

# Study of Biomass fuel production from Different Waste Residues: A Review

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## Abstract

Due to the increasing population and less availability of biomass resources in the world such as coal, charcoal etc., so we need to choose the alternative pathway to meet the energy demand in future. Biomass fuel production have been immersed as a most suitable method for reducing the usage of fossil fuels such as coal, charcoal, oil, natural gas and also reduces the fossil fuel price in the market. In this review mainly discussed about the biofuel production from the agricultural residues (sugarcane bagasse, cassava waste, rice husk, jatropha, sweet sorghum, groundnut shell, cashew shell, almond shell, coffee husk, sunflower leaves etc.), forestry residues (wood pellets, bamboo sticks, sawdust, bark, branches etc.), industrial residues such as (paper waste, cotton waste, plastic waste etc.) and municipality solid waste by using the following process such as fermentation, gasification, pyrolysis, direct combustion, anaerobic digestion, chemical conversion and briquetting which undergoes two main processes of analysis such as proximate analysis and ultimate will be carried out to determine the moisture content, ash content, fixed carbon, bulk density, total solids, carbon nitrogen ratio, calorific value, hydrogen and nitrogen content. Main conclusion which is obtained from the various studies provides the valuable information about the

behaviour of biomass fuel and their characteristics for the future development of biomass conversion process to meet the future energy demand.

**Keywords:** biomass, renewable resources, recovery, biofuel, waste residues

## I. INTRODUCTION

Nowadays, renewable energy sources such as charcoal, oil etc., are considered as primary energy in the world. Due to the increasing population these non-renewable energy sources will be depleted within the next few years [28]. Emission produced from these resources can cause global warming, acid rain, urban smog, climatic changes, environmental pollution [18] and numerous health problems to the human beings such as asthma, lung infection etc., are caused due to the emission of these non-renewable energy resources [17]. In other words, biomass is a type of biological matter which is derived from the living or recently living organisms. Biomass is referred as a plant or plant-based material referring to the organic matter or renewable resources which comes from plant and animal material. According to world bioenergy association (WBA) global bioenergy statistics of 2016 global final energy consumption is shown in the Fig.1 [36].

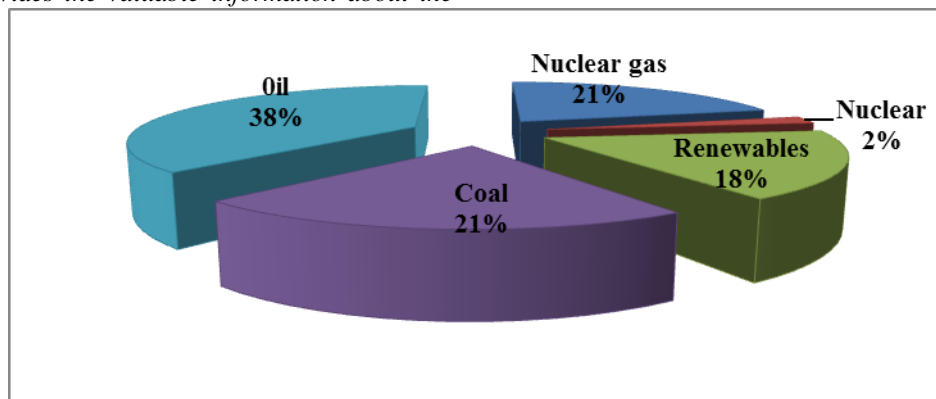


Fig. 1. Global final energy consumption in 2013 (WBA)

Biomass based fuels is one of the renewable energy fuels because it is derived from the renewable resources such as agricultural, forestry, industrial and municipality residues. Agricultural waste residue is considered as one of the main sources of biomass fuel production. These residues mainly consist of organic waste which contains numerous quantity of waste; it is used mainly as a fodder for animals [25]. But major parts of waste are not used properly and these wastes are mainly dumped in the land fill [7].

