Savonia
University of Applied Sciences

BIOMASS ENERGY PRODUCTION

Thesis

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Degree Programme in Industrial Management
Engineering and International Business

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ABSTRACT

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Abstract

The recently experienced climatic change represents the greatest threat facing the world on its, social, environmental and economical factor. This thesis explain the relevance and importance of biomass as a renewable energy resource. Its possibilities is still expected to be fully tapped and utilized.

The main objective of the thesis is to ascertain means or methods in which Europeans can put together resources from biomass.

The aim of this thesis is to inspire and motivate the developed and developing countries to support the use of biomass as substitute to fossil fuels, so as to reduce total dependency on usage of fossil fuels as well as bringing the release of carbon dioxide to the environment to a minimal level.

Qualitative research is informal accurate and reliable through verification and it developed theories and patterns for better understanding. The qualitative analysis was arrived on by interpreting information obtained from internet, journals and textbooks. In qualitative research, relevance, reliability, conciseness and validity are important. They all describe the authenticity and trustworthiness of the information gathered.

Combustion is the process of generating heat and energy by burning fossil fuel. It can be burnt with an existing fuel either directly or by co-firing.

The process is said to be success because it converts different biomass because of the following characteristics: gasification takes place in a high heat inertia; in controlled and relatively low temperature; before combustion takes effect, char is removed; and reduction in solid waste, since the quantity of particles produced is less than quantity of material feed.

Keywords

Biomass, Combustion, Gasification, Pyrolysis, Woodchip, Cyclone

Confidentiality

Public

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I will like to say that, it has been quite challenging and brainstorming from the start to the completion of my thesis. All glory, adoration and praises to the Maker of the Universe who saw me through it and gave me ultimate success.

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May you be abundantly bless and favour by Heavenly Father. Amen

DEDICATION

The work is dedicated to the almighty God, the maker of the Universe, the author and finisher of my faith. You shall forever be my God.

TABLE OF CONTENTS

1 INTRODUCTION

The recent climatic change represents the greatest threat facing the world on its, social, environmental and economical factor. Activities carried out by all human on daily basis have seriously contributed to the experienced climate change, such activities includes fossil fuels burning, deforestation and other agricultural events. The above mentioned human daily activities caused emission of carbon dioxide, which is classified as important gas that is responsible for climatic change.

The thesis explains the relevance and importance of biomass as a renewable energy resource whose possibilities is still expected to be fully explored and utilized. Another reason is to enable those that are not familiar with development on modern technology in converting biomass to useful energy have the information at the tip of their fingers as such information are not widely publicized.

By making the information well known, this thesis can help in bringing about a great investment in the use of the newly developed technologies and as well enable developing countries to make use of their biomass resources better and help them to narrow down the difference between the amount of energy required and the amount supplied.

The proper and adequate usage of biomass as alternative to fossil fuel will serve as means of creation for graduates that are seeking employment, for it will aid entrepreneurship, the effect which will be felt on the nation(s) economic. It will raise the economic well being of such countries that encourage the usage of biomass as alternative ways of generating power, fuels, electricity and heat.

1.1 Background of study

Biomass is among the carbon cycle. The atmospheric carbon is converted into biological substance through photosynthesis of plants. When living things such as plant dies and animals breaths combustion the carbon goes back into the atmosphere as carbon dioxide.

Biomass is widened sources; biomass has been providing energy for mankind for time immemorial in view of this it is regarded as main source of energy. Also, recently biomass contribution to the world's energy supply is tremendous.

Energy in biomass is stored in materials such as such as wood, straw, wastes from agricultural sectors and vegetable oils.

Bioenergy is renewable energy obtained from organic material like plants or animals. Biomass is a formidable and promising alternative to petroleum; it is a resource that could be found in any part of the Earth's surface than finite energy sources. It can be explored by using of equipments that does not pose threat or cause any adverse effect to the environment. [1]

Presently, resources from biomass are used to generate power and electricity, as well produce fuels for transportation. Coal and biomass materials have properties that are different from each other.

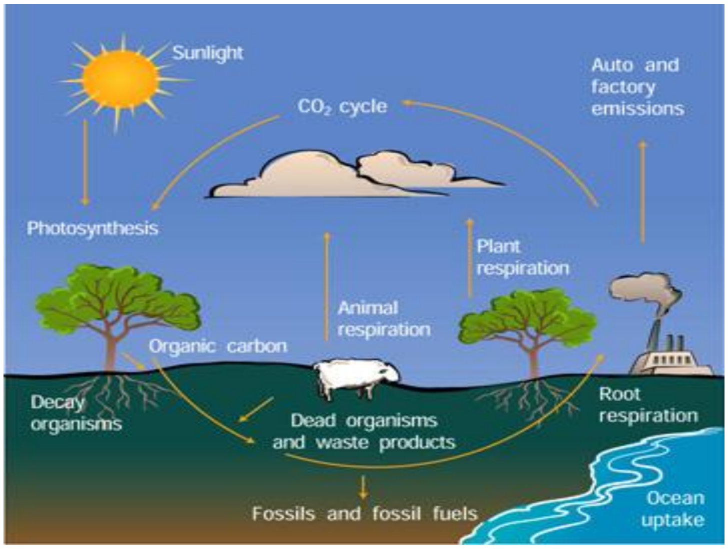

Figure1. Carbon Cycle [4].

Reasons for the usage of biomass as energy source in Europe and other part of the world are enormous. The recent global climate change really plays an important role, together with European and national considerations. Biomass from forest are considered as capable of being a maintained source of energy, because the carbon dioxide released during combustion is taken away from the atmosphere by the vegetation so that new biomass can be produce.

Moreover, emission of carbon dioxide to the atmosphere would alternatively take place as a part of the mineralization. It is also a domestic and distributed fuel, which guarantees improvement in domestic security of energy supplies, increased activity, income and employment in rural areas and possible lowering costs for agricultural excess production in Europe.

The possibility of biomass energy from agricultural waste throughout the world can be valued at about 32 EJ/yr [4]. If biomass will add a significant effect to the supply of energy in world, there is need for energy farming, and cultivation of energy crops.

The use of various forms of biomass and wood for producing heat and electricity has attracted an interest in almost parts of the world. Biomass is locally available, affordable and renewable fuel. The rapid growth in the availability of biomass and the latest development in technologies with efficient and low levels of emission enable biomass to have attractive fuel option advantage. [4]

Fuel from wood is seen to have environmental advantage than fossil fuel. The main economic benefits of energy from wood biomass over fossil fuel is the authenticity that the emission of carbon dioxide released during burning activities is less than 90 percent that what is released when fossil fuel is burned. [3]

Biomass is presently used in some region in Europe and some developing countries around the world but the method adopted are outdated and poorly maintained which results in environmental pollution and waste. If biomass is compared to fossil fuel, biomass has a possibility for making a great favourable impact on environment than fossil fuel. This means that sustainable use of biomass will seriously reduce the release of carbon dioxide.

It can be burned without releasing huge amounts of nitrogen oxides. Furthermore, the sulfur content of biomass is minimal; the sulfur dioxide emission from biomass will be at lower rate compared to the emission from coal fired combustion. Also, using biomass as a fuel will boost the usage of other neglected and abandoned environmental resources. Presently biomass record nearly 7 percents of the European energy utilization and currently the utilization of biomass in countries like Sweden, Finland and Austria is up to 21 percents. [4]

Having realized market limitation, such as high initial costs in establishing biomass power plants and lower fuel quality, researchers are expecting favourable outcome that if production and expenditures are carefully evaluated, as well as suitable standardization and modification methods for upgrading fuel, these obstacle may be overcome by market drives. This will ensure affordable cost, quality and adequate supply of biomass fuel will be critical to the successful implementation of bio- energy projects.

This thesis gives information on the situation of biomass combustion and gasification methods and identifies the merits and demerits of each method. The main purpose is to inspire potential and existing investors, individuals and industries to embrace effective and efficient equipment and good workability system that will enable them to take opportunity of under used biomass.

1.1.1 Biomass energy system

When pondering on the supply of energy from biomass, it is good to realize that there is huge difference, method of conversion, end-use, as well as difference infrastructure and applications involved.

Bioenergy system components:

Components of a bioenergy system: Biomass can be produced by the following methods; razing of committed crops, and gathering forest and other forest waste. The harvested biomass can be packed, conveyed to the store or transferred to processing units.

