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 while the estimated result for 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

Ebonyi state is one of the developing states in Nigeria that is highly endowed with enormous energy resources, both renewable and non-renewable [9]. Despite the huge endowments in these energy resources, the state like other states in the country still depends solely on fossil fuel for her electricity supply to households, institutions and industries for privates and commercial utilizations. 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 growth coupled with technological advancement are the current challenges of continued dependence on fossil fuel [9]. This overdependence on fossil fuel has generated serious negative consequences on the state's economic growth and development, environment, climate and on the health sector. According to [1], sustainable economic development of a country stands on the sufficiency of electrical energy. So, for Ebonyi as a component state in Nigeria to compete favorably 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, offer opportunities on the need for energy diversifications by developing and exploiting 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 needs [17]. 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 has necessitated the need for urgent transition to a more sustainable energy source that would be cheaper and environmentally friendly [21].

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 the state's energy needs if properly harnessed and utilized. The huge heaps of rice husks produced from the different Rice Milling Plants across the three agricultural zones of Ebonyi State where there are not used by activities such as land filling, animal bedding, fertilizer, as well as domestic heating and cooking fuel 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 heaps 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 distinguished it as a value added material for other economic and industrial purposes. To solve this problems posed by these rice husk dumps, an effective means of disposal or usage of the

husks need to be adopted [5], hence this study investigates the process of rice husk gasification technology for electricity generation in Ebonyi State. According to [26], utilizing rice husk as an alternative source of generating electricity through Biomass Gasification Technology (BGT) will make this rice husk more valuable and exceptional by-product than considering it as common agricultural waste.

Presently, the energy situation in Nigeria cannot meet the energy demand of her teaming population leading to the current energy crisis in the country. In order to ameliorate the shortfall in energy supply as well as to make provision for forecasted growth in energy demand to sustain economic growth, the government needs to diversify the energy sector by establishing very clear and decisive energy policies to guide the growth and development of the energy market through collaborative efforts between the public sector, private sector and each individual to meet the challenges and ensure sustainable energy future [22]. However, energy diversification will promote secured environment that allows for competitive economic activities in the state and the country at large. Thus, diversifying the energy sector will cause a paradigm shift away from only large coal-fired power stations feeding electricity to an energy sector where allowances are made for smaller independent power producers to participate, develop and implement new innovative technologies and solutions to energy supply.

There are enough rice husk biomass capacity in the state and the country at large to meet the energy demand for electricity generation and other purposes [6]. Rice husk biomass can be used to provide heat and electricity as well as biofuel and biogas for transport. Since rice husk biomass is a by-product from waste material, and it is capable of supplying energy if effectively harnessed, hence its utilization will proffer solution to ineffective waste management system as practiced in virtually all the states in Nigeria. Also, increase in energy will yield more productivity for individual business operators, commercial business operators and the industries.
According to [23], rice husk is a biomass material and not a worthless material since it possesses more potentials than being a source of pollution and health related issues to man and its environment, it can equally serve as a source of energy, useful raw material and other sources if properly managed.
More so, rice husk biomass has the potential to provide an affordable and sustainable source of energy, while at the same time help in curbing the greenhouse effect [6]. However, using rice husk for energy generation depends on the availability of rice hush as a raw material and the technology used for converting it to usable form of energy [24].

2. LITRATURE REVIEW

Bio-energy refers to the process of converting available biomass sources into a useful form of energy. Different technologies exist to convert different types of biomass into different forms of useful energy. The potential of biomass as a renewable energy source refers to the combined energy value of all the different types of biomass available that can realistically be converted into bio-energy [8]. Nigeria has the potential to produce an estimated 47.97 million tonnes of oil equivalent annually [14]. Also, in the study some of the biomass resources which can be tapped for renewable energy production in Nigeria were stated to include Jatropha, with high oil contents, sweet sorghum, and molasses; food crops such as cassava, rice, coconut, cashew, millet, oil palm, maize and yam; agricultural residues and waste from food crops such as cassava peels, cassava liquid sludge, mango peel, rice husk, corn residues, sugar cane straw, and bagasse; forest resources; municipal solid wastes; and animal wastes.
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. Several researches are ongoing on the future prospects of energy from agricultural wastes as an alternative source to the conventional fossil fuels [12]. 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. 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 [6]. 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 [10]. 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 [27] 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 [21]. The study puts the energy content of rice husk at 13.643MJ/Kg [8]. This energy can serve as input fuel in a chain of processes for the co-generation of electricity and heat. The research analyzes the electricity and heat generation potential of rice husk via technologies whose commercial status has been established.