Resources which is used for producing biomass production by using various agricultural resources such as Jastrophia, Sweet Sorghum and Molasses and food crops such as Cassava[1, 9], rice, coconut cashew, citrus [6], micro algae [5], oil, palm, maize [19,21], rice husk [21], animal manure [2], lignocelluloidal residues [3], cactus plant [3, 9, 24] etc., and household resources such as kitchen waste, hotel waste [2] and Municipality waste such as Municipal sludge, human excreta, pig slurry, chicken

dropping and maize silage [4] by using the process such as pyrolysis, densification, fermentation, briquetting and anaerobic digestion [1-25, 29] it undergoes following test such as Moisture content, volatile matter, calorific value, Carbon-Nitrogen ratio, fixed carbon, ash contents [25, 28, 16] to determine better resources for biomass production with different with different binders such as cow dung [21, 9], Cassava, plastic [14], micro algae [8], paper waste [29], slop waste [23] and cactus plant [21] as binders which is especially made for biomass briquettes.

Most of the developing countries has promoted biomass energy has followed the biomass conversion process. This process is mainly followed by the countries such as Nigeria, Turkey, Malaysia, Brazil, India, Iran, Germany, China etc., [32]. According to WBA (world bioenergy association), share of biomass in final energy consumption in 2014 all over the world [36] as shown in the Fig. 2.

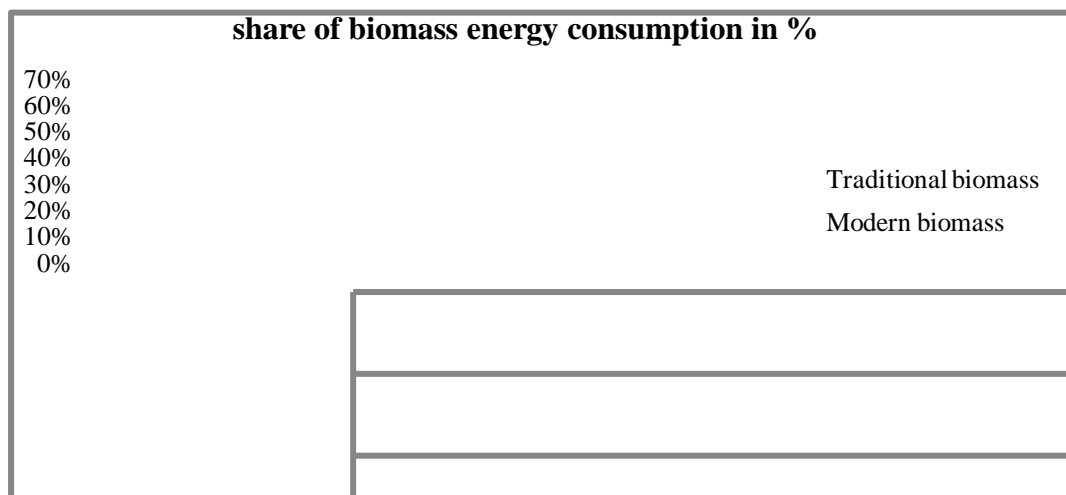


Fig. 2. .Biomass energy consumption of countries in 2014

([https://worldbioenergy.org/uploads/wba%20gbs%202017\\_hq.pdf](https://worldbioenergy.org/uploads/wba%20gbs%202017_hq.pdf))

India is one of the most populated country in the world which having large quantity of agricultural waste are produced per year. These agricultural wastes are mainly disposed by dumping and burning which causes pollution to the environment and health problems to the human beings. So it is necessary to prevent the following problems and also to explore many other sustainable energy resources to meet the energy demand. One of the main methods of biomass conversion method is biomass consumption process. In India, this method is used in the ancient time in the form of cow dung cake firewood and most of them available in the

natural feed stocks [32]. Direct usage of this biomass production can cause more emission of smoke. In order to control that Indian government has provides more development schemes for the production of biofuel by the establishment of biogas plant, briquetting production plant etc.,