Biomass conversion process to energy

Process	**Method**	**Output**
Combustion	Thermal conversion	Heat, steam and electricity
Gasification	Thermal conversion	Carbon monoxide and hydrogen
Pyrolysis	Thermal conversion	Liquid, gaseous and solid fraction
Extraction	Mechanical conversion	Heat, electric and fuels
Digestion	Biological conversion	Methane

Table 1. Biomass conversion process to energy.

Technologies such as combustion, gasification and anaerobic digestion have been deployed for energy production from biomass. The production of heat, electricity and transport fuel is possible through most of the technologies.

The new conversions technologies are hydrolysis, gasification and anaerobic digestion. The technology has the potential to help solve the environmental problems. Most of the conversion processes can be described as thermo-chemical and biochemical. A difference can be made between pyrolysis, gasification and combustion if thermo-chemical conversion process is used. [3]

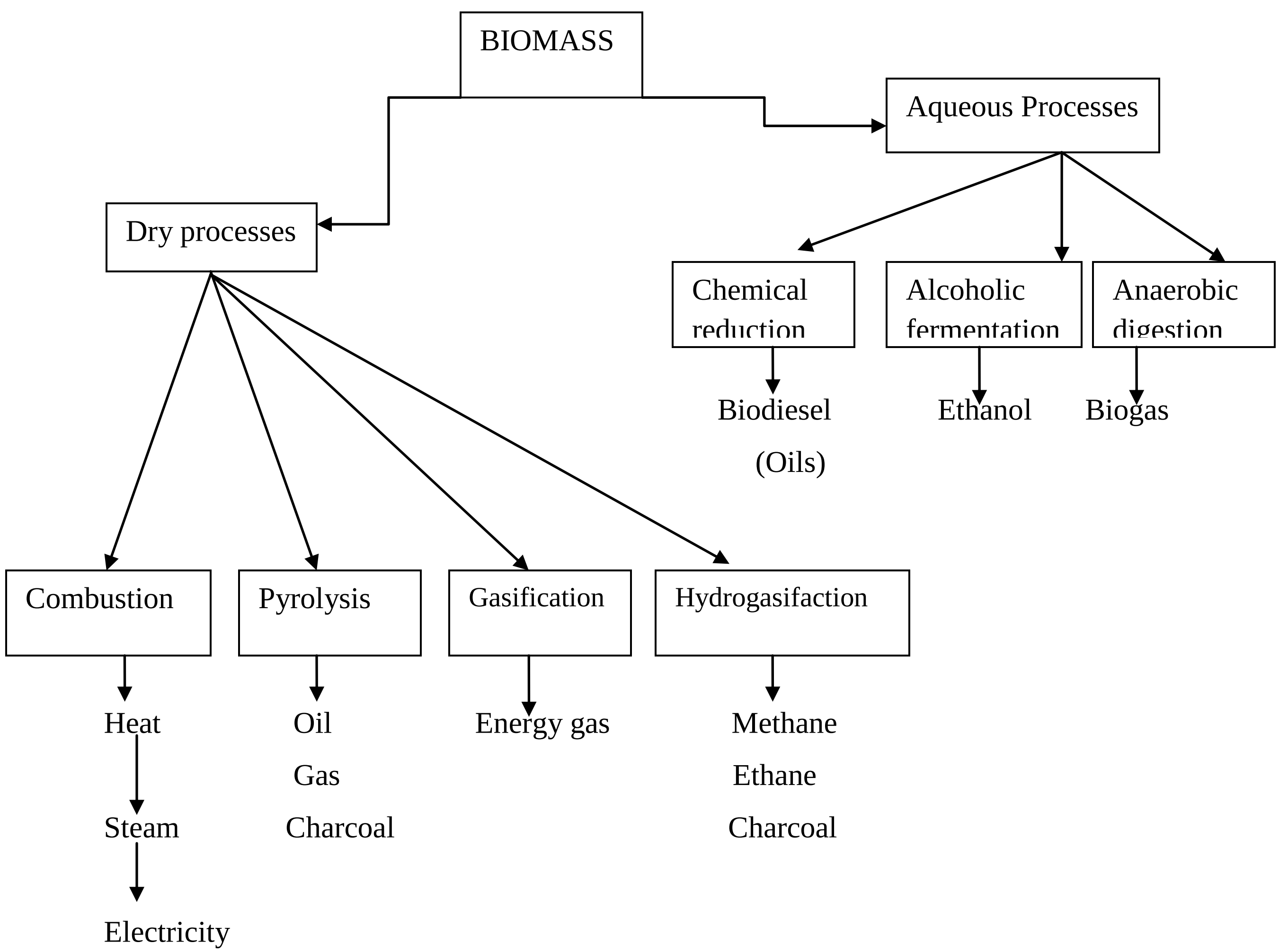

Figure 3. Biomass conversion Methods.

Biochemical conversion options can be divided into digestion and fermentation. Digestion is the production of biogas of mixture which contains mainly methane and carbon dioxide.

Combustion is the process of generating heat and energy by burning fossil fuel. It can be burned with an existing fuel either directly or by co-firing. Combustion process produces electricity, heat and steam (fig. 3). Combustion occurs when there is reaction between hydrocarbon and oxygen in the air to produce heat. When this hydrocarbon burns in the air, the reaction process will produce carbon dioxide and water. The process creates ash, sulphur dioxide, carbon monoxide, nitric oxide and nitrogen oxide. The process must be well controlled to achieve the highest combustion efficiency with the lowest emissions of pollutants. [2]

Combustion is believed to be a well known method of converting biomass to energy. There is no difference between the biomass energy and fossil fuel combustion system in principle. [2]

Before ignition and combustion could take place, three things are required:

- Availability of the fuel to be burn
- Presence of air to supply oxygen
- Availability of heat to start and continue the process. [3]

Gasification is the process of converting materials that contain carbon, such as petroleum, coal, or biomass, into hydrogen and carbon monoxide to react the raw materials with well controlled oxygen at high temperature (fig. 3). The gasification process of biomass is performed in the presence of sizeable air but at temperature and pressure higher than that of pyrolysis. [3]

Synthesis gas can be produced from biomass through gasification which give rooms for the production of hydrogen or methanol, which may have a good prospect as transportation fuels.

The system can be used in some way such as;

- Provision of steam for generating electricity
- Internal combustion as means of transportation
- Water heating in central heating. [3]

Pyrolysis is a process in which an organic substance is heated with limited oxygen to support combustion. Biomass is converted to liquid, gaseous and solid fractions at a temperature around 500 Celsius in the absence of oxygen (fig. 3).

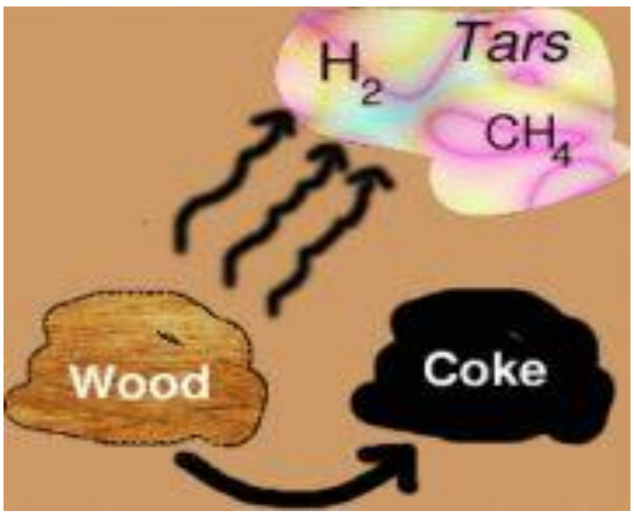

Figure 2. Pyrolysis [16].

In the anaerobic digestion, organic wastes have to be decomposed after which the bacteria will digest the materials in an airtight container to produce biogas through fermentation. The bacteria may be in the original charge material, such as manure from animal, or intentionally introduced to facilitate the process.

Extraction is a mechanical conversion process of generating energy from biomass.

1.1.2 Total bio-energy systems

To assess the execution of a bioenergy system, the whole chain from production to the user should be considered. The main criteria for determining and comparing the total bioenergy system is the net energy produce per hectare. If the net yield is low, the amount of land needed for the net production of a certain amount of energy is high and if the net yield is high, the amount of land needed for the net production of a certain amount of energy is low. Land is termed as limited commodity; high net energy produce per hectare is favoured. The environmental impacts of any specific energy crop used to produce the net energy should be considered as criteria.

