ESTIMATION OF THE ELECTRICAL ENERGY POTENTIAL OF RICE HUSK BIOMASS GENERATED WHITHIN EBONYI STATE, SOUTH EASTHERN NIGERIA.

Abstract

Nigeria's energy sector has been ailing for the past two decades due to its excessive dependency on petroleum and lack of diversity in energy sources in the energy supply mix. To address this huge energy gap, biomass conversion power plant (BCPP) is considered as a "bridging solution"- allowing waste product to be used to generate power as an alternative to the high-emitting fossil fuels. Thus, this study was conducted to estimate the electrical energy potential of rice husk (RH) generated biomass within Ebonyi State, South East, Nigeria. RH accounts for approximately 20-23% of the total paddy rice weight with about 10 – 12% moisture. Presently, Ebonyi State produces about 300,000 metric tons (300,000,000Kg) of RH annually. The average percentage mass of the RH sample was calculated to be 21.33%. The BCPP analyzed result yields an average moisture and energy content (HHV) of 2.6% and 14.80MJ/Kg with a corresponding electricity output of 70.39KWh. From the BCPP result, the electrical energy potential of RH currently generated within the state was estimated to be 214.29MW per annum. This is a clear indication of the huge prospects that lie in the use of RH as feed stock for power generation within the State.

Keywords: Rice Husk, Biomass Energy, Biomass Conversion Power Plant, Electrical Energy Potential, Gasification.

1. INTRODUCTION

Increase in electricity demand for households and industrial utilizations is fast becoming a serious issue for concern in Ebonyi state due to over dependency of the state on fossil for power generation. The depleting nature of the fossil energy sources, the rate at which carbon dioxide (CO_2) is released into the atmosphere when they are burnt and the increasing demand of the world energy due to population coupled with technological advancement are the current challenges of continued dependence on fossil fuel [9]. This has resulted to zero approach to energy diversification in the state and has adversely affected the human, social and economic development of the state. According to [1], sustainable economic development of a country stands on the sufficiency of electrical energy. So, for Ebonyi as a component state of Nigeria to compete with the rest of the states in Nigeria and the world at large, it should have sufficient electricity facilities to carry on its economic development independently in terms of electricity generation, transmission and distributions. These challenges therefore, offers opportunities on the need to develop and exploit other energy technologies that are capable of providing alternative and renewable energy sources like biomass and solar that can help the present generation to meet their energy demand without jeopardizing the ability of the future generation to meet their energy demand [15]. Also, considering the relatively high cost of the conventional cooking fuels such as gas and kerosene, and the environmental problems associated with the use of fire wood. This has necessitated the need for urgent transition to a more sustainable energy source that would be cheaper and environmentally friendly [18].

In this perspective, biomass, a renewable energy source is considered a credible and green alternative energy source with great power potential that is capable of meeting our energy needs if properly harnessed and utilized. The high volume of rice husks produced from the different Rice Milling Plants across the three agricultural zones of Ebonyi State are either dumped as waste (worthless material) or burnt into ashes with much emission of CO_2 into the atmosphere and the residue still left as waste. Evacuation of such heap of rice husk from the environment has become a serious problem due to poor waste management system, lack of awareness of its energy potentials and other properties that distinguishes it as a value added material for other economic and industrial purposes. Thus, this study identifies rice husk as a potential biomass material (feedstock) that is capable of turning the state's energy mix for optimum power generation and utilization.

Therefore, utilizing rice husk as an alternative source of generating electricity through Biomass Gasification Technology (BGT) will make this product more valuable and exceptional than considering it as agricultural waste [20].
Waste to energy recovery process is all about the conversion of waste which we often regard as materials with no prime value or worthless materials into a useful and usable energy form.
More so, several researches are ongoing on the future prospects of energy from agricultural wastes as an alternative source to the conventional fossil fuels. Thus, biomass energy refers to the energy from organic materials. It is the only renewable energy sources that can provide energy in all forms; as a liquid, solid and gas, and other essential chemical products from its bio-refinery processes [11]. It provides multiple essential energy services such as electricity, heating, cooking and transport fuel.
Biomass energy continues to be the major energy resources of about 40% of the global population living in developing countries despite its drawbacks [17]. It is probably our oldest source of energy after the sun. This biomass energy source is renewable because its supply is not limited as we can always grow threes and crops, and waste will always exists [7]. Some examples of materials used as biomass energy sources include:Forest and Saw Mills Residues, Purpose-Grown Crops, Agricultural Co-products, Food Waste, Animal Manure, Landfill Gas, Municipal Solid Waste, Waste Water Treatment Sludge, Residues etc.