In Nigeria [1], which is the 7<sup>th</sup> most populated country in order to provide sustainable development in the country, have to concentrate mainly on the solar energy and biomass production. Renewable resources available in the Nigeria such as Jastrophia, Sweet Sorghum, Molasses, Food crops,

forest residues, Municipal solid waste and animal waste [1]. Brazil can produce biomass production by using the forestry residues, wood-based industry residues, agricultural residues (Plants and Animal), sewage residue by three stages of analysis of biomass resources models high level modeling architecture [5]. In Iran, biomass production is mainly carried out by citrus waste due to the huge availability of citrus waste by food processing industry and lack of maintenance in Iran. These wastes are mainly disposed by landfills and animal feed which is converted into bioethanol and biogas because this waste contains numerous polymers of soluble and insoluble carbohydrates [6].

In Turkey, animal waste, Municipality waste, forestry waste is used for the biomass production [7] and Annual production of waste in the country is 30 million tons [7]. Turkey has produces 1.5 million tons of biodiesel, 3 million tons of bioethanol, 4 million m<sup>3</sup> of bioethanol [7]. In Malaysia, biomass produced by using the following resources such as timber, oil palm waste, rice husks, coconut trunk fibro, Municipal and sugarcane wastes. Malaysia can produce 168 million tons of biomass produced per year by using these above resources [7]. In Iran, biomass can be produced by the pistachio waste by the anaerobic digestion and pyrolysis method [20]. Biomass production from crop residues which includes agricultural and forestry waste residues which is used for the production of biomass fuel production in European Union (EU) [35]. China also use the agricultural and forestry residues which is used for the production of biofuel production to meet the future demand due to the increasing demand for non-renewable resources. In Germany biomass fuel production from agricultural, forestry, industrial and municipality waste residues for heat and energy generation.

There are two main sources are the purposely grown energy crops. Energy crops such as woody crops and agricultural crops such wastes includes the woody residues, forestry residues, temperature crop waste, tropical crop waste, industrial waste, pie waste and municipality waste [28,49,53]. Feed stocks for biomass power generation in India are mainly depends upon the energy crops for the generation of energy (Eg: bamboo, propositis etc..) [32]. Agro based industrial Waste which is released from agro based industries such as cotton industrial waste, sugarcane industrial waste, paper industrial waste [41, 50]. Second important sources are agricultural waste such as waste which comes from the cultivation or harvesting of agricultural crops such as rice, millets, jastropho, cassava waste, sweet sorghum, cashew shell, almond shell, agricultural shell, Sugarcane bagasse, sunflower leaves, coffee husks, wheat, barley husk, millet stalk and bamboo stalk etc., [34]. Third important sources such as municipality solid waste [45] such as kitchen waste, slop water, plastics etc. Municipal waste which is mainly used as a binder for the production of biofuel. Fourth important sources which comes from the forces by-products such as leaves and barks are mainly used as a forest waste which also includes the waste which is released from the forest industrial wastes such as wood pellets, saw dust etc.,

But crop and forest resources are the most abundant resources in many parts of the country [1,7,10,31] in various countries India, Nigeria, china etc., agricultural and forestry residues can produces large amount of crop residues remains on agricultural and forestry residues remains on agricultural 430Mt [31] and 110Mt of forestry residues[31] are present after the trees are harvested for wood industry, paper industry etc., The different sources of Bio mass used for the production of Bio Fuel is shown in Fig.3.