Environmental aspects

The crops that live for a longer period of time have lower environmental impact than crops that live for a year in areas of nitrogen leaching, N_2O emissions and higher energy percentage. Crops that live for a long period of time produce the highest energy and lower environmental effect. [5]

Costs of bioenergy

The location where biomass is been produced, used as fuel and used in a form of energy has a great cost implication. Mostly, the cost of the land use and targeted farmers income are cost determining factors.

1.2 Problems

The future of biomass is good and bright but certain factors pose a threat which calls for day to day development of biomass for energy purpose. At the moment there are numerous barriers hindering the implementation. When a large resource base is available, the rate at which biomass can be used to generate energy commercially differs between countries.

1.2.1 Costs

The main problem that may be attributed to full scale utilization of biomass is the fact that in most cases the energy carriers produced are not competitive; the costs are directly related to the performance of both conversion equipment and yield of energy crops.

The cost of bioenergy can be reduced drastically as a result of technology advancement. In a situation where biomass wastes are costless, it can result into fully competitive utilization of the resources. In certain countries where a tax on carbon and energy are introduced, they will witness large scale utilization of expensive wood fuels and straw. Large scale commercialization of energy crops production is not yet in place on a worldwide basis. [5]

1.2.2 Conversion technology

While considering implication of cost on implementation of the project, a critical emphasis should be given to availability of sophisticated conversion equipment that have a greater efficiency rate and minimal investment cost. It will give room for competition with fossil fuels when expensive energy crops are used as energy source. However, rapid development and use of the biomass gasifier have ability to reach higher conversion efficiency at reduce cost. [5]

The most important criteria for the further development on the technology is the availability and costs. This development leads to greater efficiencies, low investment and maintenance costs which will pave way for feasible conversion of biomass fuels.

1.2.3 Fuel supply systems

Increase in productivity and lower cost can be attained by rising pest resistance, inputs reduction, machinery development and good management techniques. Difference in climate and soil will result in varying demands on biomass production system on domestic scale. Further developments have to be made on specific crop production for different domestic conditions.

1.2.4 Biomass characteristics

When comparing biomass to coal, it was observed that biomass has a lower energy density than coal. Transportation was further seen as mitigating factor against biomass, because of the needs to have large land area to generate huge amount of energy. Also, seasonality of the production will also have effect on the logistic and supply of the entire system. Difference in yearly weather condition will also have its effect on production and quality produced. [5]

1.2.5 Socio-economic and organizational barriers

There is a major difference in the production of long live grasses and food crops. Yearly crops give farmer a constant earning per hectare of land used from production of such annual crops.

The ability of the farmers to change from one type of crops to another is not sufficient since the production of limited rotation forestry is more rewarding when it is in operation for along period of time. Moreover, the farmer may face difficulties on pest and water which can be a worrying factor in the wish for continuous fuel supply, though it was not seen as a great disturbing factor because it may be overcome partially by fuel supply diversification.

1.2.6 Public acceptability

Introduction of bioenergy in large scale will influence land-use, landscape and energy systems. It is observed that if biomass is going to contribute significantly to the total energy supply, a substantial land area is needed. Another bottleneck from public is the changes to use of land, landscape and crops. Rapid growth in the domestic transportation of biomass might face challenges. [5]

1.2.7 Ecological aspects

Possible ecological restrains are viewed to be important. Deep understanding of the effect on landscape and amount of animals and plants alive for large scale energy farming is very low. Before it could be fully implemented, public must be educated on the reason why they should accept full scale production and use of energy crops as it has environmental and ecological effect. [5]

1.2.8 Competition for land-use

The acceptability of full scale production will bring about rivalry in the claim for land in many parts of the world. If land is available or not, it will result in a serious problem for the production of energy crops which will strongly lie on developments and rationalization in agriculture throughout the world.

There is diverse opinion regarding the degree of availability of agricultural land for energy crops. It was an accepted principle that production of biomass for energy purposes should not have a conflicting effect with production food. [5]

1.3 Purpose of the study

The objective of the thesis was to ascertain means or method in which Europe can put together energy resources from biomass, the availability of biomass as a source for energy in European countries.

Another aim of this thesis is to inspire and motivate the developed and developing countries to support the use of biomass as substitute to fossil fuel, so as to reduce total dependency on usage of fossil fuels as well bringing the release of carbon dioxide to the environment to a minimal level, to add extra value to public enlightment programs which campaign reduction in the amount of carbon dioxide emitted into the atmosphere and support the use of wood burning for energy.

It is a fact that Europe is willing to reduce its emission of carbon dioxide by 8 percents to 9 percents by 2010 compared to the amount released in 1990. In other words, to determine their seriousness a drastic measure is needed towards the usage of fossil fuel. Therefore, Europe should lay emphasis on how to establish a secure energy supply. More so, priority should be given to biomass so as to reduce the importation of oil with bio-fuel.

The use of cultivated biomass for energy purposes will be examined in the thesis. The overall objective of the thesis can be summarized as follows: to describe the potential for biomass as most fast growing energy carrier with a focus on European energy system.

Furthermore, awareness on latest conversion technologies is not well circulated and disseminated to the public. This thesis will serve as a medium of such dissemination and possibly brings a good investment in the use of latest technology equipment. These will enable developing and developed countries to tap, use the biomass resources and help them in combating the quest for energy and its supply.

In years to come, there might be a need to considering energy farming in the future. However, the use of land for energy crops may have a conflicting interest with its use for agriculture, nature and urban development. The land possibility for production of biomass needs to be examined and evaluated.

Production of energy from biomass is viewed to be more expensive than one produced from fossil fuels. However, many costs and advantages are not expressed in the costs of bioenergy and fossil fuels. Moreover, to have evenly evaluated results on energy produced from bio-energy and biomass, an evaluation on external effects of bioenergy system should be carried out and analyzed.

The following objectives are formulated for this thesis:

1. Analyze the improvement on technology that could aid expansion of biomass energy production.

2. Critical examination on how biomass energy production could be domestically put into use.

1.4 Methods of research

1.4.1 Qualitative Research Definition

Qualitative research is informal accurate and reliable through verification and it developed theories and patterns for more understanding.

In providing overview of qualitative analysis, it desires that there are different approaches to the commencement of this process. When a research work is started from a deductive position, already existing theory is required to shape the approach, which is adopted to the qualitative research process and to aspects of data analysis.

The thesis topic has been chosen on my personal interest on issues that affect environment. After deciding on the topic of the study, many information sources were used to assemble needed facts. Reliability, relevance and validity of information are considered to be important when using different approach to gather information.

The information used is gathered through Internet data, lecture notes, theses and books from library archive. The qualitative analysis was arrived on by interpreting information obtained from these sources. In qualitative research, relevance, reliability, conciseness and validity are important. They all describe the authenticity and trustworthiness of the information gathered.

1.4.2 Information collection

Data collection method is performed by reviewing documentations and other records. The related materials on the thesis topic found in the library, and Internet, helped to smooth the study process. These types of materials are of great importance when literature review is carried out, because availability and accessibility to information needed is easier with less or no cost involved.

2 Characteristics and Availability of Biomass

The development of biomass power system is surrounded by multiple reasons. An alarming growth in demand for electricity within a free government control investment market that encounter environmental problems such as global warming has greatly contributed to development of renewable energy system, like biomass.