Statistically, Nigeria is the highest importer of rice globally and the largest producer in West Africa. More than seventy countries produce rice, though China, India and Indonesia are the major producers [12].

However, rice is cultivated in almost all the states in Nigeria with Ebonyi state occupying the six (6) position among the ten (10) highest rice producing states as shown in Table 1 [21]Ebonyi state produces about 1.5 million metric tons of paddy rice annually. This translate to approximately 300,000 metric tons of rice husk (RH) considering a ratio of 0.2 ton of RH for each ton of paddy rice. While rice husk has been traditionally used in low-value applications, its potential as a feedstock to generate heat and electricity is attracting increasing attention [19].

Table 1.Top 10 highest rice producing states in Nigeria and its statistics for the year 2022.

S/N	**State**	**Quantity (metric ton)**
1	Kebbi	3.5 million
2	Jigawa	2.5 million
3	Kano	1.6million
4	Ekiti	1.5 million
5	Benue	1.5 million
6	Ebonyi	1.5 million
7	Kaduna	634,410
8	Niger	380,000
9	Cross River	50,000
10	Ogun	20,000

Source: [21].

Tons and tons of rice husk are produced every year as a by-product from rice processing operations across the three agricultural Zones of Ebonyi State namely; Ebonyi North, Ebonyi Central and Ebonyi South. Thus, rice cultivation and processing (Milling) is one of the major economic activities of farmers in Ebonyi State, South East, Nigeria. In fact, just as agriculture is the main stay of the rural economy of Nigeria, rice production in Ebonyi State command significant position in the farming lives of several communities of the state such as Edaa, Ikwo, Izhia, AkaezeAbakaliki, Afikpoetc [5]. Also, [2] acknowledged Ebonyi State as one of the largest rice producers in Nigeria. The implication of this acknowledgement is therefore a confirmation of the huge volume of rice husk (RH) deposits arising from the processing of paddy rice.

Similarly, [14] stated that rice husk accounts for approximately 20-23% of the total paddy rice weight. Rice husk is one of the potential agro wastes which can be used as raw material to generate electricity, only if it can be processed properly and systematically [1].

According to [4], rice husk has enormous potential for electrical energy generation and biomass – to – energy projects, protect the environment. The rice paddy (grains) as an important biomass energy source consists of three main by-products namely; from rice straw, husk and bran [3]. Rice straw and rice bran are best used as feed for cattle, poultry and fish while the rice husk is used for energetic purposes [8].

However, rice husk in its natural form, just like any other agricultural residues cannot be effective for use for energy conversion because the use of agricultural residues is often challenging due to their uneven characteristics. It is widely agreed that the majority of the residues in their natural forms have lower density, high moisture content and lower energy density. Besides the bulk density and dusty characteristics of the biomass, also cause transportation handling and storage problems [13].

Furthermore, [6] defined biomass energy as the energy released from the degradation or fermentation of such organic matter like cow dung, poultry waste, rice husk, weed, human and animal excreta, corn stalks etc.

2.1 Materials and Method

The following list of materials/apparatus were used in the implementation of this work.
Electronic Weighing balance, Local matt, Metal Bucket (Bushel), Polythene bag, Rake, Nose Mask and Safety Boot, Local Metal Drum, Fire Wood and Water, Wire Mesh (1-2mm), UNIDO Model Biomass Conversion Power Plant, Pestle and Mortar, Eke Market Rice Milling Plant, Rice grain/Paddy Rice etc.

2.1 Sample Collection

The data for this study were collected in collaboration with the household farmers (paddy rice farm owners) at the different farm sites across the three Agricultural Zones of the Ebonyi State. The paddy rice samples were randomly collected from recently harvested paddy bag in each of the six (6) selected farm sites consisting of two local Government Areas per zone.

2.2 Sampling Technique

A multi-stage sampling procedure involving both random and purposive sampling techniques were used for the selection of the paddy rice samples across the three Agricultural Zones of the state covering six (6) Local Government Areas (L.G.A). This was done to ensure that only L.G.As with high intensity of rice farming activities in relation to high volume of rice husk dump in their Milling Stations were selected. Thus, the following L.G.As were selected;

(i) Ikwo and Ezza South for Ebonyi Central
(ii) Afikpo-North and Ivo for Ebonyi South
(iii) Abakaliki and Izzi for Ebonyi North.