Table 1: Top 10 highest rice producing states in Nigeria and its statistics for the year 2022 [27].

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

Tonnes and tonnes 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, Akaeze Abakaliki, Afikpo etc [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, [16] 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; 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 [7]. Rice husk can be converted into heat and electricity efficiently through available technologies [18]. 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. Also, the energy potential from rice husk depends upon heating value (HHV) and characteristics of rice husk and conversion technology [19]. The study further presented the result of the ultimate analysis of rice husk (RH) as shown in Table 2.

.**Table 2:** Ultimate analysis and HVV OF RH [19].

Composition (%)	RH

Carbon	36.74
Hydrogen	5.51
Oxygen	42.55
Nitrogen	0.28
Sulfur	0.55
HHV (MJ/kg)	15

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 [15]. Figure 1 shows the processing stages involved in the production of the rice husk biomass sample.

3. METOTHOLOGY

Sample Collection and Analysis

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 from each of the six (6) selected farm sites consisting of two local Government Areas per zone.

Sample Processing

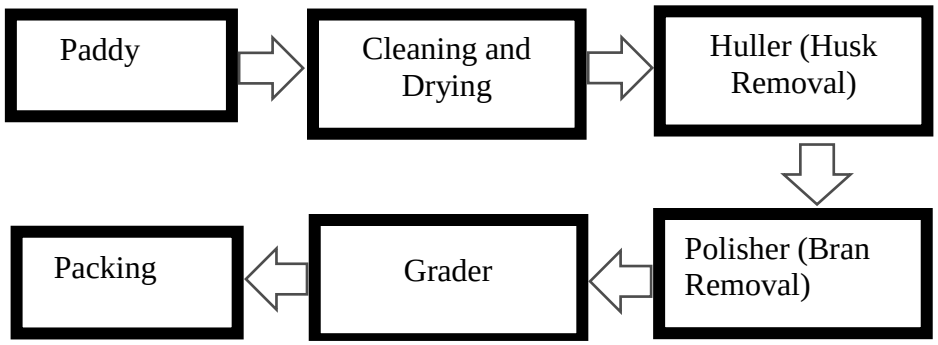

Figure 1. Flow chart of rice milling process

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 Eke Market Rice Mill Afikpo for further processing

Biomass Conversion Power Plant (BCPP) Setup

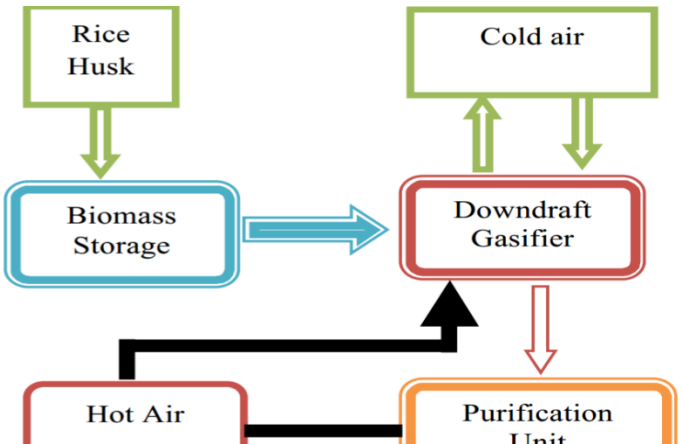

Figure 2: Block diagram of a rice husk electricity production unit [1].

The rice husk is first converted to syngas via gasification. The syngas now serves as the fuel burnt in the boiler to produce electricity via a gas turbine generator, hence the three distinct modules- gasifier module, boiler module and turbine generator module.

Study Area and Sampling Technique

Ebonyi state is located in the Southeastern part of Nigeria; within the transitional belt between the rain forest and guinea savanna. It is bounded to the North by Enugu and Benue states; to the East by Cross River State; to the South 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 nyyamely; Ebonyi North, Ebonyi South and Ebonyi Central. The state lies on latitude $6^0 31^/$ N and longitude $8^0 15^/$ [13]. Farming remains the major economic activities of the people of the State, with rice being one of the major crops farmed in the State. 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; Ikwo and Ezza South for Ebonyi Central, Afikpo-North and Ivo for Ebonyi South, Abakaliki and Izzi for Ebonyi North.

