# Performance Analysis of Bio-Energy Based Power Generation System in Nigeria Using Rice Husk Feedstock

**Dr. Ogungbenro Oluwaseyi Akinyele, Okoro Israel Chidi, Ohuabunwa Augustine Ebere, Okwuelu Nnaemeka, Tagbo Peter**

Research and Development Department, Electronics Development Institute-National Agency for Science and Engineering Infrastructure (ELDI-NASENI), Nigeria.

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**ABSTRACT**: *Bio-energy which is the energy resources derived from organic matter has contributed significantly to primary energy supply in most developed countries of the world. The extensive use of biomass for electricity generation started recently as a more efficient option of providing energy. To encourage investment in this area, detail analysis on the prospect of Biomass energy generation system in Nigeria context need to be carried out. In line with this, this study assesses the viability of setting up a Biomass Energy Plant in Nigeria using rice husk. It determine the availability of rice husk for the project and identify the economic advantage of using rice husk as a feedstock in generating electricity while evaluating the energy conversion technology adopted with consideration on its environmental impact. The proposed plant location is Abakiliki Rice Mill complex and Gasification technology was adopted for the bio conversion process. Data on the feedstock availability was collected by direct measurement of the resources at the various mill dump site in the Rice Mill Complex and analyzed using Python analytical and visualization tools (Numpy and Seaborn). The primary source of data for the analysis is data gotten from the field and Nigeria Energy Regulatory Council (NERC) while the secondary source of data is data from related work over the internet. The outcome of the study showed that the Rice Complex have the capacity to produce the quantity of rice husk required to generate 499,320KWh of electricity per year using Bio-Energy plant. Also, the mass of rice husk produced is significantly higher in the month of October, November and December due to the weather condition (dry season) and the high demand of rice as the result of the festivity (Christmas celebration). When the performance of the existing system and the proposed Bio-Energy plant was compared in terms of per Kilowatt cost of energy generation, it was observed that the new system outperformed the existing one. This is traceable to the good caloric value of rice husk and its availability in very large quantity at no cost. To determine the system's sustainability, the financial feasibility of operating a Biomass plant in Nigeria was also carried out; levelised cost, simple payback period and return on investment (ROI) as important financial metrics were calculated using real data.*

**KEYWORDS:** biomass, energy generation, rice husk, feedstock availability, bio-energy plant

## INTRODUCTION

Renewable energy sources are fast becoming more reliable source of electrical energy especially in developing countries. Nigeria is a developing nation; cheap, uninterrupted and sustainable power supply is a basic requirement for the attainment of its socio economic developmental goals. Access to stable electricity supply has been a major issue in both urban and rural area in Nigeria and this has led to economic woes like increased poverty, unemployment and retarded industrial developments.

The Nigerian biomass situation is quite favourable due to its large deposit of such resource as woods, forage grasses, industrial wastes, municipal wastes, forestry waste and agricultural wastes. There is a heavy demand for rice as a staple food in Nigeria and rice is cultivated in different part of the country. According to Knoema data hub [1], Nigeria is a large producer of rice with an estimated 8.17 million tonnes of paddy rice in 2020. West African rice development association estimated that Nigeria accounted for 57% of the total rice output in Africa which is a clear indication that large deposit of rice husks are produce daily and if properly harnessed could be a source of power to the rural communities [2].

### Problem statement

Basically, Nigeria is an agrarian nation and most of the citizens depend on agriculture for survival. There is a problem of poor management of the abundant agricultural wastes in our environment. Instead of been utilize in wealth creation, rice husk has cause serious problem due to the millions of tonnes of $CO_2$ generated and emitted to the environment when burnt. This leads to environmental degradation, sickness and subsequently death.

### Aim and Objectives

The aim of this study is to reduce the $CO_2$ emission via electricity generation using rice husk from Abakiliki Rice Mill Complex. However, the specific objectives of this study are:

1. To determine the quantity of biomass feedstock required to operate a 500Watts energy generating plant.
2. To determine the annual rice husk availability for bio-energy generation in the given locality
3. To perform techno-economic assessment and determine the minimum selling price (tariff) of bio-electricity
4. To assess the performance of the biomass power plant system.

### Research Questions

In line with the aim and objectives of this research, the following questions where ask and answered based on the fact and findings of this research:

1. What quantity of biomass feedstock is required to operate a 500Watts biomass energy generation plant for a period of one year?
2. What is the quantity of biomass feedstock available per annum at the proposed plant site (Abakiliki Rice Mill Complex)?
3. What is the levelised cost of the energy generated?
4. What is the performance of the system?