2.2 Sample Processing

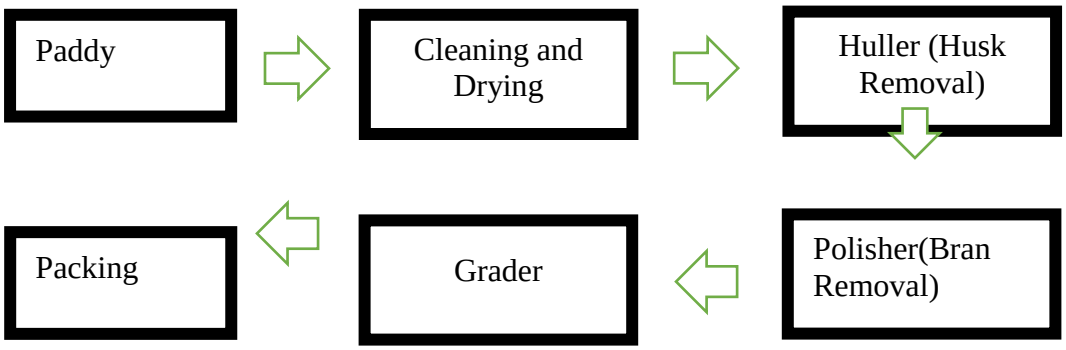

Figure 1. Flow chart of rice milling process

Samples of the paddy rice collected from Ebonyi North Zone namely, Abakaliki Local Government Area (Abakaliki Rice) and Izzi Local Government Area (Iboko Rice) were separately soaked into a local drum with cold water for some hours and then heated until the grains showed signs of splitting, where upon the heat source was removed and the rice filtered for sun-drying (2 hours or less) using local matt. At this stage, the parboiled paddy rice were packed into the polythene bags and taken to the Eke Market Rice MillAfikpo for further processing. The result of the sampling analysis is as shown in Table 2.0.

2.3 Operational Mechanism of the Model Biomass Conversion Power Plant

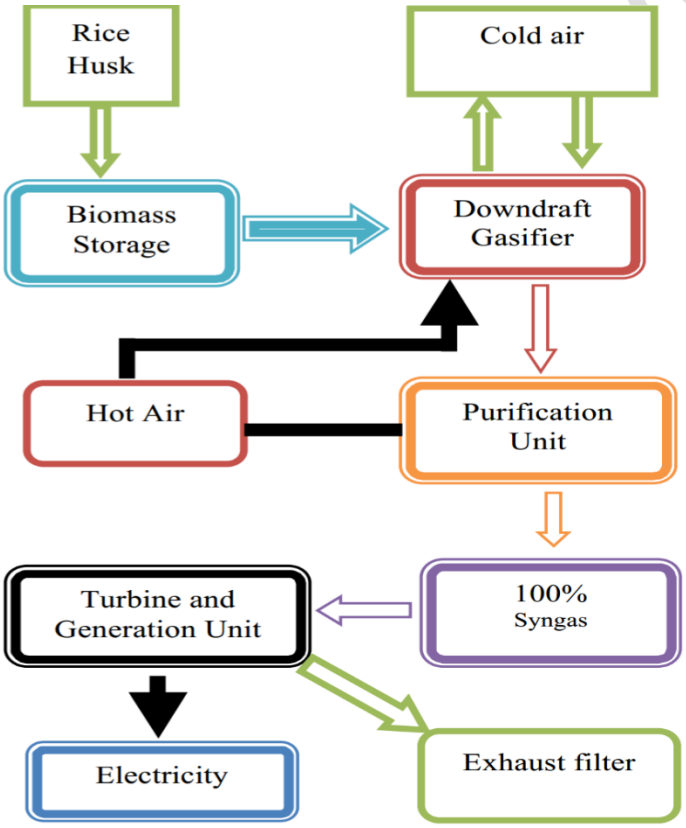

Figure 2. Block diagram of a rice husk electricity production unit

Figure 2 above, shows that the whole process starts from the biomass storage chamber through which the biomass sample is fed to the gasifier. At the gasifier/reactor unit, it undergoes certain chemical reactions to produce syngas. Then as the fuel moves downward, it reacts with air (the gasification agent). The suction of a blower or an engine supplies the air needed for the reaction and then the air is converted into combustible producer gas through a complex series of reactions like oxidation, reduction, and pyrolysis. This gas is then purified to obtain a 100% syngas which is then fed to the turbine (generating unit) and from the turning of the shaft of the turbine, electricity is generated. Thus, the steam turbine converts the thermal energy available in the steam into mechanical energy (shaft power) and finally to electrical energy.