4. RESULTS AND DISCUSSION

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

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**

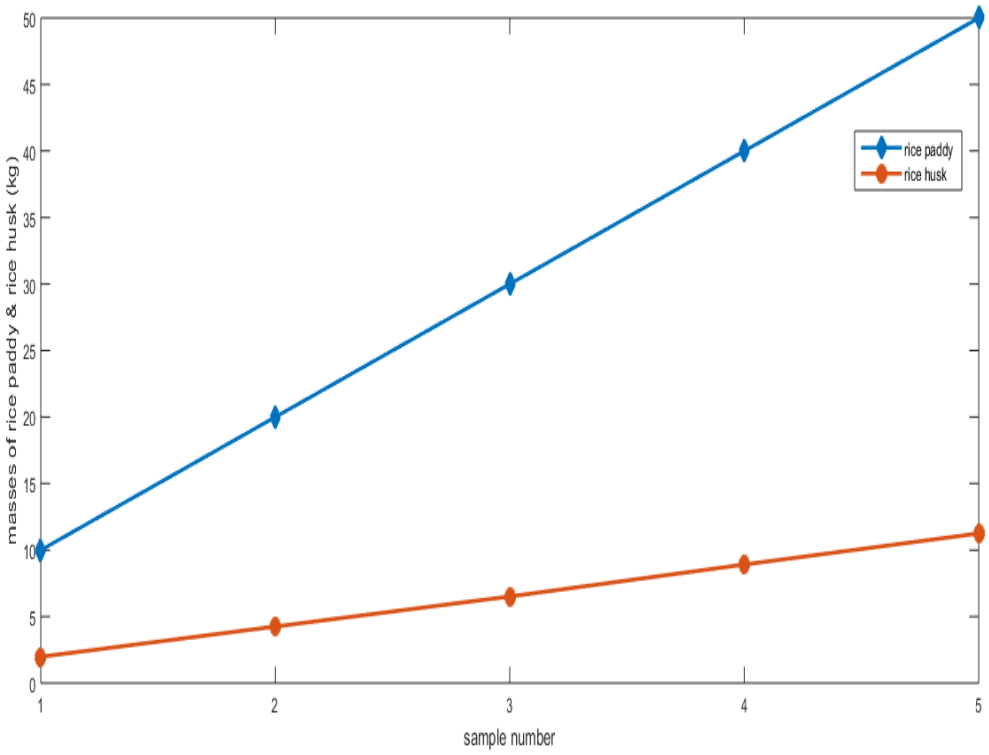

Figure 3. Graph of mass of paddy and rice husk/sample number for Ebonyi North Zone

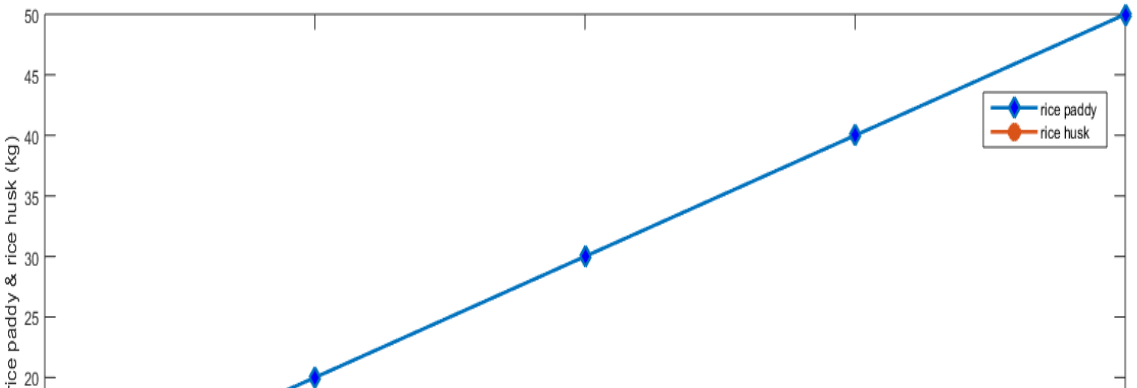

Figure 4: Graph of mass of paddy and rice husk/sample number for Ebonyi South Zone

