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A Review Assessment of the Energy Potential of Biomass around Maiduguri Metropolitan, Nigeria

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ABSTRACT
This review discusses biomass as a renewable energy source. It also defines the resources as well as the ways biomass energy is converted into electricity, technologies involved in extracting power from biomass. For Maiduguri having the climate nature of hot semi-arid according to Kooppen-Geiger climate classification with an average high temperature ranging between 31.9°C in January and 40.1°C in April and the daily mean temperature ranges between 21.8°C to 32.6°C, is indeed in urgent need of a steady electricity supply in order to cope with the condition. Biomass is the major energy source in Nigeria contributing about 78% of Nigeria primary energy supply. A variety of biomass resources exist in the country in large quantities with opportunities for expansion. Biomass resource considered include Agricultural crops (Maize corn). The Substitution of conventional fossil fuels with biomass for energy production results both in a net reduction of greenhouse gases emissions and in replacement of non-renewable energy sources. Biomass if properly harnessed can form a substantial part of future energy sources which will reduce the pressures on the global energy crises. The total energy stored in our terrestrial biomass is not only enormous but is also highly available and renewable. The type of biomass required is largely determined by the energy conversion process and the form in which the energy is required.
Keywords: Biomass, Renewable energy, Electricity, Maize corn.

I. INTRODUCTION

Energy is the mainstay of Nigeria's economic growth and development. It plays a significant role in the nation's international diplomacy and it serves as a tradable commodity for earning the national income, which is used to support government development programs. It also serves as an input into the production of goods and services in the nation's industry, transport, agriculture, health and education sectors, as well as an instrument for politics, security and diplomacy [2].

The increasing global energy demand and the adverse effects of non-renewable fossil fuels on environment had motivated considerable research attention in a wide range of engineering application of renewable resources such as biomass [1]. Biomass technology offers an attractive platform to utilize certain categories of biomass for meeting both urban and rural energy needs if it is properly harnessed. In our rural areas, various cellulosic biomasses (cattle dung, agricultural waste) are available which can be utilized in the production of bioenergy [4]. It has been established that the by-product of biomass found in urban and industrial areas constitute wastes and inadequate management of these wastes result in many untold urban and environmental health hazards in developing countries such as Nigeria. Energy from these wastes, thus has the ability of providing employment opportunities and improving the economy of the nation instead of constituting environmental pollutants [3].

Recently, investigation established that fossil fuel is fast becoming scarce and limited in terms of availability in the world. The developed and developing countries such as China, India, Nigeria, etc., have seen the need for alternative, sustained (renewed) forms of energy to meet the ever-increasing demand for basic needs by the rural and urban dwellers and therefore gave strong support for it. In 2011, USA, Brazil and European Union were responsible for 48%, 22% and 17% respectively of the world biofuel production [5].

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Overview Of Biomass Energy Source

Biomass refers to energy derivable from sources of plant origin such as trees, grasses, agricultural crops and their derivatives, as well as animal wastes, wastes from food processing, aquatic plants and algae [6]. As an energy resource, biomass may be used as solid fuel, or converted via a variety of technologies (biofuel or biogas) to liquid or gaseous forms for the generation of electric power, heat or fuel for motive power. Biomass resources are considered renewable as they are naturally occurring and when properly managed, may be harvested without significant depletion. Generally, sources of biomass as presented in Figure 2 include virgin wood (fuel wood), energy crops and agricultural residues, industrial wastes/effluents, MSW, food wastes, etc. [3].

