expectancy of the plant is 25years, then the expected profit can be calculated as follows:
Profit made after the payback period for 25 years from $26.03m^3$ of biogas = ($979.06* 30 * 12 * 25) = #8,811,540.00
Converting to US dollars using dollars exchange rate [12], profit = $24,476.5USD

Solar Energy generation
Using the same biogas energy output i.e. energy produce by biogas, analysis was done for solar PV system including costing of each component parts. Table 5 gives the insolation level values in some areas of the country captured by the study. Solar photovoltaic energy is uniquely useful in rural not served by the national grid to provide basic services such as irrigation, refrigeration, communication, and lighting

Table 5: Mean monthly solar insolation [13]

Zone	Solar Isolation											
	Jan	Feb	Mar	Apr	May	June	July	August	Sept	October	Nov	Dec
Central	6.1	6.0	6.1	5.7	5.6	5.8	5.7	6.0	6.3	6.4	6.5	6.2
East	5.2	5.3	4.9	4.0	4.3	4.4	4.4	4.0	4.9	5.1	5.8	5.6
Southwest	6.0	6.1	5.7	5.9	6.2	6.3	6.1	6.6	6.7	7.0	6.7	6.2
West	4.3	4.5	4.9	4.3	4.4	4.8	4.3	4.9	4.9	4.7	4.1	4.3
Southeast	4.4	4.6	4.3	4.0	4.4	4.4	4.5	4.6	4.9	4.9	5.2	4.8
Northwest	5.4	5.0	5.4	5.4	5.4	5.0	5.2	5.4	5.4	5.4	5.7	5.4
Northeast	5.6	5.5	5.6	4.7	3.6	3.8	4.0	4.1	4.6	5.0	5.4	5.6

Sizing of alternative solar PV system for a generation of 38.05Kwh
Total power to be generated = 38.05Kwh
$$= 38.05Kwh * 1.3\ (1.3\ amount\ for\ the\ energy\ lost\ in\ the\ system)$$
= 49.465Kwh/day
Size of the PV panel:
Total w_p (watt peak) of PV panel capacity needed
$= \frac{Total\ PV\ energy\ neede}{4.5(panel\ generator\ factor)}$
$$= \frac{\mathbf{49.465Kwh}}{4.5} = 10.99\text{KW}_{\text{peak}}\ \text{Or}\ 10992.22\text{W}_{\text{peak}}$$
Number of PV panels needed:
$$= \frac{Watt\ Peak\ (w_p)}{Peak\ rated\ output\ of\ the\ module}$$
$= \frac{\mathbf{10992.22}}{300} = 36.64$ modules
Actual requirement shall be **37 modules**. That is, if this system is to be implemented, at least 37 modules of 300w_p PV modules must be installed.
Inverter Sizing:
$$Total\ Wattage\ of\ the\ appliance = (840 + 3200 + 810 + 90) = 4940\text{watts}$$
For safety, the inverter should be considered $25 - 30\%$ more than the total wattage of the appliances i.e.
$(25\%\ \text{of}4940\text{watts}) + (4940\text{watts}) = 6175\ \text{watts}$
The inverter size should be about $7KW$ or larger
Battery sizing:
$$Total\ Wh/day = 299.04KWh$$
$$Nominal\ battery\ voltage = 10V$$
$$Days\ of\ autonomy = 3\ days$$
$Battery\ capacity = \left(\frac{Total\ watt-hour\ per\ day\ used\ by\ the\ appliance\ *days\ of\ Autonomy}{Efficiency\ *depth\ of\ discharge\ *Norminal\ voltage}\right) = \frac{\mathbf{35.22}*1000*3}{0.85*0.6*10}$
$$\frac{105660}{5.1} = 20717.64\text{Ah}$$

