ENERGY, ENVIRONMENT AND SOCIETY

Chapter - 12

Biomass and Bioenergy

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LEARNING OBJECTIVES OF THE LECTURE

- Types of biomass conversion processes
- Biofuels and its types
- Biogas and its working basics

BIOMASS CONVERSION

- The biomass can be utilized in form of energy source by their conversion into more usable efficient form (biofuels) by either of the following processes.

- Physical Conversion Process
- Chemical Conversion Process
- Bio-chemical Conversion Process
- Thermochemical Conversion Process

BIOMASS CONVERSION

Physical Conversion Process

Physical conversion techniques are aimed at physically altering the form of biomass. For example, the form of biomass or wood can be changed by size reduction techniques such as

- chipping or pulverizing
- drying to reduce water
- screening
- densification or briquetting

The main purpose of this process is to prepare biomass suitable for combustion

BIOMASS CONVERSION

Biomass Briquetting

- Bulk of the energy in rural areas for cooking and heating purposes is derived from firewood, agro and forest residues and to some extent from cow dung.
- Use of firewood leads to deforestation and inefficient combustion cow dung, agro and forest residues leads to pollution problems.
- In addition, materials like pine needles are a major cause of forest fire.

BIOMASS CONVERSION

Biomass Briquetting

- To solve these problems and to save wood, the agro and forest residues can be upgraded to convenient and smokeless briquetted fuels.
- These materials can be converted into small sized briquettes with holes (bee-hive briquettes through partial pyrolysis process.
- These briquettes can burn with smokeless and clean flame, ideal for domestic and small scale heating process.
- These briquettes are suitable for large scale and industrial applications.
- The agro and forest residues in briquetted fuel form as added advantage of easy transportation to the place of work.

BIOMASS CONVERSION

The basic principle of briquetting is densification. Densification is the process of compressing raw materials to a certain shape and form by applying pressure.

- **Beehive Briquettes**
- The process involves preparation of char from biomass materials in batch pyrolysis/drum charring unit. The char is then mixed with binder like clay with little water and kept overnight. The char-clay mix is then compacted into briquetting mould to give beehive shaped briquettes.

- **Screw press**
- In screw press technology the biomass is extruded continuously by a screw through a tapered die

- **Piston ram press technology**
- In the piston press technology biomass is punched into a die by a reciprocating ram

BIOMASS CONVERSION

- Basically in all techniques pressure is applied to the char to form briquette.
- In beehive technique, it is done manually by hand, so the pressure required to bind is not enough so binding material is used in form of clay.
- However in case of screw press and piston ram technique, it is done by the temperature of biomass and lignin present in the biomass liquifies and acts as a binder.

BIOMASS CONVERSION

The advantages of briquetting are:

- Greater combustion efficiency
- Waste utilization
- Easy handling
- Minimize waste
- Easy storage

The uses are: space heating, open fire space, cooking

BIOMASS CONVERSION

Chemical conversion processes

Chemical conversion techniques are aimed at altering the molecular structure of biomass.

Examples include the fragmentation of cellulose molecules in an aqueous slurry through the action of mineral acids.

Acid hydrolysis methods are commercially employed for conversion of wood wastes to glucose followed by fermentation and distillation.

BIOMASS CONVERSION

Bio-chemical conversion processes

Bio-chemical conversion process includes

- Anaerobic digestion to methane
- Ethanol fermentation

Bio-chemical treatment incorporates the action of micro-organisms on the biomass for the production of bio-gas. Examples include anaerobic digestion, landfilling, composting, vermicomposting etc.

BIOMASS CONVERSION

- **Biogas**

- Biogas is extensively used in Nepal. It is basically the conversion of human/animal manure into methane by anaerobic (without oxygen) digestion. The conversion is done by methanogenic bacteria which gradually decomposes the complex organic compound of the manure and water into methane.

- The biogas is used for mostly cooking purpose and also for lighting purpose. The biogas digester (the structure where biogas digestion is allowed) is an air tight structure formed to support anaerobic digestion. However, the major challenge in biogas is its reduced methane generating potential in low temperature which renders it ineffective for cold climate region or winter.

BIOMASS CONVERSION

Thermochemical Conversion Process

Thermochemical conversion process includes

- Combustion
- Pyrolysis
- Gasification
- Liquefaction

BIOMASS CONVERSION

Thermochemical Conversion Process

- These process generally require:
- Low residence time
- Low moisture content

BIOMASS CONVERSION

Thermochemical Conversion Process

- In thermochemical conversion process a nearly total conversion of biomass is possible and renders the use of biomass efficiently and economically.
- Thermochemical conversion processes employ high temperatures to convert biomass materials into energy.
- Examples are combustion to produce heat, steam, electricity, direct mechanical power; gasification to obtain producer gas; direct liquefaction to produce heavy oils or distillates; pyrolysis to produce a mixture of oils, fuel gases and char.

BIOMASS CONVERSION

Combustion

Combustion may be defined as chemical reaction of the fuel with the environment including heat and mass transfer.

It involves series of free radical reactions where by carbon and hydrogen in the fuel react with oxygen to form carbon dioxide and water vapor respectively while liberating useful heat.

Almost all of the biomass used for energy today is being used for electricity generation, process heat raising and co-generation.

BIOMASS CONVERSION

Pyrolysis

Pyrolysis refers to the thermal decomposition of organic matter in an inert atmosphere.

In this process a mixture of gaseous products, tars, water soluble oils, and aqueous solution of acetic acid, methanol and other organic compounds are evolved and a solid residue, char is produced.

The amount of various products generated are dependent on the rate of heating and the final temperature to which the biomass is subjected. In general, the higher the heating rate and the higher the final temperature, the greater fraction of the initial biomass that is converted into gaseous and liquid products.

