

Biomass Stand-Alone System for Power Supply Option to Remote/Isolated Locations

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Abstract: Reliability and continuity of electricity supply generated by the use of fossil fuels cannot be guaranteed absolutely because of the present decline in oil and gas. Because of this, it becomes necessary to consider another form of energy generation such as biomass. In this work, the potential of electricity generation for a small household rural/isolated location using combustion technique was done. Due to the availability of sufficient biomass (agricultural waste) in rural/isolated locations, rice husk combustion technique for bio-power generation was investigated in this work. The experiment was conducted at Uburu in Ohazara Local Government Area of Ebonyi State. A 12V permanent magnet DC motor was used as the alternator while rice husk was used as biomass fuel. The bio-power was achieved by heating water to steam which was used to turn the turbine attached to the permanent DC motor and a maximum of 155Whr was generated. From the result, it can be seen that the typical load of a household in a rural/isolated location is 55W and the peak experimental power is 154.96W. This peak experimental power is sufficient to carry the household load in a rural/isolated location. The peak experimental energy value is 1549.6Whr in a 10 minutes interval which is far more than the energy demand of 260Whr in a typical household in rural/isolated location. The result shows that biomass can be used to generate power for lighting point and power outlet for small households in rural/isolated locations.

Index Terms: Rice husk, power generation, rural/isolated locations, permanent magnet DC motor.

I. INTRODUCTION

Electric power supply in most cities of the world is epileptic and there is lack of it in rural communities [1]. This has been the greatest challenge confronting the economy of most nations. National power grid of most countries is insufficient to serve the cities let alone extending it to rural dwellers. Ironically, most agricultural activities are concentrated in the rural areas. This lack of power supply in rural areas has led to lack of basic amenities; thus, leading to rural-urban migration [1]. Lack of electricity access in rural part of the world is a huge challenge due to the high transmission and distribution cost [2]. To diversify the economy of any nation, greater attention should be paid to

Power sector [3]. Constant power supply in rural, commercial and industrial sites will boost: performance, productivity, efficiency, profit and reduce lost time [3]. The demand for constant power supply is ever increasing; however, the demand is met with lot of constraints [4]. These constraints include over dependency in petrol, diesel and hydro energies for firing power plants [5, 6]. The major means of power generation are hydro and thermal [8]. Hydro energy is seasonal as the output power during dry season decreases noticeably whereas thermal plants depend on petrol and diesel that are not economical to produce and discharges dangerous gases during operation [4]. Currently; more than 1.5 billion people worldwide are out of power supply. 80% of this population live in rural areas and have no hope of gaining access to electricity in the near future [2].

International Energy Agency projected that the population without access to electricity will not drop owing to population growth [7]. The rural/isolated dwellers should not be allowed to stay in darkness, remedy must be found as they are mostly agricultural sites. The remedy to this challenge is employing these four basic technical approaches: The first alternative is extending the national grid. Extending the national grid is expensive because rural areas are located far from the grid network. The high cost associated with extending the transmission lines usually makes these projects unfeasible [2]. However; cost of grid extension differ from rural locations to rural locations [8], in most of them, grid extension is feasible only at a certain distance and as long as the village has a large demand to reach critical mass [9]. This makes the national grid extension not to be feasible. The second alternative is electricity Hybrid-Mini-Off-Grid Power Supply Option [10,11]. This technology involves combination of different primary sources of energy (solar, biomass, wind, hydro, etc.) and generator sets for power generation [12]. This technology has potential to provide centralized electricity to rural/isolated dwellers, using a village-wide distribution network [13]. It can supply power to both domestic appliances and local businesses, and has the potential to solve the problem of energy poverty in rural/isolated areas [14]. But the high cost and technicalities involved in deploying Hybrid-Mini-Off-Grid power system is very challenging [15]. Also the complex business models, maintenance and sustainable operations make this option to be partly unfeasible [16]. The third alternative is Energy Home System (EHS).

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The selection of this technology depends mainly on the position of the households, and the types of load required. A village can support the installation of its own small power system [17-21], but the distribution costs represent a big share of the project and its feasibility. Thus; rural/isolated locations with scattered population, covering a large area will involve higher connection costs, due to longer distribution lines [22].