2.1 Biomass Characteristics

Biomass fuels are made up of wood, waste, and alcohol fuels. Energy from wood is derived from the following sources: round wood, fuel and wood byproduct and wood waste. Round wood are used in the industrial and electric utility sectors. Wood fuel is mainly put into use by residential and commercial sectors, while industrial sectors embrace the use of wood byproduct and wood residues. [7]

Waste energy is obtained from burning of garbage, methane gas, and anaerobic digestion. Mass burning of garbage is the process of converting garbage to refuse-derived fuel pellets for eventual burning, while methane gas is collected from burning and land fillings or waste digestion by anaerobic digestion. Alcohol is also known as ethanol; it is obtained from corn and mostly used in transportation sector. [7]

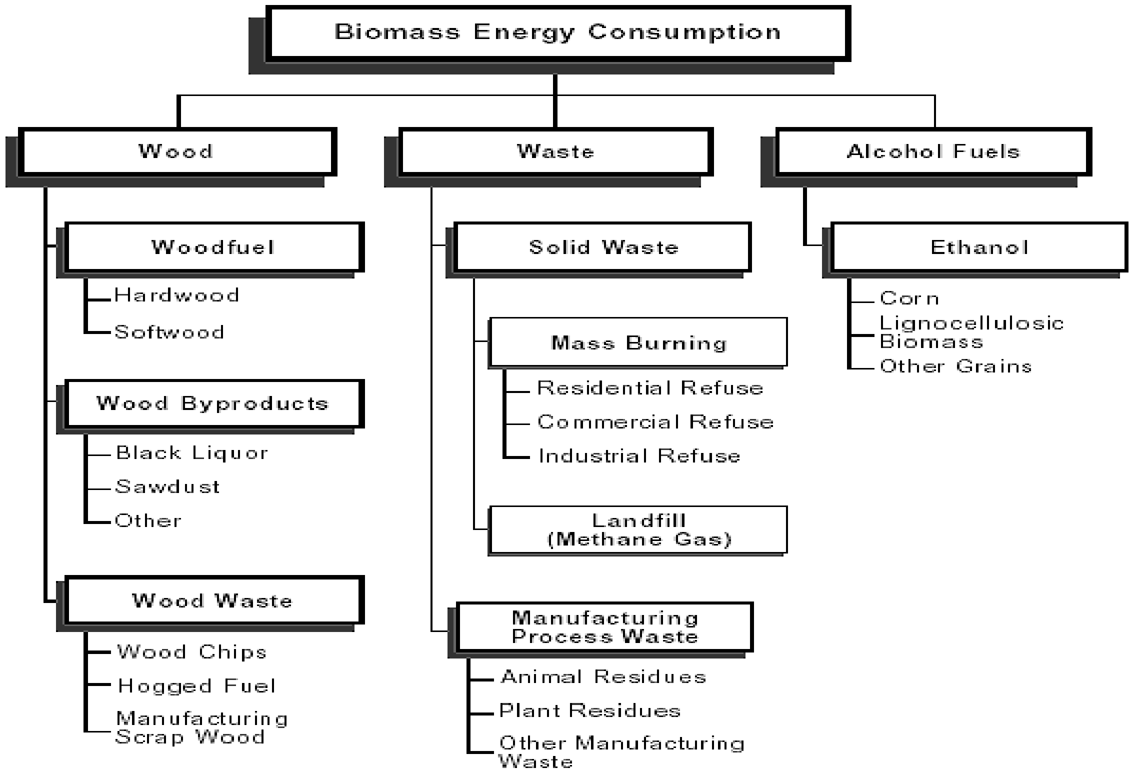

Figure 4. Biomass Resources Hierarchy [7]

2.2 Biomass availability

There is a reasonable difference in the structure of the area dependent sector in Europe and consequently also in the base for biomass production. The northern part of Europe landscape is dominated by managed forestry while other parts are dominated by arable lands. Series of study have been carried out at European and global level in order to determine the possibility of various biomass materials. The individual results give the fullest possibility of values based on the assumption and hypothesis that emphasize them. [5]

Without causing damages and havoc to the environment, what is the amount of bioenergy that can be produced in Europe? The aggregate of bioenergy that can be realized from agriculture wastes are valued to be nearly 302 million tons of energy by 2030. Out of this value, 142 million ton worth of energy will be generated from agriculture only which is realizable from 19 million hectares of agricultural land. This is the same to 12 % of the used agricultural area in 2030. [6]

The following; agricultural waste, forest biomass, energy crops, biomass streams, municipal solid waste, construction wood and food processing waste can be obtained from biomass.

Agricultural waste: Agricultural residue is obtained from field activities after straw, pruning and animal manure as been gathered.

Forest biomass: Forest biomass is a leftover from biomass gathering operation which is left into the forest after the removal of branches, foliage, roots etc from the wood. [6]

Energy crops: Energy crops contain plants cultivated as a low cost and maintenance harvest used to make biofuels, or directly exploited for their energy content. [9]

Biowaste streams: Biowaste stream are categorized into three main categories.

Municipal solid waste: The constituent of municipal solid waste which has biological origin are mainly from kitchen waste, garden waste, paper and cardboard. Municipal solid wastes also have some other waste of certain fractions which have biological sources. According to findings in some European countries, the aggregate of renewal part of the municipal solid waste is estimated to worth 60 percent, which means that nearly 60 percent of biodiesel is renewable. [4]

Construction/Demolition wood: These are woods which are cuts away from building sites during construction and wood recovered during demolition.

Food processing wastes: These are wastes obtained from wine and beer production and dairy and sugar industry.

2.3 Components of biomass energy system

Aside from gas and oil operation, solid fuel systems also need to bring different components together that will make the entire operation more efficient and effective.

These components are

- Storage facility
- Effective driveways for trucks passage
- Boiler or combustion equipment
- Fuel handling equipment
- Chimneys
- Ash disposal
- Control devices
- Machine operators

2.3.1 Storage Systems

Storage system has two known types namely above–ground and below–ground storage. The well known storage type is the rectangular shape, below-ground bin.

The below ground bin is classified as the best because it protects chips from freezing during winter period. In this storage system, self-unloading trucks can use gravity to discharge quickly into the bin without any additional equipment.

Below ground bin is visually less obtrusive than those built above the ground. Sometimes, above ground are used for biomass storage, it can present freezing problem with green fuel in the coldest weather. [4]

2.3.2 Storage sizing system

A sufficient onsite fuel onsite storage facility must be present in every biomass system. For smaller size systems, like those used in schools, the capacity of the storage bins is constructed in respect to the capacity of the delivery truck.

Under a normal condition, effective storage bin should be spacious enough to accommodate at least one and a half capacity of any delivery vehicle.

Most of the fuel suppliers hate supplying in batches due to the cost and other logistics that need to be put in place; therefore a storage facility is required not to be less than delivery truck capacity gives the operator an opportunity to make a requisition before the storage is finally empty. When constructing a storage bin, it is advisable to give room for variance between its gross capacity and its effective capacity. The effective capacity depends on the ratio of the bin that can actually be filled.

2.3.3 Fuel Handling System

Automated machines are used to transport fuel from the storage into the boiler and combustion apparatus. This is performed in stages; fuel is removed from the storage bin. The removal is most commonly done with reciprocating hydraulic scrapers at the base of the bin. The scrapers discharge fuel from the bin and drop it onto a horizontal receiving auger that runs along one of the bin’s sides.

Aside from using an automated machine, there is another system that has proved to be very effective and problem free. This is the utilization of travelling auger at the bottom of the storage for unloading fuel. The auger moves from edge to edge and clears away the flat bottom of the storage, pushing the fuel forward and drops it into the receiving auger.

The circular above-ground silo is used one of the available equipment to remove fuel from storage. The first equipment uses weighted chains fixed at an end of a rotating vertical center-post. When the post and chains rotate, the weights at the end of the chains hit chips into an open space of the slope side bottom of the silo. The other equipment is for unloading a flat-bottomed circular silo. In this type an auger which is center pivoted sweeps the silo base and drop chips into the opening at the center. It works efficiently when the silo is in a heated space to solve chips freezing to the silo walls. [5]

Most systems use screw augers to move fuel to the boiler. The less common method of transporting fuel is belt conveyor and drag chain. Bucket elevators are used in large systems for transporting fuel, but they need more maintenance than inclined augers and are not put into use in smaller systems. Majority of the systems include small metering device between the storage and combustion chamber. It sets aside the increased flow of fuel being taken out of the bin from the cautious controlled feed rate of fuel into the combustion chamber. [5]

The described handling equipment does not need intervention of site personnel. The movement of fuel is performed automatically from storage to combustion. Some facilities demand the usage of tractor in conveyance of fuel to the day bin. The day bin has a capacity to hold enough fuel; therefore the bin needs to be loaded once or twice a day in an assignment that may take the operator half an hour. After that an auger situated at the bottom of the day bin will automatically move the fuel to the combustion chamber. [5]

Although, the operator daily involvement is needed when using tractor–based system, the method proofs to be efficient and successfully used by large industrial plants, greenhouse and agricultural operations. The methods seem good because of their capital cost effective. A tractor-based system is effective when workers are on ground to make it functioning on a daily or regular basis. [5]

2.3.4 The Combustion System

Furnace is a place where burning of the solid fuel really takes place. Fuel is fed into the furnace automatically in combustion system, after which combustion air is added while the fuel burns to produce heat. The hot exhaust gases are moved from the furnace to the heat exchanger. Then heat is then circulated to the surrounding air or water as the case may be. Later, the cooled gases move out through the chimney for emission into the open air.