## LITERATURE REVIEW

Renewable energy systems and resources have contributed immensely in the fight against climate change and global warming. Among the most abundant renewable energy resources is the biomass. According to the study in [3], cereals (rice husk) were found to have a major contribution (about 74.67%) in the biomass supply and this encourages the use of rice husk for bio-energy application such as electricity generation. Research carried out by Tokarski [4] showed that the most widespread method of producing electricity from renewable sources in power plants involves the co-firing of biomass with fossil fuels. Kini et al. [5] used mills in India as a case study in their work on power generation from rice husk through gasification technique. The work focused on the likelihood of generating electricity from rice husk, but fails to consider the gasifier design and levelised cost of electricity. Furthermore, Li et al [6] researched on the impact of husk drying and heat integration on Bio-energy plant. The outcome showed that with proper drying and heat integration, the overall efficiency of Bio-energy plant using rice husk is improved by about 5%. Research on cost and environmental analysis of biomass power plant conducted by Visser et al.[7] and Roy et al. [8] indicated that bio-energy generating system have more environmental benefit when compared to other similar plants

### Rice Husk energy characteristics and composition.

Basically, the generation of electricity from rice husk has been made possible due to its characteristics and chemical composition. It is estimated that the annual paddy rice production in Nigeria stands at 8,700,000 tonnes. Also the total amount of rice husk produced annually from the paddy rice stands at 1,646,980 tonnes and the potential ash content of the production is approximately 296,456 tonnes which is about 18% of the rice husk [9]. With average calorific value of 3410 K Cal/kg, 1 ton of rice husk is capable of generating 410- 570 KWH of electricity [10]. The ash content of rice husk is in the range of 10-20% which is high when compared to other biomass fuel. It has light weight, smooth external surface, high porosity and silica content (about 87-97% of silica) which made it a choice output for other industrial application[11,12]. The property of the ash content gotten from rice husk can be influenced by various factors which includes its incineration conditions like the temperature and duration of stay; also other factors includes the rice variety, the rate of burning and the fertilizers used in the cultivation of the rice[11].

**Figure 1. The rice husk mountain in the proposed location**

**Biomass to Energy Conversion Technology**

There are many bio-energy routes which can be used to convert raw biomass feedstock into a final energy product. Several conversion technologies have been developed that are adapted to the physical and chemical composition of the feedstock. Recent years have witnessed considerable effort devoted to exploring the best ways to exploit these potentially valuable sources of energy. The most commonly used biomass energy conversion method is gasification.

**Gasification technology**

Gasification is defined as the partial combustion of carbonaceous feedstock into a gas or syngas, it is often considered as a process that fall between pyrolysis and combustion because of the controlled addition of oxygen which gives rise to incomplete combustion (the operating temperature of gasification is usually <700°C). The result of this process is a type of fuel that is used in the syngas turbine to generate electricity. The calorific value of the gas is estimated to be between 4.0 – 6.0 MJ/Nm3 [13]. The carborneous substance in biomass feedstock is converted into gas; usually the gasification agents are air, steam, oxygen or a mixture of all [14]. Gasification is considered a thermo-chemical reaction and is suitable for small scale power generation. There are different types of Rice husk gasifier (down draft, updraft, cross draft gasifiers and fluidized bed gasifiers) and each has its area of application. A down graft gasifier is relatively cheap and produces a high quality syngas during the gasification process [15]. It is flexible and most suitable for large gas production.

Fluidized bed rice husk gasifiers are more complex to operate than the fixed bed gasifiers. Also, the gas produced from the fluidized bed gasifiers has more heating effect than others [15]. Using this gasifier, the initial operation will require an external ignition which is normally done using liquefied petroleum gas. After few minutes of burning, gaseous products which contain CO, $H_2$, CH4, $CO_2$, and $N_2$ are released from the gratified rice husk. The gases are cleaned up by wet scrubbers, tar condensers and other bag filters in the cyclone separator [20]. Inert materials like sand used at the bed of the reactor help to increase the rate of the biomass reaction with the fluidize bed. The end product of this process is a fine reformed gas that is free of impurities.

In Updraft Gasifiers, air flows into the system from the bottom and the gas exits from the top. The biomass passes successively through the drying, pyrolization and reduction zones. Gases released flow upward as the increase in temperature reduces their density. With this design; the air or oxidizing agent entering the cylinder easily comes in contact with the chars creating the combustion zone while the gases coming out of the combustion zone pass through the layer of chars above them. Here, $CO_2$ and $H_2O$ are reduced to CO and $H_2$ which have enough energy to pyrolyze the descending biomass along a range 200 to 500°C; producing the chars that feed the combustion zone.

The technique for Downdraft Gasifiers slightly differs from the Updraft Gasifiers. In this case, air enters at the middle level of the gasifier above the grate. The air and gas mixture flows down into the gasifier reactor via the high temperature oxidation zone leading to thermal cracking of volatiles. Such systems have shorter contact times and therefore are more responsive than updraft gasifiers. This gasifier is preferred to updraft gasifier for internal combustion engines as the result of the low tar content. According to Pradhan et al [21] gasification reaction for rice husk (which produces syngas) proves to be more efficient than direct combustion of original fuel due to its high combustion temperature. In addition, high load capacity over a long period of time has made gasifiers a more reliable process for rice husk power generation [15, 16, 17, 18 and 19]

**Power Generation Potential of Biomass**

The producer gas obtained from biomass gasification has a low calorific value; however, it has a high heating effect in the range of 5.4–5.7 MJ/m3. The producer gas can either be burned directly in a burner to make available thermal energy or used as a fuel in an engine to provide electricity. Presently, biomass gasifiers are used in electrification of remote villages. The size of such systems can vary from 10 KW to 500 KW.