This makes this option not to be feasible for scattered populated villages. The fourth alternative is Stand-Alone System (SAS). A Stand-Alone Small-To-Medium-Sized Systems Power Supply Option is the best solution in bringing power to remote/isolated sites as it is economical and feasible. Stand-Alone Systems such as: Pico-Biomass System (PBS), Pico-Hydro Systems (PHS), Solar Home System (SHS) and Wind Home System (WHS), etc are the solution to provide energy access to remote/isolated households. In these stand-alone systems, the power generation is installed close to the load and there are no transmission and distribution costs and energy loss. This alternative is mainly to serve small appliances for lighting and communication (radios, mobile phone charging, TVs). Renewable sources for SAS are easily available at no cost but PBS gives better availability and low capital cost when compared to other sources since its availability is not affected by weather variation and the technology for the conversion of PBS is relatively cheap. This work takes a look at application of biomass as energy source for standalone power generation to rural/isolated dwellers. The biomass feedstock that was used is rice husk.

A. Technologies to convert rice husk to energy

Rice husk can be converted into energy products through two processes: bio-chemical process and thermo-chemical process.

B. Bio-chemical process

There are 2 main techniques used here - anaerobic digestion and fermentation. In aerobic digestion technique, microorganisms convert the rice husk into Synthetic Natural Gas (SNG) [23]. This biogas can be used as fuel to generate heat and energy [24]. Rice husk takes longer time to decay; this makes this method not to be a good option for energy generation using rice husk feed stock. In fermentation process, the rice husk is converted to ethanol [25]. This option is not for power generation and it takes a lot of time for rice husk to ferment, thus; making this technique not to be the best option.

C. Thermo-chemical process

There are 3 main techniques used in this process, namely: pyrolysis, gasification, direct combustion techniques [26]. The first technique is the so called pyrolysis technique. It involves controlled heating of rice husk in absence of oxygen [27]. It can be slow pyrolysis in the case of low temperature (350°C to 700°C) or fast pyrolysis in the case of high temperature (700°C to 1050°C) [28]. This technique produces more of bio-oil than biogas [29] and the technology is expensive [27]. It also produces large quantity of char which is not desirable [27]. This process involves a lot of gas and oil filtration, scrubbing and cleaning. This makes the initial cost of this technique to be high. Most of

the rural dwellers may not be able to provide the installation cost, thus; making this technology not the best option for rural dwellers. The second technique is by gasification technology. During gasification process, rice husk is directly converted to producer gases, char, tar, impurities from sulphur and nitrogen in a gasifier at a very high temperature (more than 1050°C) under a controlled amount of air or steam [28]. This technique involves sophisticated conversions, thus; making the installation cost to be high which may not be affordable by the rural dwellers [30-31]. Direct combustion technique involves burning of rice husk to produce heat which will be used to heat water to steam and the steam will be used to drive steam turbine [32]. This technique is economical and can be achieved by the use of locally sourced material, thus; making this technique to be the best option for rural/isolated dwellers. Among all these techniques discussed above, it is obvious that direct combustion technique is an excellent option for rice husk standalone power supply option. This work will center on rice husk direct combustion local technology for electricity generation. The block diagram of the process is as shown in Figure 1.

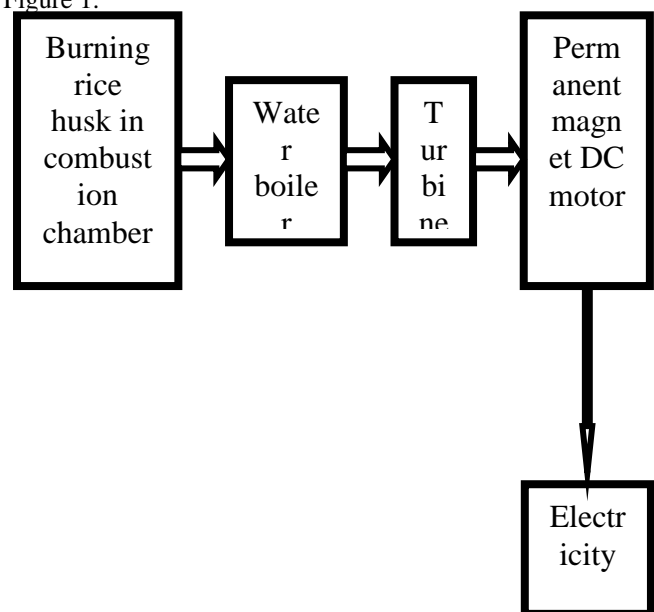


Figure 1. Block diagram of electricity generation by rice husk using combustion technique.