Combustion efficiency can be achieved by the following:

a. *Parts of the Combustion System*

Majority of the non-industrial systems uses injection auger in feeding fuel to the fire. The fed fuel can enter through an end of the furnace and be pushed up through an opening space in the middle of the grates. Suspension burning method is adopted by some system which make use of large injector fan to pump fuel into furnace because fuel in suspension makes it burn while the weighted pieces fall and get burn in the grates. [5]

b. *Combustion Controls*

The standard for biomass combustion efficiency is determined by restraining the proportion at which fuel and combustion air is fed to the fire. The less task approach has an ‘‘on’’ and ‘‘off’’ fuel feeding system. The system is ‘‘on’’ when the temperature of the boiler or pressure of the steam falls below a set value. When the system is ‘‘on’’ it will supply fuel to the fire until the temperature or pressure is restored back to its initial set value. When it reaches the required set value, the system will shut ‘‘off’’ the fuel feeding operation and combustion air. [5]

c. *Heat Exchange*

Heat is transferred by radiation from the flame to heat transfer medium within the combustion chamber where actual burning occurs. There is transfer of heat by convention from flue gases to heat exchange medium after completion of combustion process.

The main function of the heat exchanger is to convey heat from the flame and fuel gases to the medium. Type of exchanger to be used depends on the medium of heat transfer; boiler and furnace design is determined by the types of the heat exchanger to be used. In designing the heat exchangers that can be used for biomass combustion, its size must be carefully measured and determined so that it can draw out enough energy from the flue gases. If the heat exchanger size falls below the expected size compared to the output of the furnace, the temperature of the stack will be higher and excessive energy will go out of the chimney and it will eventually reduce efficiency of the system. [5]

d. Boiler Room Equipment

The subsidiary equipment in boiler room is the same in size as that of any large established boiler facility. However, distinct consideration is needed for any backup fuel system.

Majority of biomass plants have oil or gas backup capability with separate boilers that burn oil or gas. The backup burner is installed to inject fire into the biomass boiler. In industrial applications, where there are full shift workers, backup feel capability is not required. [5]

e. Emissions Control Systems

Some of the burners typically burn with very low levels of undesirable stack emissions, and meet emissions standards. The air quality regulations are implemented in line to the size of the boiler heat exchanger.

The small sized biomass systems might not require special facility in reducing stack emission and might not need to satisfy emission standard requirement. Most of the manufacturers ensure installation of cyclone in the biomass system so as to remove unwanted materials from the exhaust gases irrespective of the size. The cyclone is mounted between the heat exchanger and chimney. Any biomass system that includes a cyclone must also have an induced draft fan. The induced draft fan will introduce a negative pressure in the combustion and ascertain effective movement of the flue gases up the stack. [5]

f. Ash Removal Systems

Ash is a mineral in the fuel mixed with carbon that cannot be burned. It settles in places and must be regularly removed. At least 25 pounds of ash is produced from each ton of biomass burnt. Majority of the ash leave their place and settle in the combustion chamber. If the system is designed with a slope or moving grates, the ash will be transported to the grates bottom. It is very important that ash is removed on a frequent or daily basis. Ash can automatically be removed by using aching auger. These collect ash at low points and transport it outside the combustion chamber, and it is preferred because the maintenance period is reduced. [5]

g. Manual ashing

Ash can be removed from combustion chamber manually; this can be performed by raking and shoveling ash out of the system by hand. It can be carried out between 25-30 minutes. This can be done with ease without switching off the boiler. The exercise is more complex in automatic ashing and requires cooling the boiler. [5]

h. Safety Devices

Biomass can be safely burned and if necessary, safety features are included in the system. It mandatory to have a safety equipment and code, as well as control associated with any biomass heating system. [5]

Combustion system must be protected against possible backward of burning of fire from combustion area along the incoming fuel stream. Automatic water quenching system must be installed in the burning system at the incoming fuel feed. [5]

The safety equipment that prevents the injection of fuel to the furnace when there is accidental fire failure should be installed. Failure of the fire is sensed by a stack temperature probe connected to a fuel cutoff switch. Also alarm equipment which will alert in case of any unexpected malfunction should also be installed at the boiler room.

i. Chimney

Chimney is the last components of any combustion system. Its principal function is to remove product of combustion from the system and the building, as well as release the flue gases to the atmosphere. The connection of the chimney must be well and properly carried out and fit in with connected appliances. [5]

2.4 Efficiency of Biomass combustion system

The primary goal of biomass-fired heating system installer is to save money. This can be achieved when operating costs are reduced. The cost of the fuel must be lower because biomass systems have a significantly higher capital costs than usual fuel systems. Reduction in operating costs can be achieved by guaranteeing optimal efficiency, meaningful installation costs, and low maintenance requirements.

For optimal efficiency and minimal emission to be reached, it is good to understand basic of combustion and factors that determine efficiency of the system. This will afford the interested buyer to know the needed information, especially those provided by the manufacturer.

The basics of biomass combustion

The reactions that produce heat energy are the same for all fuels. To ascertain the system efficiency, fuel characteristics must be well understood. They are:

- The amount of carbon, hydrogen, ash.
- Available chemical elements present in the fuel.
- Worth of energy that can be released from the fuel when it is burned and its moisture content.

Seasonal Efficiency

The system can be regarded as efficient if it operates steadily under normal conditions. But while in use during heating season, there are various possibility areas of losing heat which can result in less efficient system.

Seasonal efficiency serves as a medium of stating the performance of a heating system throughout the entire heating system. This long term consideration at efficiency includes the time when the system is running optimally, low loading capacity and idling combustion at low efficiency. Seasonal efficiency will always be lower than steady state efficiency. [5]

Five areas of energy loss can reduce seasonal efficiency. They are:

1. **Cycling Losses**: Seasonal efficiency is brought down when the system operation is performed by using mode, cycling to and from between full fire and the idle mode, compared to a system that automatically modulates the fire. Inefficient combustion occurs with the use of modulating fuel system when the load in the boiler falls below the minimum turn-down load.
2. **Jacket Losses**: If the system is not properly and well insulated and located where heat is not required, the seasonal efficiency will surely be reduced by the heat loss from the boiler surface.
3. **Distribution Losses**: The heat generated by the combustion system is moved through pipes from the boiler room to the area where it is needed. Any loss of heat during piping process will reduce overall efficiency, as it does with all combustion systems irrespective of fuel type.
4. **Standby Losses**: If more amount of fuel is burnt than necessary in the system during a warm weather, the fuel is wasted. It will be a great problem for over-sized systems and any system during warm weather when less heat is required.

5. **Overheating Losses**: If the system is not well controlled, to the extent that it gives out more heat than needed and overheats a space, the excess energy output is wasted.

Considerations in System Selection

When the possibility of equipment to be used is carefully selected, attention must be given to efficiency factors during installation in order to achieve maximum fuel efficiency, lower energy bills and sound operation.

Points to consider:

- Size of the system
- Instrumentation
- Combustion control
- Fuel moisture
- Multiple wood boilers
- Boiler and pipe insulation

2.5 Types of biomass combustion system

Combustion system design and selection are majorly determined by certain features ranging from the fuel to be used, the environmental laws, the cost, the functionality of the available equipment and the required energy and capacity.

There is no much difference between large scale biomass combustion and waste combustion system, but when clean biomass fuel are used, the flue gas cleaning technologies are less complex and cheaper. Improvements are made in fuel preparation, combustion and flue gas cleaning technologies on daily basis. This leads to a great advancement in efficient, emissions and costs reduction improved fuel flexibility, plant availability, and new opportunities for biomass combustion equipment under a situation that were too expensive or insufficient before.

Emission reduction and efficiency advancement is considered to be major combustion application goals.

Biomass can be converted into heat or electricity or energy conveyor such as charcoal, oil, or gas using thermo and biochemical conversion methods. Combustion is the more useful and often practiced process used because of its low costs and high reliability. However, the system developer needs to give unrelenting attention to the technologies so as to make it more competitive than other conversion technique.

All combustion systems have similar operational and design attributes with each other. They all inject fuel into the hot environment of the combustion chamber when air is available. Moisture and easily evaporated content in the wood fuel are driven off by the process called pyrolysis.

As the gases from wood are mixed with excess fire and under-fire air, they burn to release heat. The temperature of the combustion chamber is maintained by the heat by reflecting off the refractory, and increase the temperature of the combustion fuel. The hot exhaust gases give up their energy to the boiler water when passing through the heat exchanger, changing the energy into useful heat.