**Biomass feedstock availability**

Biomass feedstock required for this study is rice husk which is quite available in Nigeria. The total amount of rice husk needed to run a bio-energy plant largely depends on the annual paddy rice production and the rice straw/husk ratio. The total quantity of rice straw and rice husk generated in Nigeria is determined using a Straw to Grain Ratio (SGR) and Husk to Grain Ratio (HGR). According to Singh .J [3] the SGR and HGR value stands at 0.75 and 0.2 respectively. The paddy rice production data obtained from the National Bureau of Statistics [22]indicated that a total of 3462 million tonnes per year of paddy rice was produced over a ten years period from 2005–2014. Also, the availability of a biomass feedstock could depend on its competitive uses, and constraints in harvesting [23].

## METHODOLOGY

**Determination of feedstock availability**

To determine the quantity of available rice husk per annum in the given locality and establish its adequacy to sustain the operation of the rice husk plant, resources assessment is carried out using the 15 clusters of rice mill labeled Mill1, Mill2, Mill3…Mill15. The rice husk produce in each mill at the end of every month is weighed using weighing balance and recorded. The measurement is taken for the period of one year starting from 1$^{st}$ January, 2021 to 31$^{st}$ December 2021.

**Gasification Process and Models**

Gasification of biomass feedstock involves all the processes required to produce electricity from the raw material. This includes feedstock processing; the feed stock is first lifted from their dump site to the location of the gasifier plant. To reduce the cost of transportation, the plant is sited in the same location as the dump site. The second stage is the gasification process, followed by the input of the pure producer gas and purification.

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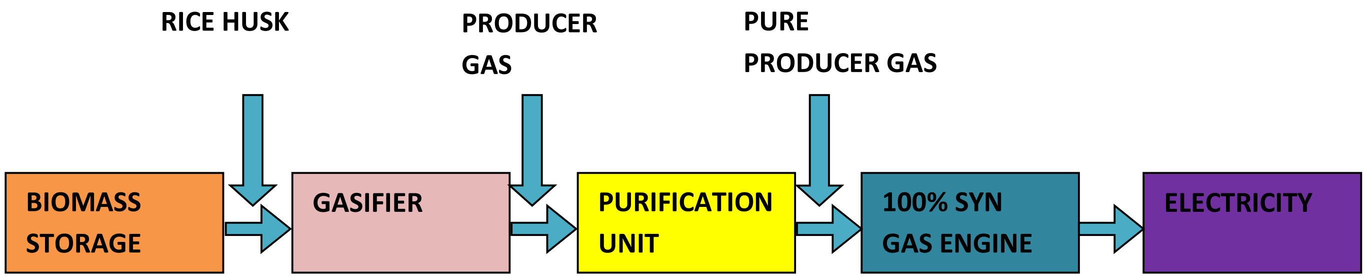


**Figure 2. Electricity generation using rice husk gasification process. (Islam and mondal, 2013)**

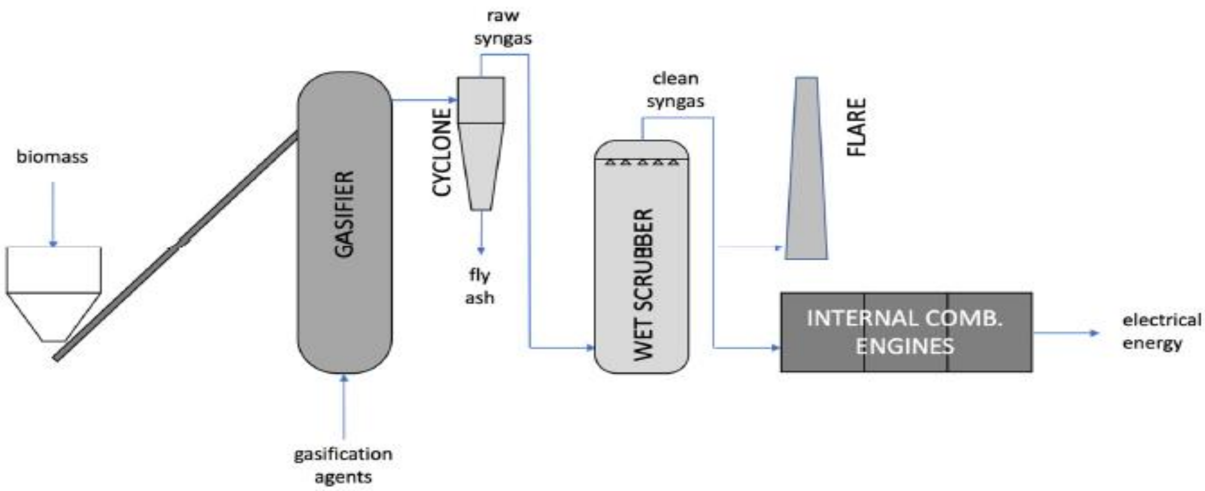


**Figure 3. Biomass-Energy plant**

The proposed plant for this project is a 500 KW gas turbine plant, with 60% efficiency and an availability of 100% Potential electricity generation from rice husk:
The quantity of Biomass feedstock required per annum is calculated as shown below-