The experiment was carried out at Uburu in Ohaozara Local Government Area of Ebonyi state, Nigeria. Rice husk obtained from AkpaNwaokorori's farm in Amenu rice mill of Ohaozara Local Government Area of Ebonyi state, Nigeria was used as energy source. Combustion chamber, boiler unit and turbine constructed from locally available materials were used for the work. Permanent magnet DC motor was used as the alternator to generate the DC power. These are shown in Figures 2 to 4. The work will benefit dwellers in rural/isolated locations as they will use it for lighting point and power outlet for powering their electrical appliances; thus, providing basic social amenities which in turn minimizes rural-urban migration. It will also reduce over burden on electricity providers.



Figure 2. Combustion chamber



Figure 3. Water boiler



Figure 4. DC motor coupled with turbine

II. LITERATURE REVIEW

In this section, we shall review some works on rice husk combustion technique for electricity generation. The purpose of this literature review is to identify the knowledge gap that justify this work and also for referencing. Thipwimon et al [33], conducted an assessment on rice husk combustion for power production. A 10 MW pilot plant using rice husk as feedstock was used for the study. The environmental impacts from rice husk power plant were evaluated by using the Life Cycle Assessment (LCA) methodology. Energy, material and carbon balances were determined for tracing the system flow. Carbon closure was used for describing the net amount of carbon (iv) oxide (CO₂) released from the system in relation to the amount being recycled between the power plant and the CO₂ adsorbed by rice husk. The results showed that the impact potentials from rice husk power plant are lesser than the conventional plants for most of the categories considered. This is the case of EHS that will suffer from high implementation cost this may not be feasible in many rural location as a result of distribution and maintenance cost. Memon et al [34], conducted an assessment on resource potential of rice husk generated in the rice mill. They also carried out technical and economic evaluation of rice husk based 1 MW fluidized bed combustion (FBC) power plant. It was estimated that through the FBC power plant, annual electricity of 5360 MWh can be generated with rice husk fuel consumption of 6968 tons; cost of generating electricity through FBC was approximately Rs.4/kWh This is the case of EHS that will suffer from high implementation cost this

may not be feasible in many rural location as a result of distribution and maintenance cost. Muhammad et al [35], conducted a study to determine the potential of electrical energy of rice husk as fuel for power generation in Indonesia. The estimated potential of rice husk in each province of the country was calculated using the statistical data of rice production from 2011. The estimated annual potential of rice husk development was calculated using statistical data from 2001 to 2012. The results indicate that the development potential of rice husk, potential for electrical energy and economic potential increased by approximately 36.8% over 12 years; an average of about 3.1% per year. In 2011, the 33 provinces had rice husk potential of around 10.52 million tons, which is equivalent to about 5.24 million tons of coals, provided electrical energy and electrical power potentials of about 39,272 GWh and 4, 481 MW, respectively. About 26 provinces had potential of rice husk for electrical energy greater than 100 GWh, providing a total electrical energy potential of approximately 39,076 GWh, and electrical power of around 4, 460 MW. This is the case of EHS that will suffer from high implementation cost this may not be feasible in many rural location as a result of distribution and maintenance cost. Jenkins et al [36], investigated the financial feasibility if utilising leached rice husk as fuel for existing biomass boiler, using rice husk combustion technique. Their finding shows that rice husk combustion technical shows a good financial feasibility when used as a fuel. This is the case of EHS that will suffer from high implementation cost this may not be feasible in many rural location as a result of distribution and maintenance cost. Bakker et al [37], demonstrated that leached rice husk can be utilised as fuel in fluidised bed combustion. Their finding shows that by pre-treating the rice husk with leached process, rapid and undesirable ash deposition generally associated with untreated rice straw will be reduced. This is the case of EHS that will suffer from high implementation cost this may not be feasible in many rural location as a result of distribution and maintenance cost. Permchart et al [38], reported the result of combustion performance of various biomass fuels, such as: sawdust, rice husk and pre-dried sugar cane bagasse, in a fluidised bed combustor. Rice husk shows the best performance in power production and less environmental damages. This is the case of EHS that will suffer from high implementation cost this may not be feasible in many rural location as a result of distribution and maintenance cost. Okasha[39], investigated the efficiency of staged combustion in fluidised bed for rice husk to reduce NO_x emissions, in particular, at high combustion temperatures. From their findings, at a high temperature, NO_x emission was reduced. This is the case of EHS that will suffer from high implementation cost this may not be feasible in many rural location as a result of distribution and maintenance cost. Madhiyanon et al [40], studied the combustion performance of co-firing rice husk with bituminous coal in a cyclonic fluidised bed combustor with capacity of 120 kW, along with the effects of fuel blends excess air ratio and fuel blend to combustion efficiency and emission.