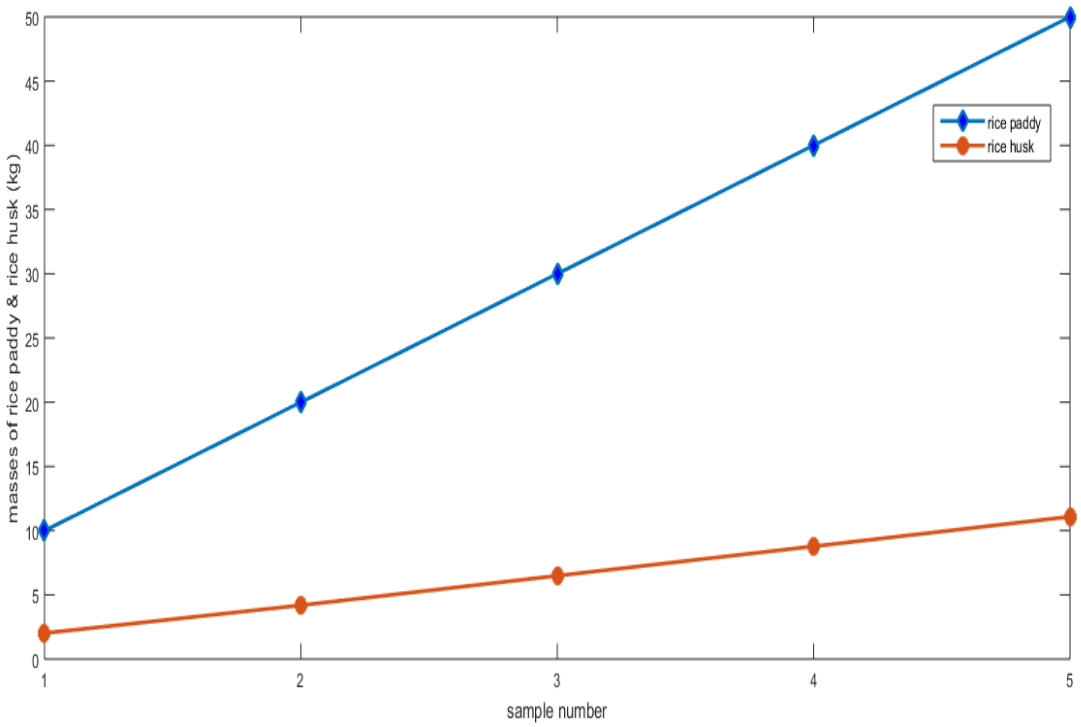

Figure 5: Graph of mass of paddy and rice husk/sample number for Ebonyi Central Zone.

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

The basic function of a Biomass Conversion Power Plant (BCPP) is to convert biomass energy to electricity. The BCPP at Ekweshi Ngbo in Ohaukwu L.G.A of Ebonyi State is a gasifier type that uses rice husk (RH) as its fuel/feedstock for the gasification technology process. The Gasification technology is more tolerable to feed particle size, but would still preferably be smaller than 30mm in diameter as it affects the reaction rate [24]. Also, drying of the biomass is very important as the moisture lowers the heating value of the biomass sample and decreases the BCPP conversion efficiency. However, securing consistent qualities of feedstock at low cost that meets the specifications of the reactor system, Sensitivity to feedstock specifications, and non- flexibility of the gasification technology process are the major factors that affects the performance of the (BCPP) [24]. Sensitivity to feedstock specifications as a requirement for homogeneity simply shows that gasification technology is far less flexible than biogas technology, hence does not permit a variety of available feedstocks to be used and this limitation restricts the potential resource base. Also, gasifiers are sensitive to feedstock moisture contentment, heating value and particle seizes and usually require clean, homogeneous material that is low in ash with a moisture content of 13% or less.

Estimation of the Electrical Energy Potential

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 = $98.54/35 \times 25 = 70.39$ KWh

Also, estimating for the quantity of electricity the current volume of rice husk 300000000Kg will produce =

$300000000/35 \times 25 = 214285714$KWh = 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.

5. Conclusion

Energy availability is critical to the development of any nation or state because it affects all sectors of the economy. However, the electricity supply in Ebonyi state is much less and incapable to meet the demand of the teaming population because of increased dependency on fossil fuels. To overcome this energy crisis, the utilization of renewable and sustainable energy sources should be embraced at all scale levels (small, medium and large) across the states of the federation since our economy is dependent on agriculture and forestry which are potential sources of biomass energy. Nigeria is among World Nations that tremendously cultivates rice which is a good example of biomass energy sources. In Nigeria, rice is grown in virtually all the thirty six (36) states of the country with reference to Ebonyi state as one of the major rice producing states and market for locally produced rice. The implication of this is the generation of high volume of rice husk dumps across the state. Due to inadequate information on the energy potential of rice husk and the technological developments that enhances energy recovery from wastes,