Qbm = TEG/ (Erh x Pe) (1)

Where:

Qbm is the quantity of Biomass feedstock required per annum,
TEG is total annual energy generated,
Erh is the energy per Kg value of rice husk
Pe is plant efficiency

TEG = Tyh x Pc x Pe (2)

Where:

Tyh is the total yearly hour,
Pc is plant capacity

Tyh is 8760 (i.e. 24 x 360), Pc is 500 and Pe is 0.6 (i.e. 60%), Substituting into equation (2)

TEG = 8760 x 500 x 0.6 = 2,628,000KWh

Also, the standard value of Erh is 3.91 KWh/kg, substituting into equation (1)

Qbm = 2,628,000/ (3.91 x 2,628,000) = 1120204.6036kg per annum

The Annual electricity generated is as shown below-

Annual electricity generation (Ae) = TEG – (TEG x Pl) (3)

Where:

Ae is the annual electricity generated

Pl is the parasitic load

The biomass plant parasitic load is the total energy consumption on the generation site. This is estimated as five percent (5%) of the annual electricity generated and Pe is 0.6 (i.e. 60%), Substituting into equation (3),

At 100% availability:

Ae = 2,628,000– (2,628,000 x 0.05) = 2,496,600KWh

At 80% availability:

TEG at 80% availability = TEG at 100% availability x 0.8 = 2,628,000 x 0.8 = 2,102, 400KWh

Ae = 2,102, 400 - (2,102, 400 x 0.05) = 1,997,280KWh

**Economic and Financial analysis**

The economics of biomass gasifiers is evaluated based on cost using discounted cash flow technique. Data regarding installation cost, cost of fuel, and cost of labour for the operation and maintenance of the system was determined. Discounted cash flow measures the productivity of the invested capital, cash flow and returns over project life (25 years). Different measures of capital productivity are used in the economic evaluation of investment in biomass energy system to draw out its comparative picture.

The main aim of this analysis is to prove that biomass feedstock in Nigeria could be a cheaper source of power for rural dwellers. For biomass power plant to survive and attract investors there is a need to prove that investments in this area could yield profits for investors and help to resolve the prevalent power challenges encountered in Nigeria. For the purpose of this financial analysis, some assumptions which are in tune to real life situations were made. Prices and values for this analysis are based on present market values. The cost of the generating plant is estimated to be 135,200,000 naira. The life cycle is 25 years. It was assumed that the project will be financed by 100% equity and the operational and maintenance cost is 20% of the capital cost per year. Also the cost is calculated in Nigerian naira at an exchange rate of NGN 490 for $1. These calculations are done based on present day assumptions that the capital cost for a gasification plant is approximately between $1500 to $2000/kW.

**Cost of energy generation**

The financial analysis of the proposed power plant was carried out in order to determine the levelised cost of electricity from the power plant. The levelised cost refers to the minimum amount at which a particular product or services is sold without making a loss [24]. Considering the various cost factor, the levelised cost of electricity is determine as shown in equation (4):

LCOE = (Ac)/ (Ae) (4)

Where:

LCOE is the levelised cost of energy,

Ac is the annualized cost of the total system,

Ae is the annual energy generated.

Annualized cost of the total system includes; the cost of capital per annum, cost of replacement per annum, cost of maintenance per annum and the salvage value of the system.

Ac = Cc + Cr + Cm + Cf- Cs (5)

Where:

Cc is the cost of capital per annum,

Cr is the cost of replacement per annum,

Cm is the cost of maintenance per annum,

Cf is the cost of fuel,

Cs is the salvage value of the power plant system.

**Capital cost per annum (Cc)**

This includes installation cost with all other supporting infrastructure to ensure the site is ready for operation. Capital cost per annum was calculated as,

Cc=C x CRF (6)

Where:

C is the cost of capital,

CRF is the capital recovery factor.

$CRF(r, n) = r\ (1+r)^{n} / (1+r)^{n-1}$ (7)

Where:

r is the discount rate on capital,

n is the project lifetime,

In this study: r=11.5% and n is 25years, substituting into equation (7) will result to:

$CRF = 0.115(1+0.115)^{25} / (1+0.115)^{24} = 0.1282$

Also, the capital cost of the system is 135,200,000 Naira, substituting into equation (3) gives the Capital cost per annum as:

$Cc = 135{,}200{,}000 \times 0.1282 = 17{,}332{,}640$ Naira

**Cost of replacement per annum (Cr)**

The annual replacement cost of the system is the cost of replacing the failed component of the system per annum. This was calculated using:

$$Cr = CR \times CRF \times 1/(1+r)^{y} \quad (8)$$

Where:

CR is the replacement cost of the system for the entire life cycle.

y is the biomass gasifier system lifetime in years.