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From their findings, co-firing of rice husk with excess air gives better result and reduces the effect of CO₂ on the environment. This is the case of EHS that will suffer from high implementation cost this may not be feasible in many rural location as a result of distribution and maintenance cost. Sathitruangsak et al [41] studied the combustion performance of co-firing rice husk with coal in a fluidised-bed combustor with a short combustion chamber. From their results, co-firing of rice husk reduces the environmental effects of CO₂. The potential of rice husk for power generation, productive use of electricity and load assessment of the study area were not considered.

Owing to the drawback in the works of [33 - 41] a PBS was designed and used to supply power to rural/isolated dwellers in Amenu, Uburu, Ohaozara Local Government Area of Ebonyi state, Nigeria.

III. EXPERIMENTAL PROCEDURES AND RESULT DISCUSSIONS

We have considered block diagram of Figure 1 in the implementation of this work. The typical load for this standalone power supply option is as shown in Table 1.

Table 1: Typical load for an isolated location

S/N	Load	No. in use	Power (Watts)	Hrs/Day	Watt-hrs/Day
1	Low-energy DC lights	4	5	5	100
2	Radio	1	10	6	60
3	DC ceiling fan	1	15	4	60
4	DC standing fan	1	10	4	40
5	Total		55		260

A bottle was placed at the center of the locally constructed combustion chamber as shown in Figure 5. Rice husk of 7kg used as the fuel was divided into three places (3kg, 3kg, and 1kg). The first 3kg was gradually poured into the combustion chamber as shown in Figure 6 and was compressed with feet in order to make it strongly compacted as shown in Figure 7. The bottle placed at the center of the combustion chamber was pulled up in order to come out of the compressed 3kg rice husk. Additional 3kg was added at this point, compressed and the bottle pulled up again. The remaining 1kg was finally added, compressed and the bottle was finally brought out. The purpose of putting the bottle is to create cavity at the middle of the combustion chamber as shown in Figure 8a. After preparing the combustion chamber for operation, the boiling unit, the permanent magnet DC motor coupled with turbine, the voltmeter and ammeter were positioned as shown in Figure 9. The combustion chamber was lighted up and the experiment commenced. The voltmeter was connected in parallel while the ammeter was connected in series to the output of the permanent magnet DC motor. At 100 degrees centigrade, the water started boiling and steam produced. The steam produced at this point was used to drive the turbine attached to the permanent magnet DC motor. When the turbine

started rotating, the permanent magnet DC motor started producing power. The output cable of the motor was extended for convenience purpose in order to take readings at ten minutes interval. Obtained output DC voltage, DC current and calculated DC watt-hour are as presented in Table 2.



Figure 5. 7kg rice husk



Figure 6. First 3kg rice husk being poured and compressed in the combustion chamber



Figure 7. Compression of 3kg and 1kg rice husk in the combustion chamber



Figure 8a. Compressed 7kg rice husk in the combustion chamber.