In view of achieving greater efficiency, clean-burning, various combustion manufacturers build and design their combustion systems in unique ways. The two main combustion apparatus design are discussed below with their variations. [4]

Direct-burn and two-chamber systems are made and installed by some manufacturer, their selection on the type of fuel to build and install depends on the type of fuel that will be burnt in that particular facility.

Irrespective of system used either direct burn or two chambers, certain important features must be considered.

- High appliance efficiency is achieved in the system

- Less operator attention is required during operation
- Operation reliability and minimal repairs record of the equipment is guaranteed. [4]

2.5.1 Direct-Burn Furnace

In direct-burn method the furnace (Fig. 5) is a single combustion chamber which is situated directly below the boiler, in a distinct built base on which the boiler sits. The grates and fuel feed system are situated in the refractory-lined setting, and the combustion air is fed into both below and above the grates. [5]

In former designs, the furnace capacity of the setting is made open to the boiler combustion chamber which is placed above it. The hot gases pass through the grate into the boiler combustion chamber an area where combustion of the hot gases and solid combustible particles is finishes. After that, the hot exhaust gases move into the heat exchanger. [5]

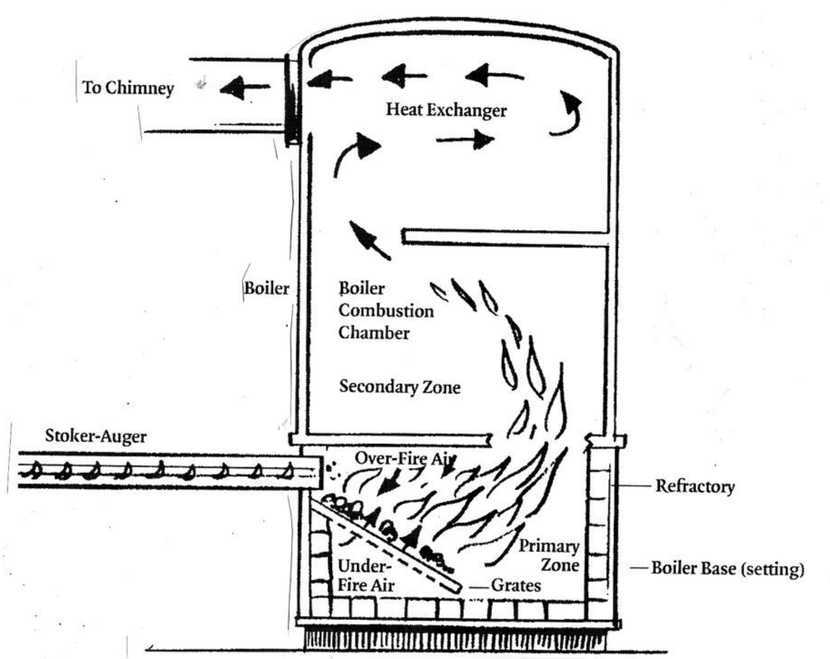

Figure 5. Direct – Burn Furnace [5]

The latest design of refractory baffle is introduced to separates the primary and secondary combustion area from each other. The primary combustion area is located above the grates through the refractory, thus raising temperature in the primary combustion area and making the flame route to give more time for the carbon in the hot gases to oxidize completely. The system produces better burning in low- load conditions. [5]

2.5.2 Two-Chamber Furnaces

A separate refractory pipe or combustor is situated next to the boiler in the two chamber method (Fig. 6) which is joined by a short horizontal movement point that is also refractory-lined. This movement point can be a round blast tube that will function as connector between the combustor and boiler.

From the combustor, hot gases moves to the combustion chamber of the boiler through the connector. With this, boiler's combustion chamber becomes the secondary chamber of the combustion system. [5]

High and low moisture biomass fuels can be burnt in double chamber system and are often used specifically for high-moisture fuels. Because the furnace capacity of the combustor is not absolutely small and the chamber is situated on top with refractory when the fuel is more than half of the water in the primary combustion area, it is easier to maintain and achieve higher temperature. [5]

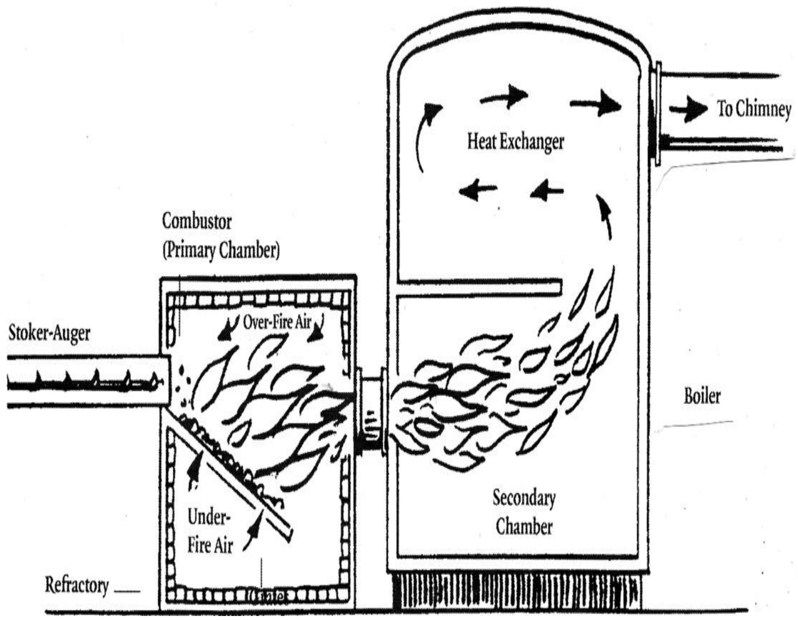

Figure 6. Two Chamber Furnace [5]

Two-chamber system is built so that it is impermeable to air, to ensure that the aggregate available oxygen for combustion is limited. The result is that excessive air will cool the fire and reduce its efficiency. Double chamber is mainly designed to prevent unintentional air from passing through the combustor with the incoming fuel.

3 Conversion process

When considering methods of converting biomass to a more useful energy, combustion method was finally seen as the best method. Combustion was viewed as the well known system both technically and commercially while gasification is of recent and not well known. Combustion process converts solid fuels to combustion gaseous product by oxidation through greater temperature.

Combustion has the production similarity with fossil fuel power plants. Converting biomass to gas under combustion system does not require ranges of energy devices which might be needed under gasification. In gasification there is a need for biomass heating in an environment where the solid biomass is processed to produce a flamable gas.

Wood chip is domestically available resource, which is often dumped to rot away. Inspite of its low energy density, it can still give heat and power free of pollution, as well as considerable economic savings.

Next, the components found in conversion process will be introduced. They are:

- Hopper
- Auger
- Cyclone
- Fluidized bed gasifier
- Wood chips
- Steam turbine
- Combustion apparatus
- Boiler
- Gas burner
- Feeding apparatus
- Air lock

Hopper

Figure 7 Hopper includes an agitator which protects the feed from bridging in the hopper. [11]

Auger

Figure 8 Auger is used to transport materials in different forms by means of rotating. The material is moved along the axis of rotation. [12]

Cyclone

Figure 9 Cyclone is a popular, economical, and effective means of controlling particules. Cyclone can not control alone the stringent air pollution, but functions as precleaners for control devices. [13]

Fluidized bed gasifier

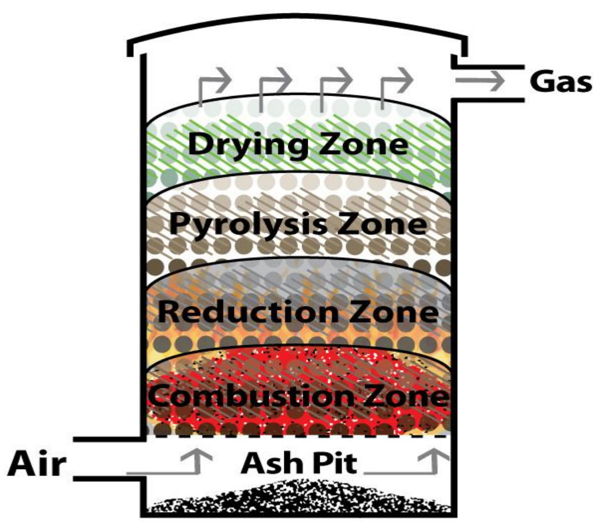

Figure 10 Gasifier receives an air stream in association to the biomass fed in from the auger through hopper. [14]