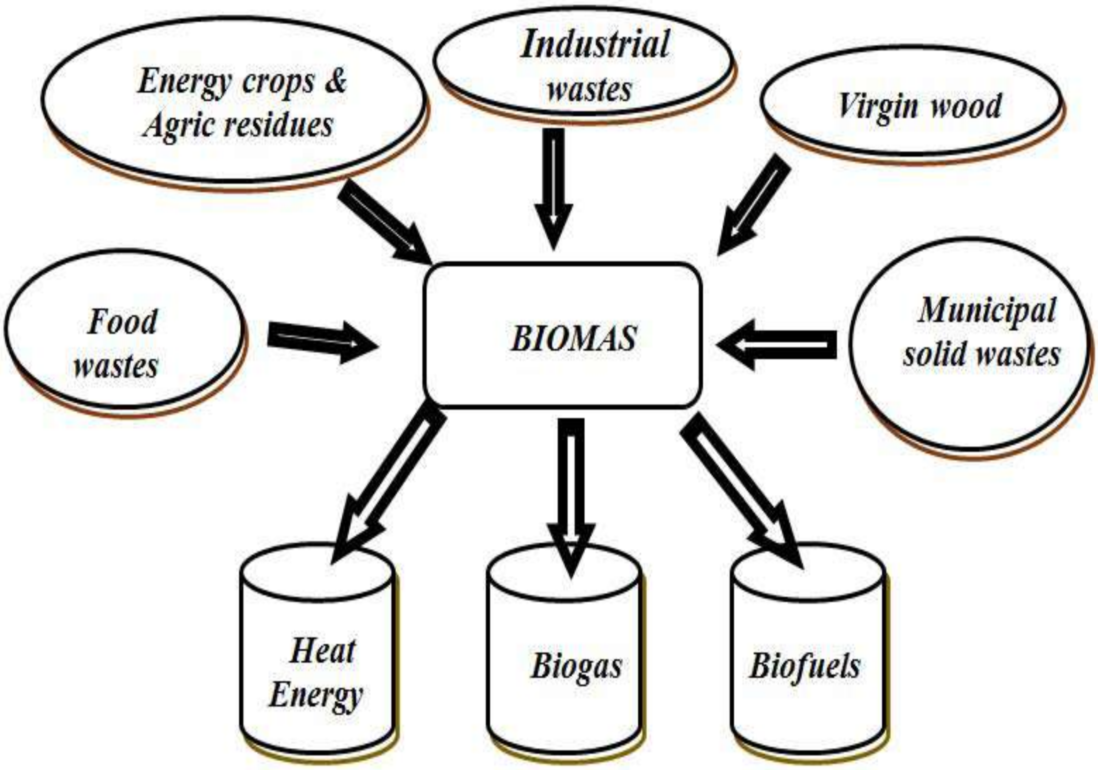

Figure 2.1: Display Biomass structure

Generally, biomass is a compounds of carbon, oxygen, nitrogen and Sulphur, with Significant amounts of free energy in the form of chemical bonds [7]. Depending on the type, when combusted, the chemical energy in biomass is released to generate heat, which can be converted to mechanical work or electricity. Biomass can also be used as a raw material for transport fuel if it is transformed into a liquid form. In principle, both food and non-food biomass can be used to produce fuels commonly referred to as biofuels, which can either be solid, gas or in liquid form. Liquid biofuels can either be first-generation or second-generation biofuels. First-generation biofuels are made from sugars, grains or seeds using only a specific, often edible part of the above ground biomass. Examples of first generation biofuels are sugarcane ethanol, starch-based or corn ethanol, biodiesel, and pure plant oil. Second-generation biofuel is generally made from lignocellulosic biomass, also called cellulosic biomass (OECD/IEA, 2010). The suitability of a particular biomass as a potential feedstock for biofuels production depends on various characteristics such as moisture content, calorific value, fixed carbon, oxygen, hydrogen, nitrogen, volatiles, ash content, and cellulose/ligninratio.

Generally, cellulose is the largest fraction, and constitutes about 38–50% of the biomass by weight [6]. Biomass feed stocks can be obtained from conventional agricultural products (such as sugar- or starch-rich crops, and oilseeds) and lignocellulosic products and residues [8]. Lignocellulosic feed stocks (such as trees, shrubs, grasses, agricultural and forest residues) are potentially more abundant and cheaper than feedstock from conventional agriculture because they can be produced with fewer resources and on marginal and poor lands.

In Nigeria rural areas, various cellulosic biomasses (cattle dung, agricultural waste) are available which can be utilized in the production of bioenergy. It has been established that the by-product of biomass found in urban and industrial areas constitute wastes and inadequate management of these wastes result in many untold urban and environmental health hazards in Nigeria. Energy from these wastes, thus has the ability of providing employment opportunities and improving the economy of the nation instead of constituting environmental pollutants [3].

The type of biomass resource available in Nigeria varies with climatic region in the country. In the rain forest zone, we have woody biomass while in savannah zones we have crop residues [2].