2.3 **Area of Study**

Ebonyi state islocated in the Southeastern part of Nigeria; within thetransitionalbeltbetweentherainforestandguineasavanna.ItisboundedtotheNorthbyEnuguand Benue states; to the East by Cross River State; to theSouth by Abia State and to the West by Anambra State. This study was carried out in Ebonyi State, South East, Nigeria with Abakaliki as its capital. Ebonyi State has thirteen (13) Local Government Areas namely; Abakaliki, Afikpo-North, Afikpo-South, Ebonyi, Ezza-North, Ezza-South, Ikwo, Isielu, Ivo, Izzi, Ohaukwu, Ohaozara and Onicha. Ebonyi. The State is further divided into three (3) Agricultural Zones namely; Ebonyi North, Ebonyi South and Ebonyi Central. The state lies on latitude $6^0 31^/$ N and longitude $8^0 15^/$ [10], with a population of 2,173,501 people [16]. The mean temperature, ranged between 20^0C and 28^0C, while the topography and soil types of Ebonyi State are very favorable to agricultural activities. Thus, farming remains the major economic activities of the people of the State, with rice being one of the major crops farmed in the State.

3. RESULTS AND DISCUSSION

Table 2.Details of the Eke Market Milling Plant Afikpo where the paddy samples were processed.

Operating Parameter	**Value**
Capacity (Tons/hr)	6.00
Rice as output (Tons/hr)	4.20
Operating time (hr/day)	16.00
Paddy milling (Tons/day)	96.00
Residue to paddy ratio	1:5
Electrical load (KW)	400.00
Moisture of paddy after drying (wt %)	11.20
Milling duration (hrs/yr)	5360

Table 3.Result of the average mass of sample (M_{AH}) from the three agricultural zones of the State

Sample Number	**Mass of Sample M_P (Kg)**	**Mass of Husk M_H (Kg) from the Zones**		
		Ebonyi North	**Ebonyi South**	**Ebonyi Central**
1	**10**	1.98	2.01	2.02
2	20	4.25	4.20	4.19

3	30	6.51	6.70	6.49
4	40	8.91	8.81	8.78
5	50	11.25	11.35	11.09
Total	**150**	**32.90**	**33.07**	**32.57**

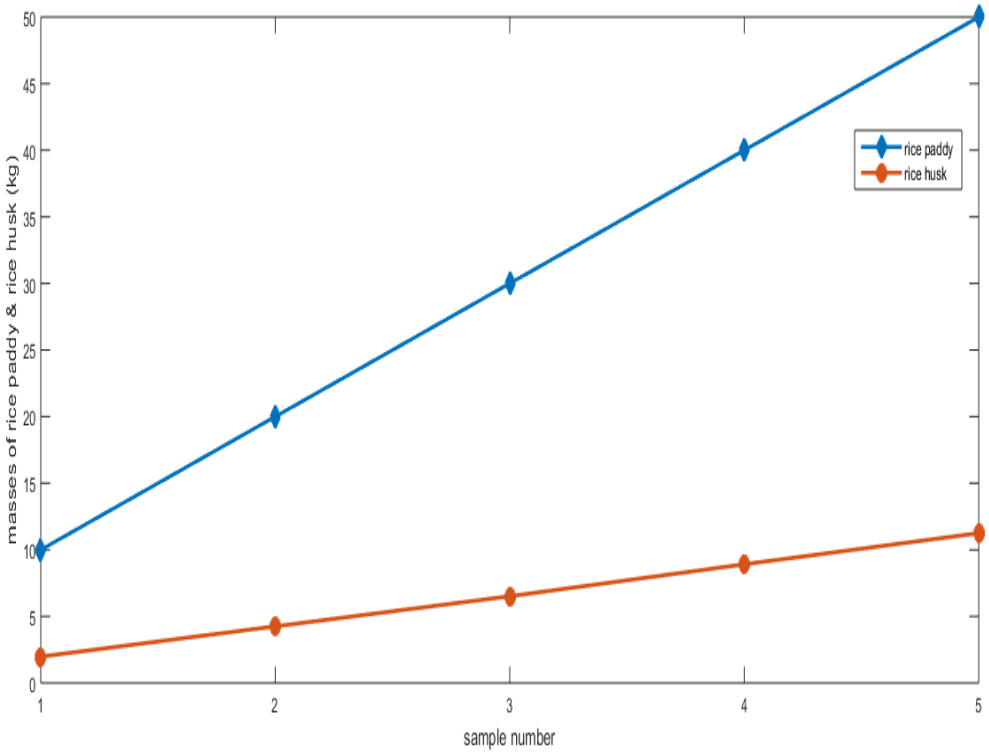

Figure 3. Graph of mass of paddy and rice husk/sample number for Ebonyi North Zone