The battery should be rated $10v, 20717.64Ah\ for\ 3\ day$ autonomy. If, for example, a $10v\ 1600Ah$ battery is to be used, the total numbers of batteries needed to be connected in parallel to produce $17000Ah$ shall be:

$$Total\ batteries = \frac{20718}{1600} = 13\ batteries$$

Solar charge controller sizing:
Given the PV module specification as follows:

$$p_m = 300\ watts$$
$$v_m = 16.7$$
$$I_m = 6.6A$$
$$I_{SC} = 7.5A$$

The solar charge controller rating = [$(No\ of\ modules * I_{SC}) * 1.3$]
= 37 * 7.5 * 1.3 = 361Amp

The solar charge controller capable to withstand the current produced by the PV modules at 10v is to be rated361 Amps or higher**.**

Cost analysisof alternative solar PV system for a generation of 38.05Kwh

Cost of solar module needed:

According to market survey, a 300Watts Poly PV solar panel cost $100 USD/piece

i.e. $1\ Module\ (300\ Watts) = \$100\ USD$

$37\ Modules = \$\ \mathbf{3700}$ equivalent to #1,332,000.00

Cost of inverter needed:

N-series pure sine wave inverter 7KW inverter cost$ 1500 equivalent to #540,000

Cost of Storage battery needed:

$$Cost\ of\ a\ 10V,\ 1600Ah\ sealed\ solar\ battery\ is\ \$238\ USD$$
$$i.e.\ 1\ Battery = \$238\ USD$$

$15\ Batteries = 15 * 110 = \$\ 3{,}570\ USD$ equivalent to #1,285,200

Cost of Solar charge controller needed

$$A\ 60Amps\ solar\ charge\ controller\ cost\ \$140\ USD$$

$Therefore,\ 60Amps * 5\ Pcs = \$140 * 5 = \$700$ USD Equivalent to #252,000.00

Payback Period:

Payback period can be calculated as follows:

Payback Period $=\frac{Cost\ of\ Solar\ PV\ plant}{Total\ savings}$

Table 6 : the summary of the cost of each solar PV component

S/No	*Component*	*Rating*	*Qty*	*Cost in Naira*
1	Solar PV Module	300W	37	**1,332,000**
2	Pure sine wave DC-AC Inverter	7KW	1	**540,000**
3	MPPT charge controller	60Amps	5	**252,000**
4	Moll 10 opzv 1600Ah Battery	1600Ah	15	**1,285,000**
	TOTAL			**3,409,000**

The total cost ($) of the proposed PV system to satisfy a total load of $38.05KWh$ is **#$\mathbf{3,409,000.00}$**

As at June 2019, electricity tariff in Nigeria = #25.731/KWh or $0.071USD for single phase [11].

Therefore total savings of power generated from solar/day

$= 38.05 * \#25.731$ = **#979.06**

Therefore the payback period = $\frac{3{,}409{,}000}{979.04}$ = 3481.895days

The payback of Solar PV capital cost is 3482days (approximate)

IV. Summary Of Results

Calculation of the total cost investment and its corresponding payback period for biogas and solar PV system is executed for a remote station. The table below shows the comparison estimation between the two systems.

Table 7: Cost and payback period disparity between biogas and Solar for a remote residential building

Renewable Energy source	Total Invested ($)	Payback
BIOMASS	2996	*61 days*
SOLAR	64,500.00	3481.895days

From the table above, it is shown that the use of biogas for power generation is better compared to standalone solar PV system due to large disparity between the payback periods of the two systems.

V. Conclusion

Currently, it is observed that renewable energy from biogas in Nigeria, Tanzania and other developing is not developed to generate electricity [13]. This made communities mostly in rural areas to depend fully on electricity from the grid. This work has really shown that enough power could be harnessed domestically from both human and kitchen waste. The analysis shown above compares the viability of biogas in any remote location to that of solar PV system. Solar PV has its numerous advantages such as generation of clean and noiseless power among others but requires very huge high installation capital. Biogas on the other hand, compared with photovoltaic and wind energy, can be stored and used on demand, providing an opportunity for use as a base load. It also requires small installation cost and could produce gas that will generate power and at the same time be used domestically. From the above study, it will take 3481.895 days to recover solar PV installation cost while it will only take 61 days to recover biogas installation cost at a profit of #8,811,540.00in 25 years. This shows that if a street has an average of 30 houses and each apartment with an average of 10 people each, then, each house will generate $0.8585m^3$ of biogas per day. Channeling the generated biogas into a central holding tank, then a total of $25.75m^3$ of biogas can be stored. This gas is capable of generating 136Kwh for the whole 30 houses. This in turn will eliminate the problem of depending on the unreliable grid, greenhouse effect and cost savings.