The replacements are necessary if the lifetime of the project is greater than component lifetime. The replacement cost of the system for the total life cycle is N 229,794,800. Substituting into equation (8) gives the annualized replacement cost as:

$Cr = 229{,}790{,}800 \times 0.1282 \times 1/(1+0.115)^{25} = 1{,}930{,}277$ Naira

**Cost of maintenance per annum (Cm)**

The maintenance cost of the bio power system include; labour costs, repairing and other charges to operate the system and it was estimated as 20% of the capital cost of the system

$Cm = 0.2 \times 135{,}200{,}000 = 27{,}040{,}000$ Naira

**Cost of fuel per annum (Cf)**

Rice husk is the input feedstock used as fuel in this work. The fuel cost is the product of the quantity of rice husk feedstock consumed in a year (in kg) and the price of 1kg of rice husk.

The Cf was calculated from the equation:

$$Cf = Pr \times TEG \times q(t) \quad (9)$$

Where:

Pr is the price of rice husk per kg,

q (t) is the rate of rice husk consumption by the bio-energy plant

Rice husk used at the project site were disposed waste, therefore the price of rice husk per kilogram is 0 Naira. Hence,

Cf = 0 Naira

**Salvage value (Cs)**

Salvage value is the value of the remaining component of the system at the end of project life. This was calculated using this formula:

$$Cs = Cr_{x} R/n \quad (10)$$

Where:

Cr is the cost of replacement per annum of the component,

R is the remaining life of the project system

n is the life span of the gasifier system.

The remaining life of the biomass power plant was derived from the scrab value of the project. Stainless steel lasts for more than 40 years and the generators can be sold as scrab as the project life span. So, the remaining life of the gasifier is 15 years. Substituting into equation (43) yields:

Cs = (1,930,277) x 15/25 = 1,158,166 Naira.

Substituting the values of Cc, Cr, Cm, Cf and Cs into equation (5) gives:

Ac = 17,332,640 + 1,930,277 + 27,040,000+0-1,158,166

Ac = 45144751

The total energy generated per annum by the system (Ae) is 2496600(KWh),

Substituting into equation (4)

LCOE = 45144751/2496600 = 18.08 Naira/KWh

3.4.2. Annualized Return on investment

This is a financial ratio use to calculate the benefit that an investor will receive in relation to the investment cost. It helps to evaluate the performance and efficiency of an investment. The higher the value of this ratio, the bigger the benefit earned. Annualized Return on Investment was obtained as follows -

$$ROI = 1 - \left[\frac{C - Ap}{C}\right] \quad (11)$$

Where:
C is cost of capital
Ap is profit per annum

$$Ap = Ai - Ac \quad (12)$$

Where:
Ai is annual income

$$Ai = Ae \times Up$$

Where:
Up is the amount received from selling 1KW of electricity. Assuming energy is sold at the NERC rate of 52.76Naira-

$$Ai = 2496600 \times 52.76 = 131{,}720{,}616$$

Substituting Ai into equation (8)-

$$Ap = 131{,}720{,}616 - 45{,}144{,}751 = 86{,}575{,}865$$

Substituting Ap into equation (7)

$$ROI = 1 – (135{,}000{,}000-86{,}575{,}865)/135{,}000{,}000 = 0.6413$$

**Simple payback period**

Payback period is the time it takes to recover the cost of an investment from the cash inflows by that investment. It is a simple investment appraisal technique. Generally, investments with a high payback period are not attractive to the investors.

$$\text{Payback period} = \frac{C}{Ap} \quad (13)$$

Where:

C is the Cost of capital (Initial investment)

Ap is the annual profit (yearly net cash flow)

Payback period = 135,000,000/86,575,865 = 18month.

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## RESULT

**Table 1. Summary of monthly feedstock availability from each rice mill (Source: Field survey 2021)**

| Month | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mill 1 | 7400 | 7608 | 5356 | 6732 | 4588 | 3932 | 4016 | 4924 | 6240 | 8288 | 9140 | 10216 |
| Mill 2 | 7332 | 9208 | 6152 | 7532 | 5368 | 4044 | 5012 | 5512 | 5840 | 8528 | 10292 | 10324 |
| Mill 3 | 5112 | 5740 | 3984 | 3652 | 4328 | 2988 | 3248 | 4440 | 5072 | 6568 | 7780 | 8032 |
| Mill 4 | 7000 | 7992 | 5756 | 6364 | 5028 | 3532 | 4092 | 4956 | 5984 | 9084 | 9920 | 11020 |
| Mill 5 | 8568 | 9400 | 7976 | 6572 | 5804 | 5148 | 4536 | 5724 | 6754 | 9402 | 8667 | 10052 |
| Mill 6 | 6524 | 7424 | 5008 | 6892 | 4908 | 3336 | 3800 | 5404 | 5742 | 9548 | 8576 | 12616 |
| Mill 7 | 7444 | 7892 | 6640 | 7408 | 4732 | 3948 | 4816 | 6764 | 7056 | 9468 | 10688 | 10460 |
| Mill 8 | 7072 | 7656 | 6344 | 6296 | 4876 | 3280 | 3792 | 6060 | 6732 | 9360 | 9608 | 10864 |
| ll 9 | 6692 | 7360 | 5740 | 6724 | 3904 | 3064 | 3876 | 609 | 6556 | 9084 | 10744 | 11244 |
| ll10 | 6880 | 8404 | 4860 | 6928 | 4512 | 4492 | 3896 | 5820 | 5932 | 8720 | 8612 | 10048 |
| ll11 | 7800 | 8408 | 5756 | 7052 | 5258 | 3428 | 3964 | 5704 | 5789 | 7368 | 9440 | 9352 |
| ll12 | 4992 | 5340 | 4052 | 3928 | 4736 | 2612 | 3848 | 5280 | 5844 | 7012 | 7936 | 10520 |
| ll13 | 6600 | 7608 | 5356 | 4892 | 4588 | 3744 | 4216 | 4828 | 6012 | 8048 | 10380 | 12360 |
| ll14 | 7340 | 7672 | 6732 | 5388 | 4632 | 3308 | 4164 | 4944 | 6376 | 8108 | 9500 | 11540 |
| ll15 | 4792 | 5724 | 5384 | 4800 | 3772 | 3240 | 4440 | 5324 | 5548 | 6620 | 8448 | 9651 |
| Total | 101548 | 113436 | 85096 | 91160 | 71034 | 54096 | 61716 | 76293 | 91477 | 125206 | 139731 | 158299 |