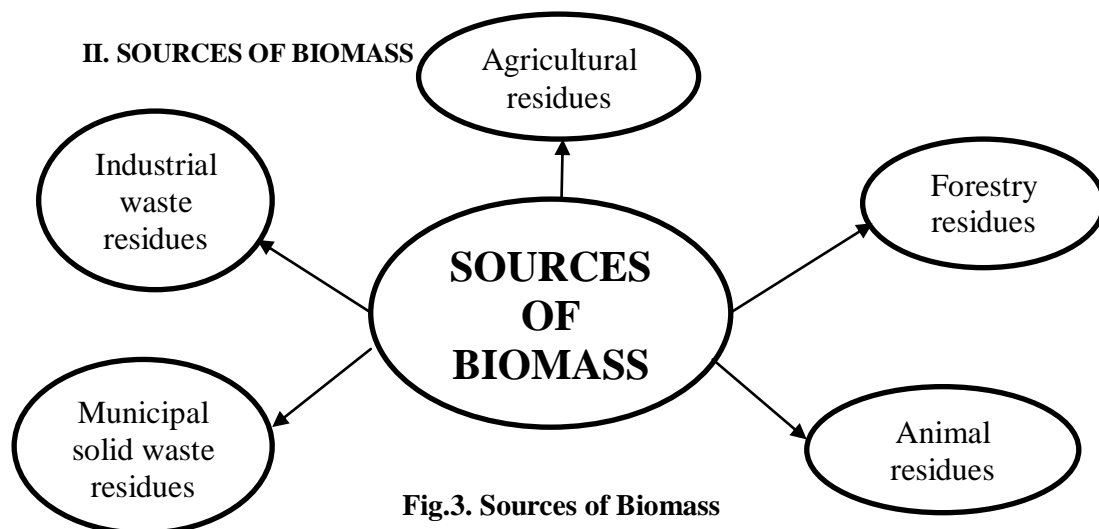


Fig.3. Sources of Biomass

### **III. BIOMASS CONVERSION PROCESS**

Biomass is converted into energy by numerous methods. Selection of process will mainly depends upon type and quantity of available resources of biomass, environmental standards, economical condition and other factors. Several methods available to convert biomass into usable form by the following process such as combustion, pyrolysis, gasification and biochemical conversion of biomass by using microorganisms during fermentation, anaerobic digestion and esterification is used for conversion of energy from the biomass.

#### **A. Pyrolysis**

Pyrolysis is the process of thermal decomposition of organic matters in the absence of oxygen. This process is relatively a slow chemical reaction which is occurred at low temperature to convert biomass into fuel [43, 46]. Pyrolysis mainly depends upon temperature, heating rate, particle size and catalyst used in this process which is used to convert municipal waste, rice husk and bagasse [4, 7]. It is also used to convert citrus plant into biofuel [6].

#### **B. Direct combustion**

In this type of biomass conversion method, biomass resources are directly burned in to the waste to energy plants without undergoes any chemical processing for producing steam for making electricity [44]. Direct combustion of coal for producing electricity from the biomass resources is one of the most promising resources for a future production of biomass. It provides heat energy for industries and home. Agricultural waste residues such as bamboo, rice straw, coffee husk, microalgae etc., [9, 14] which is used direct combustion process of producing biofuel.

#### **C. Gasification**

Gasification is one of the thermochemical conversion processes for converting biomass into gaseous fuel by means of partial oxidation of the biomass resources at a higher temperature. This process is adopted for converting municipal waste to biofuel in Nigeria and it is also used for heat generation [1, 48]. Gasification is mainly used for the conversion of municipal solid waste to biofuels. The main disadvantage of gasification is the absence of waste sorting which causes waste that contains substances that are incombustible and produces inadequate amount of gas that is required

for electricity generation[1].

#### **D. Fermentation**

Fermentation is the biomass conversion method for converting biomass in to bioethanol fuel. There is numerous numbers of processes that can be used for producing ethanol from various plants. Mainly two commonly used processes involved using yeast to ferment the starch in the plant species to produce ethanol which can be used as fuel transportation. One of the newest processes involved in the process is enzyme which is used for the breakdown of cellulose in the plant fibers for the maximum ethanol production. [21].