II. MATERIALS AND METHOD

The main biomass resources include; Agricultural sources (Crop residues and animal/poultry wastes, starch crops (Maize, Wheat), Forest residues (Wood and coal) etc

Biomass Conversion Technologies

There are several technologies for the conversion of biomass into either biofuels, bio-power or bio-products. Biomass can be processed through two major conversion pathways: biochemical and thermo-chemical. The appropriate biomass conversion process is determined by the type and quantity of the biomass feedstock and the desired form of energy (end-use requirements, heating value of the biomass feedstock. In the modern pursuit for clean energy, anaerobic digestion has been investigated for biogas production and for recycling of CO_2 in flue gas. Third and fourth generation biomass feedstock, algae, have the capacity to produce methane (biogas) and recycle nutrients by direct use of anaerobic digestion. At present, anaerobic digestion is employed primarily on agricultural residues, animal waste and other wastes in Nigeria for fertilizer and biogas production.

Fermentation

Fermentation is an enzymatic controlled anaerobic process. It is the third step in the production of bioethanol from lignocellulosic biomass. Raw biomass is first pre-treated, then hydrolysed, before fermentation. Pre-treatment increases the surface area of the biomass, decreases the cellulose crystallinity, eliminates the hemicellulose, and breaks the lignin seal. Enzymatic hydrolysis converts the cellulose

economic considerations, environmental standards, and product specification) Furthermore, biomass conversion efficiency is dependent on the feedstock particle size and shape distribution and the type of reactors. A review of some of the conversion technologies is given below.

Biochemical conversion

Biomass composition can be defined from three major components: cellulose, hemicellulose, and lignin. Biochemical conversion processes involve the breakdown of the hemicellulose components of the biomass for the reaction to be more accessible to the cellulose, while the lignin components remain unreached. Using a thermo-chemical conversion process, the lignin can be recovered and used as fuel. Biochemical conversion involves two main processes: anaerobic digestion and fermentation.

Anaerobic digestion

Anaerobic digestion is a multi-benefit, flexible technology suitable for energy production from agricultural residues and other biodegradable wastes]. It is a feasible option for producing renewable energy for both industrial and domestic use. In anaerobic digestion, high-moisture content (85–90%) biomass is converted by microorganisms in the absence of oxygen to produce a mixture of carbon dioxide (CO_2), methane-rich gas (biogas), and traces of other gases such as hydrogen sulphide. The by-product or nutrient rich digestant from anaerobic digestion can serve as fertilizer for agriculture. Biogas produced from anaerobic digestion has an energy content that is about 20–40% of the lower

component of the biomass into glucose, and the hemicellulose component into pentose and hexoses. The glucose is then fermented into ethanol by selected microorganisms. Fermentation uses microorganisms and/or enzymes for the conversion of fermentable substrates into recoverable products (usually alcohols or organic acids). Currently, ethanol is the most desireable fermentation product, but the production of several other chemical compounds such as hydrogen, methanol, and succinic acid at the moment, is the subject of most research and development programs. Hexoses, mainly glucose, are the most common fermentation substrates, while pentose (sugars from hemicellulose), glycerol and other hydrocarbons require the development of customized fermentation organisms to enable their conversion to ethanol. Fermentation technology is established and widely used for waste treatment, and for sugar to ethanol production.