**Table 2. Statistical description of the monthly feedstock availability (Source: Field survey 2021)**

| | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **count** | | | | | | | | | | | | |
| **mean** | 1269 | 141 | 106 | 113 | 8879 | 67 | 771 | 9536 | 1143 | 1565 | 1746 | 1978 |
| **std** | 2371 | 264 | 198 | 213 | 1658 | 1263 | 1440 | 1785 | 2135 | 292 | 3261 | 3695 |
| **min** | 47 | 53 | 39 | 36 | 37 | 26 | 32 | 6 | 50 | 65 | 77 | 80 |
| **25%** | 65 | 74 | 52 | 52 | 45 | 32 | 38 | 49 | 5827 | 78 | 86 | 100 |
| **50%** | 70 | 76 | 57 | 66 | 47 | 34 | 40 | 53 | 59 | 86 | 94 | 104 |
| **75%** | 74 | 84 | 64 | 69 | 508 | 39 | 44 | 57 | 66 | 937 | 103 | 113 |
| **max** | 1015 | 1134 | 850 | 911 | 710 | 540 | 617 | 762 | 914 | 1252 | 1397 | 1582 |



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**Table 3. Overview of monthly and annual feedstock availability (Source: Field Survey 2021)**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Month** | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec | Total |
| **Feedstock** | 101548 | 113436 | 85096 | 91160 | 71034 | 54096 | 61716 | 76293 | 91477 | 125206 | 139731 | 158299 | 1169092 |