#### **E. Anaerobic digestion**

Digestion process is the process of biochemical conversion of organic material to biogas by bacteria in the absence of air. Biomass composition is mainly consists of methane and carbon di oxide with small amount of other gases consists of nitrogen, hydrogen, hydrogen sulphide, ammonia, water vapor etc., which depends upon substrate and digestion condition [2]. It is one of the widely used for treating wet organic waste. This process is used for degradation of palm mill effluent in Nigeria cow dung [4] and pistachio waste [20] is converted into biofuel. In this experiment showed the COD removal where efficiency will be 93.65%-97.7% and BOD removal which having efficiency of 98.35% [1]. Activities of biomass have been evaluated by following four steps namely hydrolysis, acidogenesis, acetogenesis, and methanogenesis [2,6].

##### **a) Hydrolysis:**

It is the process of converting complex matter such as carbohydrates, protein, fat, cellulose, hemicellulose in to smaller molecules such as sugars and amino acids by a bacteria or enzymes or microorganisms such as lipase, hemicellulose or cellulase etc., and duration of this process varies mainly depends on types of material used [6,17].

##### **b) Acidogenesis:**

Second step will be acidogenesis in a anaerobic digestion process and it is similar to the process of fermentation. Same type of microorganisms which is used for hydrolysis process to break down the single molecules such as sugar, amino acid, acetic acid etc., and it also produces carbon dioxide and acetic acid [6,17,21].

##### **c) Acetogenesis:**

Third step will be acetogenesis in a anaerobic digestion process which cannot be directly converted to methane will be changed to methane substrate by methane bacteria which converts ethanol and fatty acids are converted into carbon dioxide, hydrogen and acetic acid [6,17].

**d) Methanogenesis:**

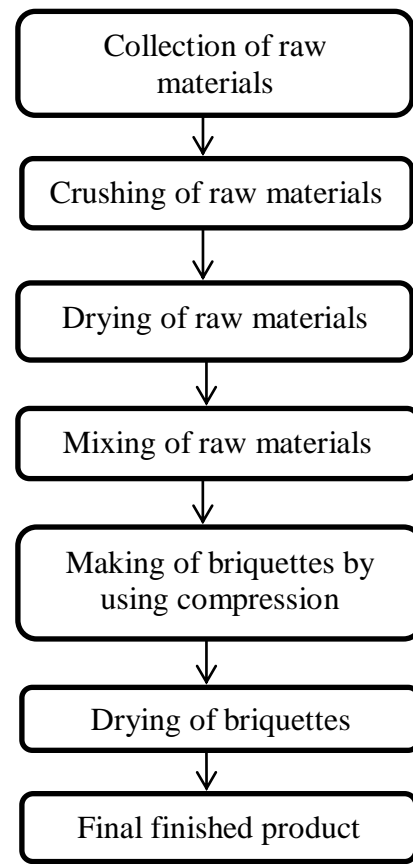
Third step will be methanogenesis in a anaerobic digestion process converting methane substrate into methane gas through two pathways. Firstly acetic acid is converted into carbon dioxide and methane and then combination of carbon dioxide and hydrogen produces methane and water. Finally it produces a biogas which is converted into biofuel and also provides digestate, fertilizer and other products [6,17].

**F. Chemical conversion**

The Conversion of biomass resources into gas or fuels by using chemicals which is used for converting forestry waste and cotton industrial waste in to biofuel.

**G. Briquetting**

Briquetting is the process of biomass converting technology for producing biomass energy. Briquettes is a process of compressing material in to small block which can be used as an alternative fuel wood because briquettes ensure cleaner combustion [1,47] and briquetting process is operated manually by piston press and screw press [25] but is serving only for house hold heating process [27,28]. Because of increased generation of biomass resources, briquetting is the most important process of biomass energy conversion and it is the best solution of reduced usage of biomass resources because of clear combustion of briquettes. Increased energy efficiency can be done by using hybrid biomass such as saw dust, rice, millets, jastropa, cassava waste, sweet sorghum, cashew shell, almond shell, agricultural shell, Sugarcane bagasse, sunflower leaves, coffee husks, wheat, barley husk, millet stalk and bamboo stalk etc.,[1]. Process flow diagram for biomass briquettes as shown in Fig.4.