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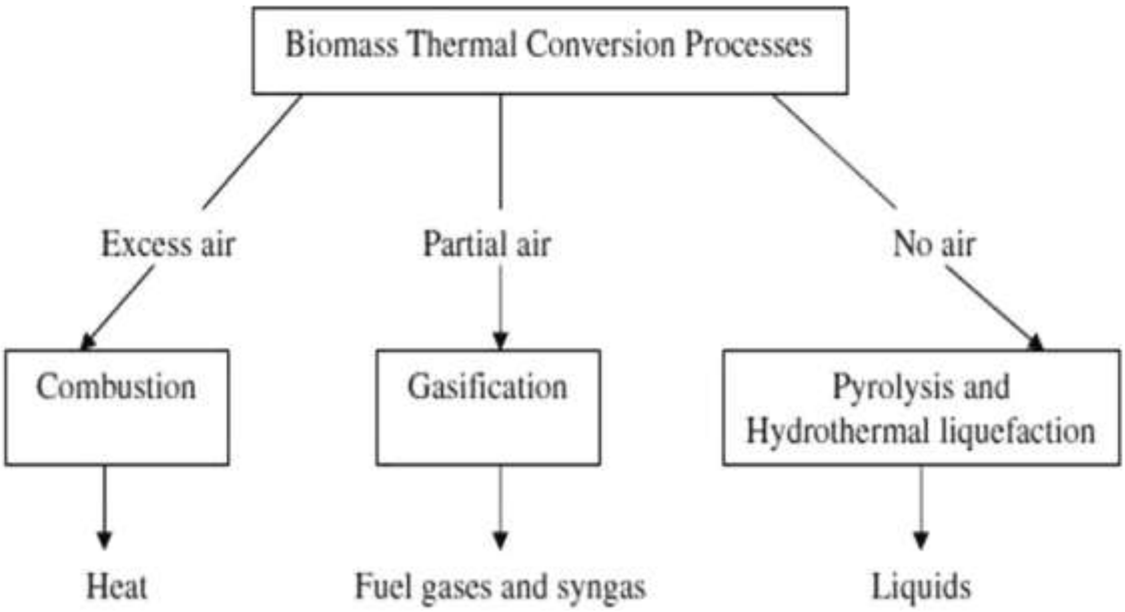

Fig 3.1 Thermochemical conversion processes

III. RESULTS AND DISCUSSION

4.1 The Amount of Biogases (Energy) To Be Produced By Each Source

The table **4.1** below shows the summary of the amount of renewable energy which is to be produced by each source

Sector	Type of biomass feedstock	Example of biomass	Biogas yield (m3 CH4/tonnesVS)
Agricultural	Animal manures and slurries, crops, grass, and other by-products	Cattle slurry Maize (whole crop)	200 205–450

However, from the summary table above, the amount of energy to be produced by each source depends on the type of feeding, food, species and other environmental factors in case of animal sources. While those of plants biomass sources depend on the weather, fertilizer applied, land and other factors concerning the outputs which includes the method used in the processing (recycling).

General nature of the combustion

As maize corn undergoes pyrolysis, combustion takes place if oxygen is available. When a new piece of maize corn is added to a fire, it is heated up by its hot surroundings. Since maize corn is a moderately good thermal insulator, the heat cannot be conducted quickly into the interior of the maize corn; so only a very thin layer at the surface is affected initially. It dries very quickly and decomposes into volatile matter and char. Heating rates appear to be important. Maize corn is normally burned either in the open, in open fire places or in single-stage closed combustion units. It could also be used in a fluidized combustion unit of the type used in which only carbonaceous material and volatile matter are burned out in the freeboard. Clearly this last type is preferable.

The studies work out with excess air. With limited amounts of air the results are relevant to both direct complete combustion and partial combustion (gasification).

Effect of secondary air

Combustion of maize corn (complete) is a desirable objective, and this does required the burning of both the evolved gases and solid maize corn. This requires certain minimum amount of air, sufficiently with high temperatures, and adequate distribution and mixing of the air with combustible materials. As the maize corn was added to the hot bed and the secondary air inlets were closed there was a considerable pyrolytic decomposition of maize corn, but little combustion and little air to dilute the smoke. But as the air was introduced, directly into the free-board zone, smoke reduced. In fluidized bed of the type used here, plenty of air through the bed would be needed to burn these gases as well as the maize corn. In practice, putting plenty of air through the bed did not seem to burn the gases but only increase the particle elutriation rate and diluting the combustion products. The former point is in contrast to burning of coal.

Air through the bed was admitted at a point where there is very little flame. Since maize corn contains about 80% volatile matter, volatile matter loss from the bed is likely to occur and travels up to the free-board region above the bed to burn there if enough oxygen is there with which to ignite the smoke. The rough rule of thumb with other types of maize corn burner, is that secondary air will only help if admitted into a region where flame already exists. This seems to be the case for fluidized bed too, because when flames filled the free-board region, the supply of secondary air let to more complete combustion. The amount of secondary air admitted was also critical. Visual observation of the combustion behavior at the start, that when it was too little, not much of the combustible gas was burnt. When it was too much its cooling and diluting effects inhibited combustion. Thus, combustion is the free-board was only possible over a moderately wide range of secondary air flow which is in accordance with the work of [9].