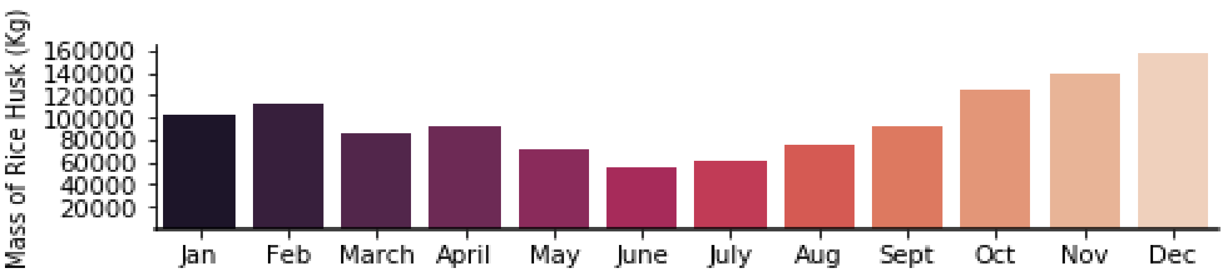


**Figure 4. Bar graph of feedstock availability (Source: Field survey)**

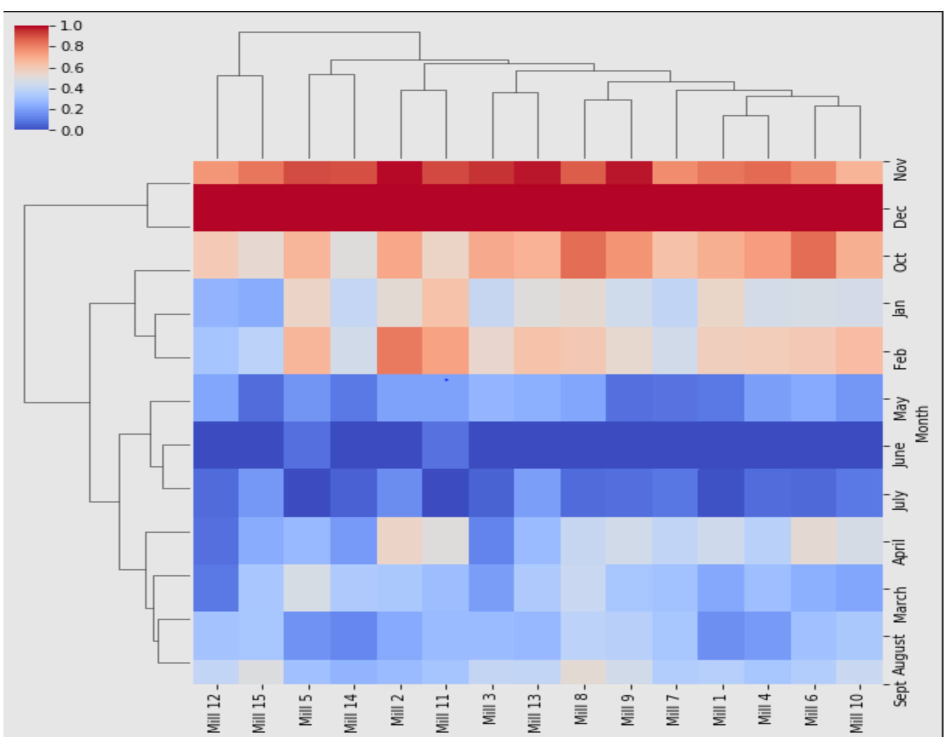


**Figure 5. Clustermap of feedstock availability (Source: Field survey)**

| S/N | DESCRIPTION | VALUES |
|---|---|---|
| 1 | Biomass plant capacity(KW) | 500 |
| 2 | Plant efficiency | 60% |
| 3 | Parasitic load | 5% |
| 4 | Total installation cost(NGN) | 135,200,000 |
| 5 | Biomass feedstock (Kg) | |
| | 100% Availability | 1,120,204.60 |
| | 80% Availability | 896,163.68 |
| 6 | Annual electricity generation(KWH) | |
| | For 24 hours | 2,496,600 |
| | For 19 hours | 1,997,280 |
| 7 | Total Cost (capital and maintenance) | |
| | capital cost(NGN) | 135,200,000 |
| | maintenance cost (20% of capital cost) | 27,040,000 |
| | Discount rate/Annual fixed charge rate | 11.5% |
| | Project life time (years) | 25 |
| 9 | Project gross annual income(NGN) | |
| | For 24 hours | 131,720,616 |
| | For 19 hours | 105,636,139 |
| 10 | Levelised cost of electricity(NGN/KWh) | |
| | For 24 hours | 18.08 |
| | For 19 hours | 23.22 |

. **Table 4. Biomass plant financial and technical parameter and values (Source: Field survey)**

## DISCUSSION

The economics of 500KW biomass gasification power generation system and its feasibility was evaluated by estimating the levelised cost of energy (LCOE), simple payback period and return on investment. Analysis has been carried out for power generation availability at 100% and 80% (8760 and 7008 hours respectively). The maintenance cost was estimated as 20% of the total capital cost on both power availabilities. Biomass fuel (rice husk) was considered to be free at the site of the proposed biomass power plant. From Table 1, Table 2 and Table 3, the feedstock supply at plant location is 1,169,092Kg (the total quantity of feedstock produced from January to December) which is more than the 1,120,204.6036kg required for plant operation. This showed that the available feedstock is adequate for the operation of the power plant. Also, Figure 4 is a chart of monthly rice husk production. It showed that the mass of rice husk produced in the month of October, November and December is significantly higher than the monthly average of 24,535kg. This is attributed to the combine effect of the weather condition (since rice requires heat for drying) and the usual rise in rice demand due to Christmas celebration. The feedstock cluster according to months is represented in Figure 6. According to the cluster map; October, November and December have the highest amount of feedstock production while May, June and July witnessed the lowest quantity of feedstock production.

The economic viability of this project was determined based on techniques for evaluating investment profitability. As indicated in the table 4, the total energy generation from 500KW biomass plant for one year is estimated to be 2,496,600KWh and 1,997,280KWh for plant availabilities of 100% and 80% respectively. The fixed charge rate used for the calculation is 11.5%. Also the levelised cost of energy was evaluated to be NGN 18.57/KWh for biomass plan availability of 100% and NGN 23.22/KWh for biomass plant availability of 80%. This agrees with the work done by researchers in [18, 23]. Return on investment (ROI) which is the common profitability ratio of the project is 0.6413 for 100% biomass plant availability. The simple payback period for the project is 18months for biomass plant availability of 100% which indications that investment in biomass feedstock based power generation is a worthwhile investment, the economic feasibility are encouraging, and this technology proved to be the way forward in solving the persistent power problems prevalent in Nigeria.

## CONCLUSION, RECOMMENDATION AND FUTURE RESEARCH

The application of rice husk for electricity generation presented in this paper is one of the possible ways of solving the problem of inadequate power supply facing Nigeria, as rice husks are readily available in large quantity in the country. This paper presented an off-grid gasification power supply system. First, a comprehensive assessment of the availability of rice husk for power generation in Abakiliki Rice Mill Complex was conducted. Secondly, a techno-economic analysis approach was applied to ascertain the economic viability of the biomass power system considered in this work. The annual availability of rice husk in the study area is 1,169,092Kg and it has potential of 2,496,600KWH per annum. The Levelised Cost of Electricity of the proposed power system is 18.08 Naira/KWH, which is cheaper than 52.76 Naira/KWH tariff from national power grid supply to the area. Using the proposed rice husk power plant, $CO_2$ emission is drastically reduced and the electricity demand of the communities in Nigeria could be satisfy in most economical way which leads to sustainable development. It is recommended that further research be carry out to determine the viability of energy co-generation using biomass and other renewable energy sources like solar and wind.