**Fig.4. Process of biomass briquetting**

**IV. ANALYSIS OF BIOMASS**

There are four methods to analysis the biomass which includes the proximate analysis, ultimate analysis, physical or chemical composition and artificial neural network. First two methods of analysis are considered as a common method of analyzing the biomass [36, 40, 39, 29, 52].

**A. Proximate analysis:**

Proximate analysis is one of the methods to analysis a biomass to determine the bulk density, volatile matter, moisture content, total dissolved solids, calorific value which is carried out during the biomass production.

**a) Bulk density:**

The bulk density is defined as the ratio of mass to volume. A container with known volume is first weighted and then the container filled with the sample and again reweighted. The difference between the initial weight of the container and final weight of the sample will provide bulk density of the biomass. Bulk density can be calculated by the following formulae

$$\text{Bulk density} = (w_s - w_c) / v_s \quad (1) \text{ [39]}$$

Where:

$w_s$  = Weight of the sample along with the container

$w_c$  = Empty weight of the container

$v_s$  = Total volume of the sample

**b) Moisture content:**

Sample of weight two grams is taken in to the already weighted crucible and then the sample is reweighted along with the crucible. The samples are heated in an oven at a temperature of 100°C to 105°C for at least four to five hours. Heated samples are cooled in a room temperature for 24 hours and then the amount of moisture loss to be determined by the following formulae

$$\text{Moisture content (\%)} = (w_2 - w_3) / (w_2 - w_1) * 100 \quad (2) \text{ [39]}$$

Where:

$w_1$  = Initial weight of the empty crucible

$w_2$  = Weight of the sample along with the crucible before heating

$w_3$  = Final weight of the sample along with the crucible after heating

**c) Total solids:**

Total solids of biomass can be defined as the ratio of total percentage to the percentage of moisture content. This can be derived from the following formulae

$$\text{Total solids (\%)} = 100\% - \% \text{ moisture content} \quad (3) \text{ [39]}$$

**d) Ash content:**

Sample of weight two gram is taken in to the already weighted crucible was burned or heated in a muffle furnace at 760°C to 1000°C, this process is continued until the samples are completely burned. Again cooled in to the room temperature and then the cooled samples are again weighted. The percentage of ash content was calculated by using the following formulae

$$\text{Ash content (\%)} = (w_3 - w_1) / (w_2 - w_1) * 100\% \quad (4) \text{ [39]}$$

Where:

$w_1$  = Initial weight of the empty crucible

$w_2$  = Weight of the sample along with the crucible before heating

$w_3$  = Final weight of the sample along with the crucible after heating

**e) Volatile matter and Fixed Carbon:**

Volatile matter is defined as the addition of percentage of moisture content and the percentage of ash content. Fixed carbon is defined as the ratio of percentage of ash content and volatile matter. It is derived from the following formulas

$$\text{Volatile matter} = \% \text{ moisture content} + \% \text{ ash content} \quad (5) \text{ [39]}$$

$$\text{Fixed Carbon} = \% \text{ ash content} + \% \text{ volatile matter} \quad (6) \text{ [39]}$$

**f) Carbon Nitrogen Ratio (C: N ratio) and Net Calorific Value:**

C: N ratio can be defined as the ratio of percentage of fixed carbon present in the sample to the percentage of nitrogen present in the sample and the net calorific value of the sample is derived by the combination of calorific value, volatile matter and moisture content.

C: N Ratio = % Fixed carbon in the sample / % Nitrogen in the sample

$$\text{Net calorific value (NCV)} = 18.7 * (1.0 * AC * MC) * (2.5 * MC) \quad (7) \text{ [39]}$$

Where:

NCV = Net calorific value

AC = Ash content

MC = Moisture content

**B. Ultimate Analysis**

Ultimate analysis which is used to determine the amount of hydrogen and nitrogen content present in the biomass.