this biomass material is often dumped and treated as worthless materials across the three agricultural zones of the state especially within the milling cluster areas. Contrary to the public perception of rice husk as a waste material, this study identifies it as a unique and important biomass energy source that is readily available across the length and breadth of the state, hence the need to tap and explore its energy potential for the benefit of man and his environment. Therefore, this study explores the option of energy derivation from locally and freshly generated rice husk biomass in Ebonyi state via gasification technology as a viable means for electricity generation and at the same time managing solid wastes. The processed rice husk biomass sample was anealyzed at the UNIDO Demonstration Gasifier Model at Ekweshi Ngbo in Ohaukwu Local Government Area of Ebonyi State. This process of power generation from rice husk is one of the modern use of this solid biomass material (rice husk). The result of the moisture content, high heating value (HHV) and the electrical energy potential of the processed rice husk biomass as analyzed by the plant are *2.6%, 14.8MJ* and *70.39Kg* respectively while the estimated electrical energy potential value of rice husk based on the annual husk generation is *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. However, securing consistent quality of feedstock at low cost that meets the specifications of the reactor system (sensitivity to feedstock), moisture content, heating value and particle sizes are the barriers that affects the power output of the gasification plant, hence limiting or restricting the potential resource base.

A clear and decisive policy decisions by the state government to fund the installation of Biomass Gasification Projects like the UNIDO Gasifier Model that will be capable of utilizing other available biomass sources order than rice husk across the agricultural zones of the state especially within the rice milling cluster areas. Therefore, biomass energy in Nigeria is promising with heavy investment, stakeholders' corporation and development of indigenous technologies. The deployment of large-scale biomass energy system will not only significantly increase the state's electricity capacity but also ease power shortage in the state.

Implications and Future Prospect

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, hence 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. Since the Rice Mill does not utilize the rice husk, the availability factor was taken to be 100%. 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 as shown in Figure 3, 4 and 5 respectively shows uniformity in the mass compositions of the samples generated across the three Agricultural Zones of the state. The results from the sampling technique analysis as shown in Table 3 shows that a uniform mass of *150Kg* paddy yields *32.57Kg* of Rice Husk (Ebonyi Central), *32.90Kg* of Rice Husk (Ebonyi North) and *33.07Kg* (Ebonyi South). Figure 3 shows the process of converting rice husk biomass into energy that will in turn be used to generate electricity. Thus, the turbine converts the thermal energy available in the steam into mechanical energy (shaft power) and finally to electrical energy. Also, the processed rice husk biomass sample was found to possess suitable moisture content and energy content (HVV) for use in electricity generation as shown in the BCPP analyzed result in Table 4. Also, Table 4 shows that the total mass (*98.54Kg*) of the processed rice husk biomass sample yields an average moisture content and energy content (HHV of 2.60% and *14.77MJ/Kg* with an electrical energy output of *70.39KWh*. The heating value, upon which of energy conversion depend is in consonance with the literature value presented in Table 2. Meanwhile the estimated electricity output based on the estimated RH generated within the state per annum is *214.29MW*. This is huge and will help to boost the energy sector of the state for sustainable energy generation and supply.

Future Research Direction

For further study on this work or related works, we recommend for the comparative study of individual assessment and analysis of the different paddy species in terms of mass composition, physical and chemical compositions, energy content (HVV) and moisture content.

Also, a comparative study of results of rice husk biomass sample from existing rice husk dump with freshly generated rice husk biomass sample in terms of the mass composition, physical and chemical composition, energy content (HVV), Moisture content and the electrical energy potential.

References

[1] Abedin MR, Himadry SD. Electricity from rice husk: A potential way to electrifying rural Bangladesh. *International Journal of Renewable Energy Research*. 2014; 4(3): 657-666.

[2] Adebowale S. Ebonyi State records 190,000 tons of rice in 2016. Accessed March 24, 2022. Available: www.theeagleonline.com.

[3] Ahiduzzaman M. "Rice husk energy technologies in Bangladesh". *International Journal of Agricultural Engineering*. 2007; 4(1): 17–21.

[4] Ahiduzzaman M, Baqui MA, Tariq AS, Dasgupta N. Utilization of rice husk energy for rice parboiling process in Bangladesh. *Intl. Journal of Bio-Resources*. 2009; **6**(2): 47-79.

[5] Ame-Oko A, Adegboye BA, Tsado J. Analtytical method to determine thepotentialof using rice husk for off-grid electricity and heat generation. 2018; 37(1): 222-225.