Wood chips

Figure 11 Wood chips are a solid fuel made from woody biomass. [13]

Steam turbine

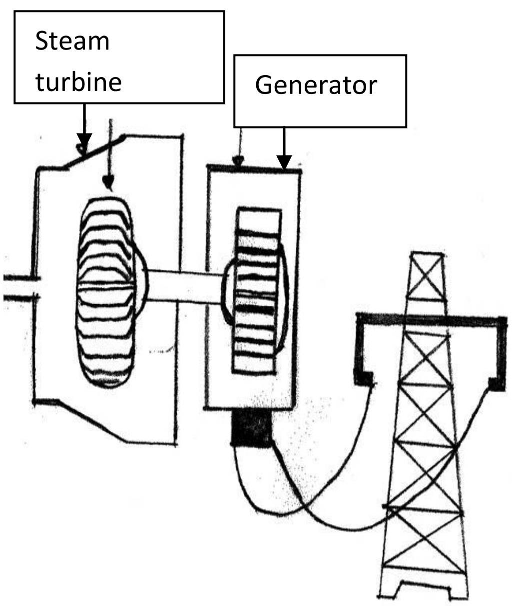

Figure 12 A steam turbine is a mechanic device that extracts heat energy from pressurized steam, and change it into rotary motion so as to generate electricity.

Combustion apparatus

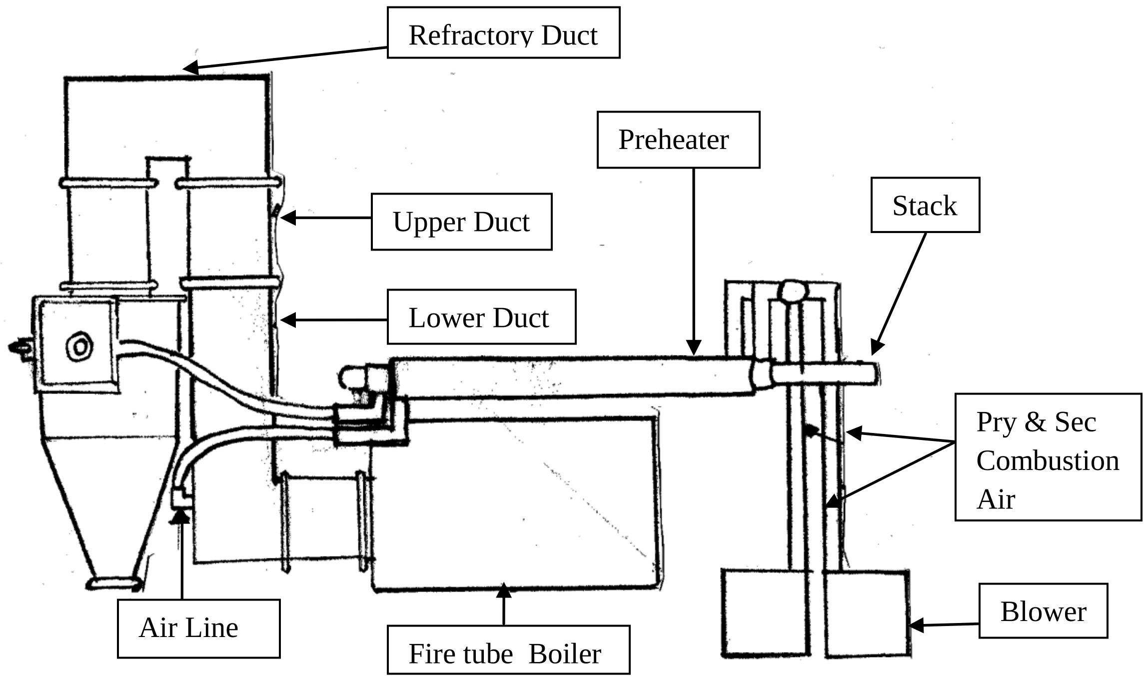

Figure 13 Combustion apparatus is an equipment in which all combustion processes are carried out. [10]

Blower: Is used to feed air into the gasifier.

Gas Burner: Is used to preheat the fluidized bed materials to the desired temperatures

Feeding apparatus: Feeds the chips into the hopper at a exact rate despite the wide variance in size and shapes.

Air lock: An air lock is used to prevent gas generated from gasifier from flowing back into the hopper.

3.1 Process

The wood chip is fed into the hopper (Fig. 7) through the feeding apparatus at a exact rate without any existing conditioning, despite the variance in sizes and shapes of the feed material.

An agitator in the hopper prevents the wood chip (Fig. 11) from bridging the hoppers, since a small thin branches of tree may give rise to bridging of the hopper.

A feed metering auger (Fig. 8) and fuel injection auger carry the feed material from the hopper to gasifier. The air lock in the system prevents gas produced in the fluidized bed gasifier (Fig. 10) from flowing back to the hopper through auger. If the gas escaped through the auger back to the hopper, it could lead to explosion. [10]

The material in the gasifier are contnued in a fluidized state by the flow air which pass through the plenum. A turbulent fluidized state of inert particles in the gasifier bed creates a nearly isothermal zone having high thermal inertia and ensures accurate control of reaction temperature. [10]

The energy produced by heat in the bed particles of the gasifier is quickly transferred to the solid biomass fuels. The gasification reaction carried out with less than proportional oxygen present produces a combustible gas and particles char. [10]

The combustible gas and suspended particles pass through the free board of the gasifier and are piped to a cyclone. The cyclones (Fig. 9) are arranged in phases, the output of the gasifier function as the cyclone input. Most of the particles separated from combustion gas are pass out through the open place in the bottom of the cyclone. Since all the suspended particles cannot be fully separated from the combustible gas at once, the combustible gas with the remaining particles enter the second cyclone which also removes particles from the combustion gas and the particles trapped are passed out through the opening bottom of the cyclone.

The combustible gas stream is free of particles with less than 0.2 g/m3. The combustible gas and air from primary combustion are combined at the initial stage of combustion equipment. Another cyclone is attached to the initial stage of the combustion chamber. [10]

At the entrance where air stream and combustible gas enter the combustible apparatus the cyclone is a natural gas pilot. The natural gas pilot preheats the refractory in the primary combustor to a temperature in excess of the ignition temperature of the lower calorific value gases entering the first stage cyclonic combustion.

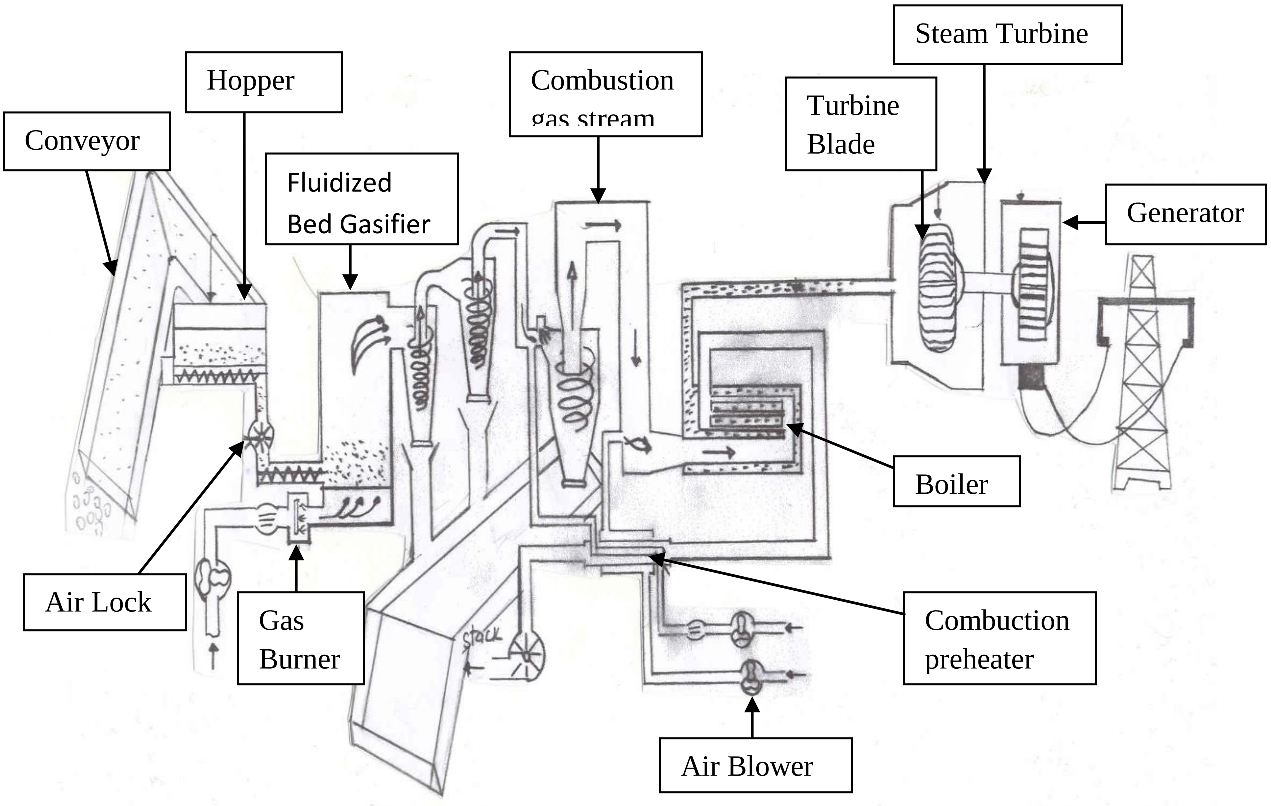

Figure 14. Conversion process.