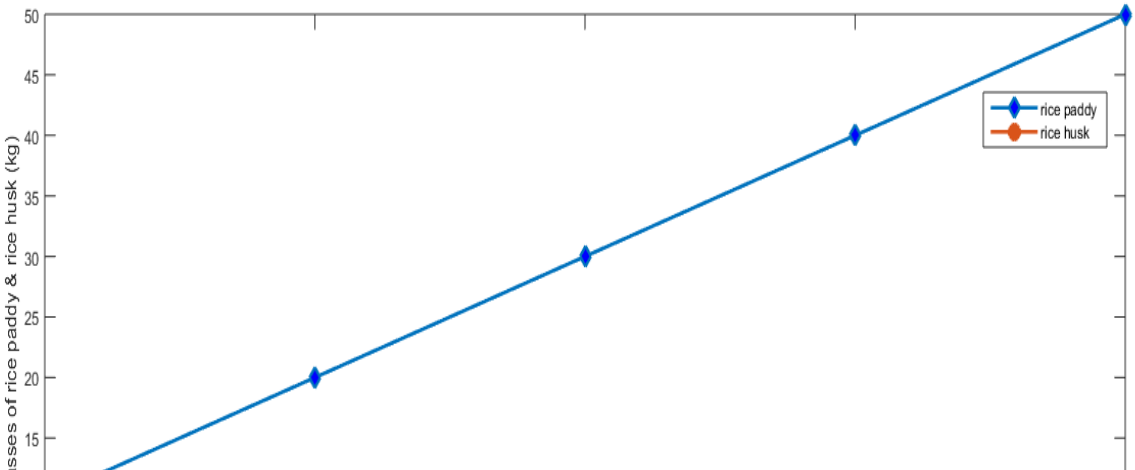

Figure 4: Graph of mass of paddy and rice husk/sample number for Ebonyi South

Figure 4. Graph of mass of paddy and rice husk/sample number for Ebonyi South Zone.

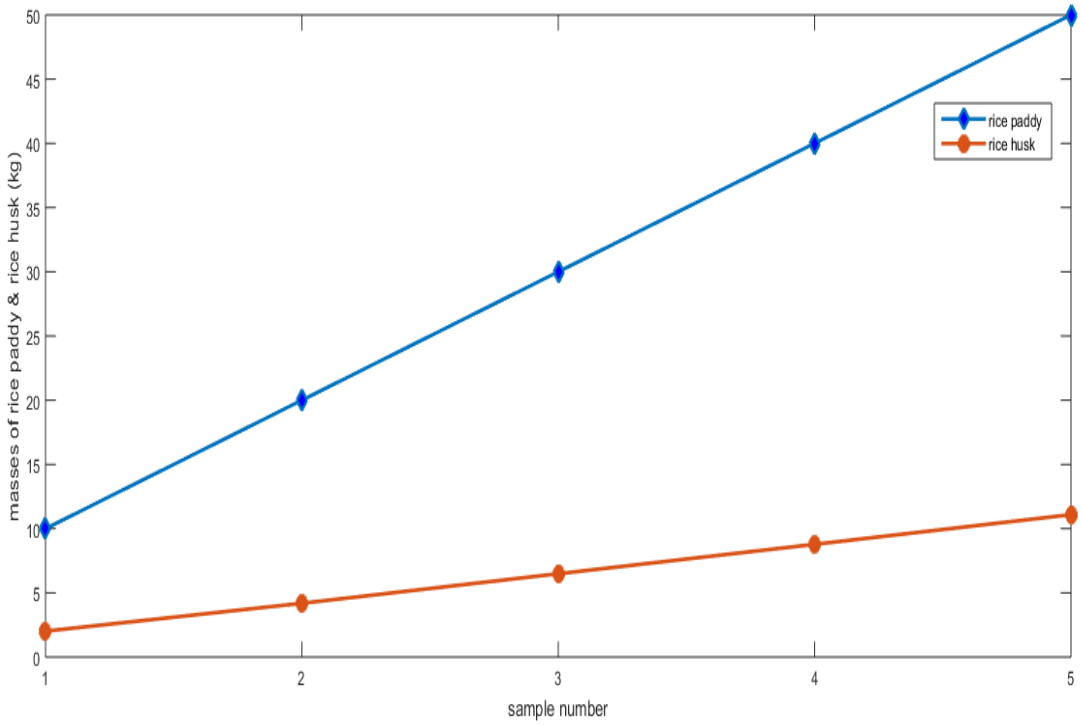

Figure 5: Graph of mass of paddy and rice husk/sample number for Ebonyi Central Zone.