This analysis shows that it is cheap and reliable when biomass system is used as an alternative source of power supply compared to solar PV system and fossil fuel based generators. If the government put in place policy to motivate small power producers (SPP), excess power could sold to other buildings.

Reference

[1]. Obadia, K.B; Lingling, Z.; and Gerald, M. (2018). The Potential Renewable Energy for Sustainable Development in Tanzania: A Review. Clean Technology vol.1 Pp 70-88

[2]. Akinbami, J. F. K.; Ilori, M. O.; Oyebisi, T. O.; Akinwumi, I. O. and Adeoti, O. (2001). Biogas Energy use in Nigeria: Current Status, future prospects and policy Implications. Renew Sustain Energy. Vol. 5, pp 97 – 112.

[3]. Energy Commission of Nigeria (1998). Rural Renewable Energy Needs and Five supply Technology: Papers prepared for the joint ENC-NYSC Rural Renewable Energy project Training workshop pp 40-42.

[4]. Kevin, N. and Christopher, E. (2017). Comparative Biogas Yield Analysis of Selected Animal and Non-Animal Waste Substrates in the Tropics. 16th International Conference on Sustainable Energy Technologies – SET 2017 17th - 20th of July 2017, Bologna, IT

[5]. Rajib, B.; Sujan, K.T. and Md., A.Z (2016). Biogas Utilization from Biomass and Kitchen Waste and its Impact on Energy Cost on a University Campus. American Journal of Engineering Research (AJER) Volume-5, Issue-11, pp-150-157

[6]. Mariangela, S.; Francisco, G.; Luigi, P.; Ilaria, Z; Daniele, S. and Andrea C. (2017). Costs-benefit analysis of a small-scale Biogas plant and Electric Energy Production. Bulgarian Journal of Agricultural Science, 23 (No 3) 2017, 357–362

[7]. Smruti, R.P.; Prajna, P.B.; Sangram, K.S. and Satya P. (2013). Design of Standalone Hybrid Biomass & PV System of an Off-Grid House in a Remote Area. Int. Journal of Engineering Research and Applications Vol. 3, Issue 6, pp.433-437

[8]. **SurekhaManoj and Puttaswamy P. Srinivasaiah (2012).** 'Estimation and Cost effective analysis of Hybrid-wind/PV generation for Rural/Remote Electrification'. International Journal of Emerging Technology and Advanced Engineering.www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 2, Issue 12)

[9]. **Sanaullah Ahmad (2015).** 'Designing and Strategic Cost Estimation of Biogas Plant: An Alternative for Current Energy Crisis in Pakistan'. International Journal of Renewable Energy and Environmental Engineering. ISSN 2348-0157, Volume 03, No 03, July 2015, pp 209-212, https://www.researchgate.net/publication/308207779

[10]. Biogas Plant designs and Energy Calculations. https://www.slideshare.net/mobile/alisaqlain111/biogas-plant-designs-and-energy-calculation-energy-calculation-ali-saqlain

[11]. Nigeria Electricity Prices (2019). https://www.globalpetrolprices.com/Nigeria/electricity_prices/. Accessed on 8th February, 2020

[12]. **Currency converter (2019).**www.exchangerates247.com (accessed on the 4th September, 2019)

[13]. **Urbanus F.M.; Josef T. and Zdeněk M. (2018**). Use of Renewable Energy for Electrification of Rural Community to Stop Migration of Youth from Rural Area to Urban: A Case Study of Tanzania. http://dx.doi.org/10.5772/intechopen.74956

ADENLE, JOHNSON GBADEBO, et. al. "Comparative Analysis between Biogas Yield of Human Waste, Kitchen Waste and Solar PV for the Generation of Power in A Remote Station." *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, 15(4), (2020): pp. 37-45.