**a) Hydrogen Contents:**

Presence of hydrogen content can be determined by taking two grams of samples and allowed to burn completely and the exhaust produced by the sample is passed through the two grams of anhydrous CuSO<sub>4</sub> and then the colour change is observed. Final weight of sample is taken after the complete combustion process. Percentage of hydrogen content present in the sample is calculated by using the following formulae

$$\% \text{ Hydrogen content} = (\text{Weight of water} * \text{Molar mass of hydrogen} / \text{Weight of .sample}) * 100\% \quad (8) \text{ [39]}$$

**b) Nitrogen content:**

Sample of weight two grams are kept in to the digestion flask and add the suitable catalyst and 20 ml of acidic solution is added to the sample and then fix the digester after obtaining clear solution. After the digestion process can be takes place and then it is transferred to the 100 ml volumetric flask, In this stage suitable acid solution and indicator should be added depends upon the sample and then it is diluted with the distilled water of 75 ml. 10 ml of digest was made with the 20 ml of alkaline solution and then it is diluted. Amount of nitrogen present in the sample can be determined by the following formulae

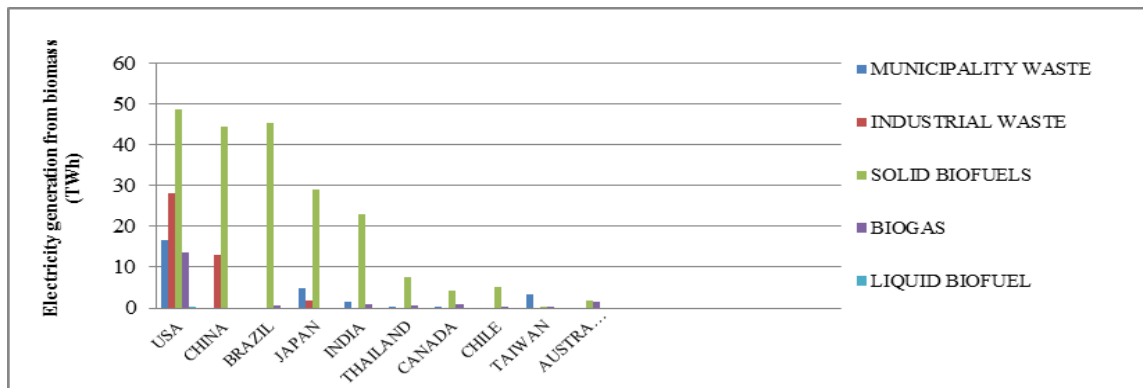
$$\% N = \left( (\text{titre} - \text{blank}) * N_f * D_f * 100\% \right) / S_w \quad (9) \quad [39]$$

Where:

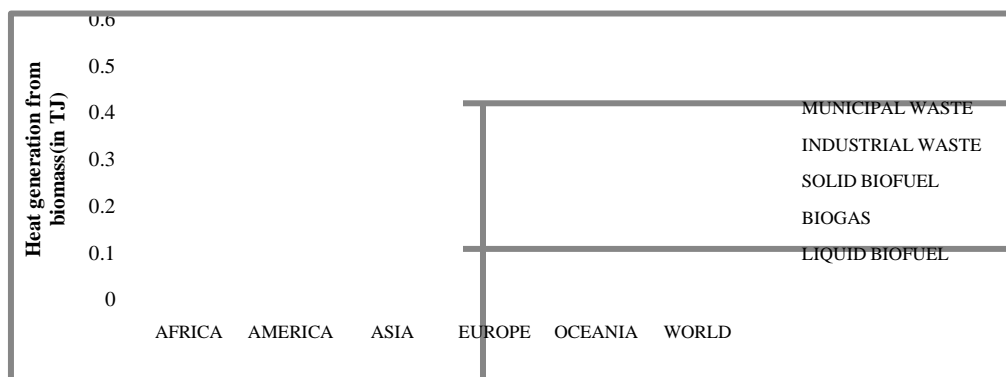
- N = Normality of solution
- N<sub>f</sub> = Factor of nitrogen
- D<sub>f</sub> = Factor of dilution
- S<sub>w</sub> = Weight of the sample.