Table 4.Results from the biomass conversion power plant (BCPP)

Agricultural Zone	Mass of Rice Husk, RH (Kg)	Moisture (wt %)	HHV (MJ/Kg)	Electricity Output (KWh)
Ebonyi North	32.90	2.60	14.80	23.50

Ebonyi Central	33.07	2.66	15.00	23.62
Ebonyi South	32.57	2.54	14.50	23.27

Estimation of the Electrical Energy Potential of Rice Husk Generated within Ebonyi State

The basic function of a Biomass Power Plant is to convert biomass energy to electricity. Result from the United Nation Demonstrations Biomass (Rice Husk) Power Plant analysis showed that;

35Kg of rice husk produced 25KW of electricity.

If 35Kg of rice husk produced 25KW of electricity

Therefore, 98.54Kg will produce = 98.54/35 × 25 = 70.39 KWh

Also, estimating for the quantity of electricity the current volume of rice husk 300000000Kg will produce = 300000000/35 × 25 = 214285714KWh = 214.29MW per annum

Hence, the estimated quantity of electricity that can be generated from Rice Husk currently produced in Ebonyi State stands at 214.29MW per annum.

3.1 Discussion

Currently, the production capacity of paddy rice in Ebonyi State as shown in Table 1 stands at 1.5 million metric tons. This translate to about 300,000 tons (300,000,000 Kg) of rice husk generated annually. Thus, husk to paddy ratio is taken as 0.2 or 1:5. This is in agreement with the percentage (%) husk values (20 – 23%) obtained from previous literatures. Details of the Milling Plant was collected from the Technical Personnel (TP) of the Mill as presented in Table 2. Since the Rice Mill does not utilize the Rice Husk, the availability factor was taken to be 100%.The selection and collection of paddy rice samples were done by ensuring that only L.G.As (Abakaliki, Izzi, Afikpo North, Afikpo South, Ikwo and Ezaa South) with high intensity of rice farming activities in relation to high volume of rice husk dumps in their Milling Stations were selected. The result of the sampling analysis shows that an average of 30Kg paddy rice yields an average mass of *6.50Kg* of rice husk across the six selected L.G.As.

Similarly, the graphical analysis of the average mass of the paddy rice in relation to the average mass of the generated rice husk for each of the three agricultural zones of the state against the sample number was done using MATLAB. Thus, the results of the sampling analysis shows that a uniform mass of *150Kg* of paddy rice collected across the three Agricultural Zones of the state yields *32.57Kg* of Rice Husk (Ebonyi Central), *32.90Kg* of Rice Husk (Ebonyi North) and *33.07Kg* (Ebonyi South).

Meanwhile the BCPP result analysis as presented in Table 4 shows that the total mass (*98.54Kg*) of the processed rice husk biomass sample has an average energy (HHV) content of *14.8MJ/Kg* with an electrical energy output of *70.39KWh*.

4. Conclusion

Nigeria is among World Nations that tremendously cultivates rice. It is the largest producer of rice in Africa. In Nigeria, rice is grown in virtually all the thirty six (36) states of the country. Ebonyi state is one of the major rice producing states and market for locally produced rice in Nigeria resulting to high volume of waste generation (rice husk) across the state. Thus, rice husk is one of the most widely available

agricultural waste in Ebonyi state. However, there is inadequate information on the energy characteristics, utilizations and technological applicationsof rice husk biomass which is one of the by-products of rice milling activities that is commonly dumped and treated as wastes products among the three agricultural zones of the state especially within the milling cluster areas.Therefore, the process of power generation from rice husk (gasification process) is one of the modern use of this solid biomass material. The result of the study estimated the electrical energy potential of rice husk as *214.29MW*per annum. This is a clear indication of the huge prospects that lie in the use of rice husk as feed stock for power (electricity) generation in Ebonyi State for households' consumptions, institutions and industrial applications.

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