Figure 8b. Rice husk compressed in the combustion chamber



Figure 9. 7kg rice husk

Table 2: Results showing DC voltage, DC current and calculated DC watt hour.

Time(minutes)	10	20	30	40	50	60
DC Voltage (V)	0.00	1.88	3.33	4.67	5.88	6.24
DC Current (A)	0.00	0.22	0.52	0.94	1.22	1.87
DC Power (W)	0.00	0.138	0.865	2.93	5.978	11.669
DC Power (Whr.)	0.00	1.38	8.65	29.30	59.78	116.69
Time(minutes)	70	80	90	100	110	120
DC Voltage (V)	8.32	11.70	12.12	12.73	14.02	15.91
DC Current (A)	2.10	3.77	3.97	4.12	4.43	4.87
DC Power (W)	20.34	58.81	74.62	87.41	113.87	154.96
DC Power (Whr.)	203.4	588.10	746.2	874.1	1138.7	1549.6

As seen in Table 2, the experiment lasted for 2 hours. In the first 10 minutes, the voltage, current and power was zero respectively because the turbine has not started rotating. But, from 20 minutes and beyond, the turbine started rotating and the permanent magnet motor started generating power. Measurement of DC voltage and DC current were done at 10 minutes interval and their corresponding DC watt hours were calculated. The voltage and current increased as the time increased. Also, the calculated power and watt hour increased with the increased in voltage and current. The peak power is 154.96W while the peak watt-hour is 1549.6Whr. The typical load and energy demand of a household in rural/isolated area is compared with the peak power and peak energy generated during the experiment is as shown in Figure 10.

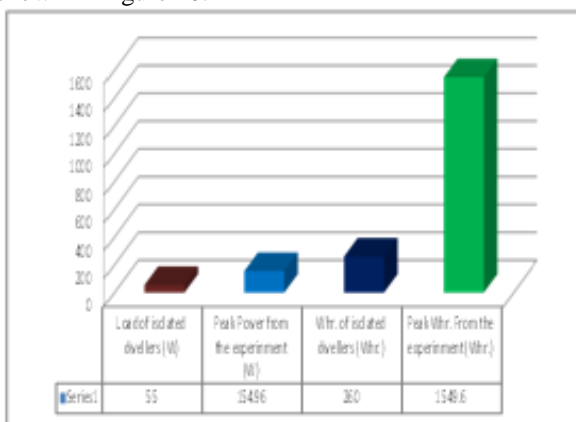


Figure 10: Comparison of rural household standalone load with the experimental values.

From Figure 10, it can be seen that the typical load of a household in a rural/isolated location is 55W and the peak experimental power is 154.96W. This peak experimental power is sufficient to carry the household load in a rural/isolated location. The peak experimental energy value is 1549.6Whr in a 10 minutes interval which is far more than the energy demand of 260Whr in a typical household in

rural/isolated location. The cost of the work is shown in Table 3.

Table 3: Cost of the locally sourced materials

S/N	Device	Price(₦)
1	Permanent Magnet DC Motor	5,000
2	Combustion Unit	1,500
3	Boiler Unit	2,000
4	Construction work	2,000
5	Total	10,500

IV. CONCLUSION

The conversion of biomass into electricity has been proven economically and viable especially for rural/isolated community applications in developing countries. PBS presents a very viable option for rural/isolated locations because biomass is abundantly available in the location and its power conversion can be done through local technologies. In this work, the analysis and experimental backup of biomass power generation was done. The experimental backup was implemented by combustion technique using local technology. The experiment was conducted for two hours. A 12V permanent magnet DC motor was used as the alternator while rice husk was used as fuel. The bio-power was achieved by heating water to steam which was used to drive the turbine attached to the permanent DC motor and 155Whr DC power was achieved. From the result, it can be seen that the typical load of a household in a rural/isolated location is 55W and the peak experimental power is 154.96W. This peak experimental power is sufficient to carry the household load in a rural/isolated location. The peak experimental energy value is 1549.6Whr in a 10 minutes interval which is far more than the energy demand of 260Whr in a typical household in rural/isolated location.

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