**V. ADVANTAGES**

Biomass conversion method is used to develop sustainable development in Nigeria, Iran, Brazil, Turkey and Malaysia [1, 6-7]. This method is very much helpful for producing biofuel, bioethanol and biomass briquetting in highly populated country to meet the energy demand for non-renewable sources is mandatory [1, 12, 15]. It is used for reducing deforestation, emission of greenhouse gases, recycling and reducing of waste generation and also for controls odour and environmental pollution. Biomass conversion method is also used to reduce landfill space by recycling of municipal waste and paper waste produced by the industry [23]. This process is used to achieve some energy policies of various developing countries such as Turkey, Sweden, Iran, Brazil and other developing countries. This review provides the future guidance for adopting for biofuel conversion process and also for analysing the technologies for environmental life cycle thinking perspective contributing to their sustainable use is performed [16]. This biomass conversion process can be mainly plays a important role in heat and electricity generation. Heat and electricity generation from biomass in leading country was shown in



**Fig.5. Electricity generation from biomass in top countries(Data source[37])**



**Fig.6. Heat generation from biomass in leading countries (Data source [37])**

## VI. IMPACTS

Use of agricultural and forestry waste [15, 51] has chemicals like substances due to the use of fertilizer which can cause unsafe emission. Due to the combustion of such biomass can cause emission of hazardous substances can have an impact of human health, presence of particulate matter and certain oxides such as sulphur oxides have been mainly affecting the respiratory system of the body. According to the recent report on world health organization (WHO) [18] reveals that the smoke released by burning of biomass contributes approximately 3% global burden of disease and it causes 1.6 million premature death every year which includes 0.9 million children will death under 5 years of ages and it also causes numerous diseases such as lung infection, asthma, stinging eye, low birth weight and sinus problems for human beings as well as animal. Adopting biomass conversion process required huge investment and high transportation cost these are the main drawback of biomass conversion process.

## VII. CONCLUSION AND DISCUSSION

Now I finally concluded that use of biofuel conversion method is one of the best alternative methods for the recycling of waste material such as agricultural, forestry, industrial and municipality waste residue into usable biofuel, bioethanol and biomass briquetting to attain the sustainable development and achieving various policies achieved by various developing countries. Various results are discussed based on the reference papers which include biofuel production of sawdust with sorghum with cassava waste as binder [1]. Citrus waste, algae, cow dung and pistachio waste which produces better results for the production of biofuel and ethanol [6,20], which can produce fifty percentage of biofuel and bioethanol produced by the recycling waste particle. Adaptation of pyrolysis, gasification, anaerobic digestion is the most commonly followed method for the production of biofuel according to the following reference paper. Microalgae is the best binders for the production of biomass briquettes [8]. Spruce wood shaving and molasses by using coal tar binder used to reduce the emission of greenhouse gases up to 59.9% [10]. Good quality briquettes are produced by the following biomass resources such as mopani leaves with ground nut shells [21], rice straw briquettes of ratio of 30:60:10(30% of rice husk, 60% of rice straw and 10% of rice husk) [22] and municipal solid waste and sawdust char (20:80) with 20% of slop waste as binder for producing best soil briquettes, it is mainly used for

alternative fuel for industrial use [23]. Residues such as poultry manure 18.58%, olive residues 75% and other residues 42.06% which is used for electricity production [28]. The main conclusions from various intentional studies are provided for addition to future research and development of biomass conversion process to meet the global energy demand. Proximate and ultimate analysis of groundnut shell, corn cobs, sheep dung provides better efficiency when compare to others [39]. The total of about 540 Mt of crop and forest residues can produce about 12% of biofuel consumption of United States. On the basis of proximate and ultimate analysis of rice husk is found to be more efficient when compared to wheat straw, mustard straw and wheat husk.

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