Effects of bed temperature

The bed temperature became stable at 750^{o}C and 660^{o}C respectively within 25 minute of maize corn feeding. Bed temperatures continued to rise as the combustion progressed. It was found that as long as the bed temperature was about 600^{o}C or higher, combustion would sustain and be nearly complete when burning maize corn. This may be attributed to the good mixing of bed inert particles promoted by bubbling or turbulent action which allows the inert particles to receive radiant energy from the flame and convective heating which helps to maintain bed temperatures.

The nature of combustion products

The products of combustion were $CO_{2,}$ CO, O_2 and CH_4 (Heavier hydrocarbons could not be detected due to limitations imposed by the hydrocarbon analyzer for higher boiling point hydrocarbons). The extend of the following homogeneous reactions, possible between these species, could be dependent on resident time, temperature in the fluidized bed and the equilibrium conversion conditions

$CO + 1/2O_2$ --------------------------> CO_2
$CO + H_2O$ --------------------------> $CO_2 + H_2$
$CH_4 + H_2O$ --------------------------> $CO + 3H_2$
$H_2 + 1/2O_2$ --------------------------> H_2O
$CH + 3/2O_2$ --------------------------> $CO + 2H_2O$

Each of the above reactions can affect the heating value of the dry gas without affecting the total carbon to nitrogen ratio. According to [10], methane must be produced from the pyrolysis of maize corn or tar and not by the reaction of CO and $H_{2.}$

The products of reactions obtained indicate that oxygen is reacting with pyrolysis products faster than they are formed in the later periods of reaction (when char and tar are being converted).

In addition their variation with combustion conditions followed the expected pattern. The levels of $CO_{2,}$ CO produced increased generally with increase in bed temperature. Thus, the formation of carbon monoxide was evidently due to partial combustion at low temperatures, should excess air cause CO formation, then it probably does so by lowering of the bed temperature.

Energy balance

The energy difference between the reactants and the products indicates firstly weather the process requires a net energy input or weather is a net producer of energy and secondly the minimum level of energy required or maximum level of energy produced.

Energy loss from the combustor comes from different ways. The heat loss accounted for in this study is the heat losses from the bed to the surroundings. The estimated heat losses amounted to 0.4KWin the bed was 0.3KW in the free-board.

IV. SUMMARY

The paper presented a review assessment of the energy potential ofbiomass which can be burned in thermo-chemical conversion plant that is combustion, to produce steam for use in a turbo-generator to produce electricity: some biomass species are better suited for biochemical conversion processes to produce gaseous or liquid fuels. The energy content of biomass (on a dry, ash-free basis) is similar for all plant species, lying in the range 17-21MJ/Kg. The principal selection criteria for biomass species are growth rate, ease of management, harvesting and intrinsic material properties, such as moisture/ash/alkali content, the latter properties influencing the operational characteristics of thermal conversion plant.

Utilization of bioenergy has not been given serious implementation attention in Nigeria as if the fossil fuel will be continuing forever. It is important for Nigeria in general to look inward to see that the future generations will not be put at disadvantage through the continued exploitation of fossil resources by exploring alternatives energy sources. The energy challenge of Nigeria will be a thing of the past if the abundant biomass resources in the country is tapped and used to generate electricity. Although there has been an upscale of activities by government towards increasing the energy within the country for electricity production through renewable sources. It is hoped however that the laudable programmers and policies on bioenergy will be given some bites.

V. CONCLUSION

Biomass is one of the renewable energy sources that is capable of making a large contribution to the world's future energy supply. Land availability for biomass production should not be a bottleneck, provided it is combined with modernization of agricultural production. Recent evaluations indicate that even if land surfaces of 400-700 million hectares were used for biomass production for energy about halfway the next century, this could be done without conflicting with other land-use functions and nature preservation.

The forms in which biomass can be used for energy are diverse and optional resources, technologies and entire systems will be shaped by local conditions both physical and socioeconomic. Perennial crops in particular may offer cheap and productive biomass production systems with or positive environmental impacts. The major advantages of employing biomass from these resources includes social collaboration, ease of maintenance, economic and energy security benefits as well as enhanced environmental friendliness over fossil fuels use.

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