## Reference

1. https://www.knoema.com/atlas/Nigeria.
2. Diyoke, C. S and Idogwu, U. N. (2014) *An Economic Assessment of Biomass Gasification For Rural Electrification In Nigeria,* International Journal of Renewable Energy Technology Research, pp. 1-17.
3. Singh, J. (2015) *Overview of electric power potential of surplus agricultural biomass from economic, social, environmental and technical perspective—A case study of Punjab*, Renew. Sustain. Energy Rev. 42 286–297.
4. Tokarski, S. Głód, K. Sci ¸a zko, M and Zuwała, J. (2015) *Comparative assessment of the energy effects of biomass combustion and co-firing ˙ in selected technologies.* Energy 92 24–32.

**5.** Kini, S.G., Chandrashekara, A.S and Radhakrishna, S.A. (2016) *Power from rice husk for rice mills - a case study*, International Research Journal of Engineering and Technology pp.405–409.
**6.** Li, J and Jianjun Liu, S. L .(2010) *Hydrogen-rich gas production by air-steam gasification of rice husk using supported nano-NiO/g-Al2O3 catalyst.* International journal of hydrogen energy, science direct, pp. 7399-7404.
**7.** Visser, H., Thopil, G.A. and Brent, A. (2019) *Life cycle cost profitability of biomass power plants in South Africa within the international context.* Renew. Energy 139 9–21.
**8.** Roy, D., Samanta, S and Ghosh, S. (2020) *Performance assessment of a biomass fuelled advanced hybrid power generation system.* Renew. Energy 162 639–661.
**9.** https://www.knoema.com/atlas/Nigeria
**10.** Salman Zafar (2021) *Biomass Resources from Rice Industry*. https://www.bioenergyconsult.com/tag/rice-husk-as-energy-source/References.
**11.** Kumar, A., Mohanta, K., Kumar, D and Parkash, O. (2012) *Properties and Industrial Applications of Rice husk: A review,* International Journal of Emerging Technology and Advanced Engineering, 21 86-90.
**12.** Mohamed, R and I.A. Mkhalid, M. B. (2015) *Rice husk ash as a renewable source for the production of zeolite and its characterization,* Arabian Journal of Chemistry, 8 48–53.
**13.** Islam, M. S and Mondal, T. (2013) *Potentiality of Biomass Energy for Electricity Generation in Bangladesh,* Asian Journal of Applied Science and Engineering, 2 103-110.
**14.** Ruiz, J. and Juarez, M. M. M. P (2013) *Biomass gasification for electricity generation: Review of current technology barriers,* Renewable and Sustainable Energy Reviews 18 174–183.
**15.** Pode, R and BoucarDiouf, G. (2015) *Sustainable rural electrification using rice husk biomass energy: A case study of Cambodia,* Renewable and Sustainable Energy Reviews 4 530–542
**16.** Ezekoye, V. A., Onah, D. U., Offor, P. O and Ezekoye, B. A. (2014) *Characterization of Biogas Produced from Rice Husks and Algae using a Metal Fixed-Dome Biodigester*, Global Journal of Science Frontier Research: G Bio-Tech & Genetics, Volume 14 Issue 1.
**17.** Makwana, J. and Asim Kumar Joshi, G. A. D (2014). *Air gasification of rice husk in bubbling fluidized bed reactor with bed heating by conventional charcoal,* Bioresource Technology, Science Direct, pp. 1-8.
**18.** Natarianto, I., Betty, S., Ajay, K and Raymond L. H (2020) *Economics of Distributed Power Generation via Gasification of Biomass and Municipal Solid Waste,* Energies 13 3703
**19.** Nwofe, P. A and Agbo, P. E (2015) *Enhancement of Biogas Yield from Cow Dung and Rice Husk Using Guano as Nitrogen Source*, International Journal of Sustainable and Green Energy, 4(3). pp. 66-72.
**20.** Arun P.G., Murugan, P. C., Praveen, P., Saji Raveendran, P., and Godwin Glivin (2019) *Natural Bio-Filters For Eco-Friendly Cleaning And Enrichment Of Producer Gas.* International Journal Of Scientific & Technology Research Volume 8, Issue 10.
**21.** Prasad, L. P and Subbarao, J. S. (2014) *Pyrolysis and gasification characteristics of Pongamia residue (de-oiled cake) using thermogravimetry and downdraft gasifier,* Applied Thermal Engineering, science direct, pp. 379-386.
**22.** https://nigerianstat.gov.ng › elibrary
**23.** Nasir A. G, Umar, Z. (2015) *Rice straw & husk as potential sources for mini-grid rural electricity in Nigeria,* Int. Journal of Applied Sciences and Engineering Research, Vol. 4, No. 4, pp 523 -530

Vol.10, No.2, pp.,40-56, 2022
ISSN -2055-0197(Print),
ISSN 2055-0200(Online)

**24.** Andrea, P., Stefano, S., Davide, M., Mauro,M., Francesca, F and Alberto, P (2019) *Techno-Economic Analysis of a Small-Scale Biomass to-Energy BFB Gasification-Based System,* Energies, 12 494.