[6] Bioenergy Consult. Accessed February 26, 2023. Available: https://www.bioenergyconsult.com/tag/rice-husk/

[7] Chanchal L, Hinadri C, Pradip KC. Energy generation from fluidizes bed gasification of rice husk. *Journal of Renewable and Sustainable* Energy. 2013; **5**(4): 11-15.

[8] Elum ZA, Modise DM, Nhamo G. Climate change mitigation: The potential of agriculture as a renewable source in Nigeria. Journal of Environmental Science and Pollution Research. 2017; 24(4): 3260-3273.

[9] Ezealigo US, Ezealigo BN, Kemausuor F, Achenie LE, Onwualu AP. Biomass valorization to bioenergy: Assessment of biomass residues' availability and bioenergy potential in Nigeria. Journal of Sustainability. 2021; 13(24): 13806.

[10] Ezeh AN, Eze AV, Eze EO. Extension agent of mobile phone applications for agricultural extension service delivery in Ebonyi state agricultural development programme. *Nigerian Journal of Agricultural Extension*. 2021; 25(1): 48-58.

[11] Ezike GO. Determination of calorific value of some Nigerian biomass solid materials. Nigerian Journal of Technology. 1983; 7(1); 222-225.

[12] Farmer H, Hjerp P. Municipal solid waste incineration: Health effects, regulation and public communication institute for European environment policy; London. *Developments in Renewable Energy Technology*. 2001; 1: 1–4.

[13] FAOSTAT; 2011. Accessed 16 March, 2023. Available: https://faostat.fao.org/site/339/default. aspx.

[14] Giwa A, Alabi A, Yusuf A, Olukan T. A comprehensive review on biomass and solar energy for sustainable energy generation in Nigeria. Journal of Renewable and Sustainable Energy Reviews. 2017; 69; 620-641.

[15] Klass DL. Biomass for renewable energy and fuels. Encylopedia of Energy. 2004; 1: 193-212.

[16] Kumar A, Mohanta K, Kumar D, and Parkash OM. "Properties and industrial applications of rice husk: A review." *International Journal of Engineering Science and Technology*. 2012; 10(2): 86-91.

[17] Melgara EP, Khonde RD, Haldar S. Biomass gasification technology of agricultural waste. *International Journal of renewable energy and innovations*. 2009; 2(6): 9-11.

[18] Mathur A, Singh DU, Vijay YK, Hemlata M, Sharma M. Analyzing performance for generating power with renewable energy source using rice husk as an alternate fuel. National Conference on Emerging Trends in Electrical, Instrumentation and Communication Engineering. 2013; 3(2); 7657.

[19] Memon TA, Harijan K, Soomro MI, Meghwar S, Valasai GD, Khoharo H. Potential of electricity generation from rice husk- A case study of rice mill. Research Journal Science Series. 2017; 49(3): 495-498

[20] Obemberger I, Thick G. Physical characterization and chemical composition of densified biomass fuels with regards to combustion behavior. *Journal of Biomass and Bioenergy*. 2004; 27(6): 653-669.

[21] Ogbuefi UC, Ejiofor OS, Okoro PA, Nnabuike CV Okedu KE. Off-grid electricity generation in Nigeria based on rice husk gasification technology. *Journal of Clean Energy*. 2020; 2(5); 7-13.

[22] Okafor CC, Nzekwe CA, Ajaero CC, Ibekwe JC, Otunomo FA. Biomass utilization for energy production in Nigeria: A review. Journal of Cleaner Energy Systems. 2022; 3(1): 100043.
[23] Okoli CN, Egobueze A, Briggs DA. Waste management policy implementation in Nigeria: A study of Rivers State Waste Management Agency. International Journal of Advanced Research. 2020; 8(2): 755-765.
[24] Potgieter JG. Utilization of agricultural residues in Greater Gariep agricultural areas as a renewable and sustainable energy resource. Masters in Renewable Energy Thesis Submitted to the Department of Mechanical Engineering. 2011.
[25] Rice Knowledge Bank; 2014. Accessed January 15, 2023. Available:
http://www.knowledgebank.irri.org/rkb/rice-milling/byproducts-and-their utilization/rice-husk html.
[26] Sansaniwal SK, Pal K, Rosen MA, Tyagi SK. Recent advances in the development of biomass gasification technology: A comprehensive review. *Journal of Renew and Sustainable Energy Resources*. 2017; **8**(3): 3-4.
[27] Statistics of rice producing states in Nigeria; 2022. Accessed on January 4, 2023. Available: (http://www.commodity.port.com).