This gas referred to as inter-stage gas leaves the cyclone and enters a refractory duct which has a quarl, a meter box, a upper duct , a lower duct and a boiler transition as its component. A secondary air pipe will transport the secondary combustion air to the lower duct. The combustion gases move from the boiler into the fire tube boiler. The output gas from the boiler move through a pipe to the combustion air preheater. [10]

The primary and secondary combustion air supplied by the blower are received by the preheater. The flue gas moves from the preheater to a stack. The hot combustion gas in the boiler makes water to boil and thereby produces steam.
When the steam is produced, it needs to be further processed and converted to usable electricity. The steam produce is transferred to a steam turbine (Fig. 12) where steam pressure is reduced over the turbine blades by expansion.

When the steam goes through the turbine it increases in size and forces against the turbine blade to turn the shaft of the generator to produce electric current. The increased steam turns the blades and the rotor, the motion of the rotor is directly transferred to running a generator which will finally create elecricity. The design of steam turbine is done based on the uses, so as to maximise the production of power by steam turbine. There is A need for the steam to be cool by condesing turbine. This is the process on how the heat energy of steam is turned to mechanical energy and finally electricity is produced.

4 Results

Converting biomass to usable energy a series of stages needed before the desire result can finally be achieved. The process used can change unconditioned biomass into usable energy in form of steam. Char is expected to be produced from gasification but surprisingly activated carbon is produced.

The energy production and activated carbon process begins from the feeding of un-preconditioned biomass to a fluidized bed gasifier; the gasifier is fed with fluidized air with mass flow rate of ratio of biomass to air controlled to obtain a proportional ratio. The entire process collects all that is referred to as waste materials, process it and generate useful energy.

Conversion methods need to be compared so that its merits and demerits can be made known.

Methods	**Merits**	**Demerits**
Combustion	It is basically developed to generate high volume of steam use to provide power, heat and electricity.	It causes higher emission of Carbon dioxide particle.
	It ensures absolute combustion and reduction in the emission of SO_2.	Moderate efficiency due to subset of multistage process.
	It is quite simple, thereby reduce cost of technology	
	It enhances fuel usage at moisture condition and size level.	

Gasification	The use of fluidized bed gasifier enhances efficiency performance.	Not yet fully developed.
	It is in multistage, so it generates high level of conversion efficiency.	Low moisture content, so it requires uniform size of fuel.

Table 2. Comparisons of combustion and gasification method.[17]

The functional efficiency of biomass is conditional by biomass moisture content, climate and scale. Thus, the combination of the electric and thermal efficiency makes up the total efficiency. The electric efficiency is therefore calculated by dividing electric output by energy input. Similarly, thermal efficiency is determined by dividing available heat with energy input (Table 3).

	Scale	Power range	Thermal efficiency	Electric efficiency
Heating (Boiler)	Small	25 – 100kw	80 – 85%	-
	Large	500 – 5000kw	87 – 93%	-
Combustion heat and power (Boiler + steam turbine)	Small	1 - 10Mw	63 – 70%	13 – 21%
	Large	25 – 50Mw	52 – 59%	26 – 35%

Table 3. Functional efficiency of Biomass. [18]

The process is said to be success because it converts different biomass because of the following characteristics:

- Gasification takes place in high heat inertia, in controlled and relatively low temperature.
- Before combustion takes effect, char is removed.
- The process converts large portion of biomass energy into gas, in other words, it enables purification of the gas while lowering heat loss.
- Mixture of various nitrogen oxides emission can be reduced to a more environmentally acceptable standard.
- First phase of the combustion makes a continuous ignition while burning low calorific value gas.

In another view, combustion changes all energy to a reasonable heat and disallows clean up before introducing hot gas to the boiler. Combustion method discourages the usage of phase in reducing mixture of different nitrogen oxides as emitted by the method and reduces particulate emissions of the flue gases to less than 0.1 g/m^3.

The treatment of flue, considered to be expensive, is not needed. Wood chip utilization can be favoured to be cost effective when the prices of oil and heating electricity is higher, also when electricity is the major competitor rather than oil or gas.
There are lots of reasons for installation of biomass system. They are:

- Reduction in fuel cost
- The flexibility of boiler design
- The environmental benefits
- The societal and economic benefit

The successful prospect of the system depends on the impressions and how comfortable the owner or the users feel when operating it.

Since the interest for biomass usage has increase within all sectors, the availability of biomass energy system capacity from 3kw for home and 5Mw for big sawmill will grow well.

The cost and efficiency analysis for different application will help in ascertaining the potential of installing a wood energy system (table 4).

	Size (Mw)	Fuel use (Ton/Year) 000	Capital cost (Million €)	Operation and maintenance (Million €)	Efficiency %
Electrical					
Utility plant	10 – 75	100 – 800	14 – 105	1.4 – 10.5	18 – 24
Industrial plant	2 – 25	10 – 150	2.8 - 35	0.4 – 3.5	20 – 25
Thermal					
Utility plant	15 – 30	20 – 40	7 - 14	1.4 – 2.8	50 – 70
Industrial plant	2 – 22	5 – 60	1.4 - 7	0.7 – 2.1	50 – 70
Combined Heat and Power					
Utility plant	25	-	35	3.5 – 7	60 – 80
Industrial plant	1 – 7	-	3.5 – 17.5	0.4 – 2.1	60 - 80

Table 4. Comparisons of electric, thermal and combined heat power. [17]

5 Conclusions

The climate change currently witnessed represents one of the greatest environmental threats faced by the planet. Human activities such as fossil fuels burning; change in use of land like deforestation has really caused and contribute to changes in climate.

These human activities cause emission of carbon dioxide which is the principal gas responsible for climate change.

Climate change can be prevented by encouraging the use of renewable energy sources and energy efficiency. As European Union called for the agreement on reduction of greenhouse gas emissions by 30% by 2020, one of the best ways to achieve these is the utilization of energy from biomass.

Biomass energy has an important role to play in preventing global warming and improving the security of European energy supply. Property of biomass is different from other conventional solid fuels such as coal.

We hope to see a strong and viral competition about the use of biomass and the land to grow such biomass.

The future utilization of biomass for heat energy will depend on how available biomass is for distribution among uses for heating, electricity and other necessary applications.

Lots of developments are made towards combustion technology in making wood burning more feasible than before. Such developments are channeled towards improved combustion efficiency, cleaner air emission, and sound operating characteristics of burner.

Biomass gasification promise to pave way for more effective and efficient use of wood chips, gasifier is expected to take up the responsibility of increasing the efficiency of burning wood to produce electricity.

A method of producing electricity from solid biomass fuel is the wood fuel burning. It produces steam for a steam turbine to power a generator and electricity at good efficiency, with lower emissions and operating costs.

The future energy process is to provide sufficient primary and secondary energy forms to fulfill modern day needs. It involves installation of established technologies and research and development to create new energy related technology.

Moreover, in the future, technology like micro-turbines and fuel cells will make use of gas provided by gasifier. The technology will further increase efficiency and reduce emission which may be released while generating power and heat from biomass.

The need to embrace the use of renewable energy is clear. Renewable energy is economically viable and competitive. Its role in carbon dioxide emission reduction can not be measured.

The establishment of renewable energy especially energy from biomass, is the main aim of the European commission on energy policy.

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