BIOMASS CONVERSION

Pyrolysis

Pyrolysis is the physical and chemical decomposition of organic matter brought about by heating in the absence of air.

The products of pyrolysis are char, liquid distillates containing hydrogen, carbon monoxide, carbon dioxide, methane and other hydrocarbons and nitrogen.

The yields and composition of these products can be varied depending upon the operating parameters.

BIOMASS CONVERSION

Pyrolysis

The pyrolysis rate depends on several factors like the composition, shape and size of biomass particles, heating rate, residence time, temperature level and pressure.

The nature of the products varies according to the above conditions. High temperature and/or fast pyrolysis favors oil and gas formation, primarily those of the olefins type (ethylene and acetylene).

Slow pyrolysis favors charcoal or char and pyrolytic oil (C_6H_8O) formation but come gaseous products such as CO, CH_4, and CO_2 are also formed.

BIOMASS CONVERSION

Gasification

Gasification of biomass is one of the important thermochemical process, which has immense potentials in harnessing biomass energy.

Biomass gasification is basically conversion of solid biomass (i.e. wood/wood wastes, agro-residues and organic industrial wastes) into a combustible gas mixture.

Gasification is defined as the conversion of biomass into gaseous energy carrier by means of partial oxidation at elevated temperatures.

BIOMASS CONVERSION

Gasification

It is carried out in an enclosed reactor operating at about 900 ºC where in a part of the biomass is combusted by air to provide the heat.

The resulting gas known as producer gas contains CO (15-29%), CO_2 (5-15%), H_2 (5-12%), N_2 (50-65%) and small amounts of hydrocarbon gases.

The calorific value of the gas ranges from 1200 -1500 kcal/m^3. Gasification has certain advantages over direct combustion.

By gasification, even small-scale generation of electricity can be done without the necessity of steam cycle (as steam cycle is necessary to produce electricity from direct combustion and it is not suitable for small scale).

BIOMASS CONVERSION

Gasification

The electricity is generated from the gasification by combustion of producer gas in a reciprocating engine which in turn operates generator. Burning producer gas in existing boilers, or furnaces can also be done.

Moreover, producer gas can be cleaned in relatively compact units prior to combustion.

The disadvantages are that the gasification system has to be designed specifically to suit for particular biomass and that is complex than direct combustion

BIOMASS CONVERSION

Gasification

- The gases produced are applied mainly as a fuel gas for direct heating or for the operation of gas turbines or IC engines for generating power.
- All types of gasifiers produce gas mixed with different quantities of vaporized tars depending upon the type and physical characteristics of biomass, its ash properties, reactor type and operating conditions. For example, updraft gasifiers shall give more proportion of tar compared to down draft gasifiers.
- One important advantage of gasification technology is the complete elimination of pollution associated with combustion of biomass with progressive use of agro-residues like rice-husk, ground nut, shell, coffee husk, bagasse etc.

BIOMASS CONVERSION

Liquefaction

Direct liquefaction is defined in the broadest sense as any thermochemical conversion process, which produces liquid products from biomass, feed stock without going through a separate intermediate gas phase.

In direct liquefaction, biomass slurries are heated to moderate temperatures at high pressures with a catalyst in a reducing atmosphere of carbon monoxide and hydrogen.

The objective of the direct liquefaction is to produce liquid products which could be used as a substitute for fuel oils and distillate fractions which could potentially be used as diesel fuels, octane enhancers and for other related uses.

The liquefaction products have greater energy densities than original biomass feed stock and can be readily transported. The potential use of such liquid products after some upgrading as fuel extenders or substitutes also provides a possible source of transportation fuels.

BIOFUELS

Some of the common biofuels produced from above mentioned conversion techniques are:

First generation biofuels

- Biogas
- Briquettes
- Bio alcohols
- Bio-diesel
- Green diesel
- Syngas
- Solid biofuels

Second generation biofuels (advanced biofuels)

BIOFUELS

- **Bio-diesel**

- Biodiesel is basically the vegetable oil or animal fat based diesel fuel. It is produced by chemical reaction of vegetable (raeseed, jatropha, mahua, mustard etc.) oils, soyabean oil, animal fat with an alcohol. Biodiesel is meant to be used in standard diesel engines.

- Biodiesel can be used alone in modified engine or mixed with diesel to operate in any diesel engine.

- Nowadays biodiesel is widely used in Europe and other countries for running vehicles. Biodiesel has reduced amount of emission when compared to diesel.

BIOFUELS

- **Syngas**

- Syngas is a mixture of carbon mono-oxide, hydrogen and other hydrocarbons. It is produced by partial combustion of biomass that is combusting in limited supply of air (oxygen).
- Before the combustion the biomass is dried.
- The resulting gas (syngas) is efficient than direct combustion of the original biofuel.
- By this process more energy content of the biomass can be extracted. Syngas can be directly burned in engines and turbines to produce energy.

BIOGAS

- Biogas is a renewable source of energy that belongs to the category of biofuels. It typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. The anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material and crops produces biogas.

BIOGAS

- Biogas comprises primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulphide (H_2S), moisture and siloxanes. The gases methane, hydrogen and carbon monoxide (CO) can be combusted or oxidized with oxygen.

- This energy release allows biogas to be used as a fuel for any heating purpose, such as cooking. It can also be used in anaerobic digesters in a gas engine to convert the energy in the gas into electricity and heat.

- Biogas can be compressed, much like natural gas, and used to power motor vehicles. It can also be cleaned and upgraded to natural gas standards when it becomes bio methane. The biogas or anaerobic digestion process leaves a nutrient-rich digestate that can be used as fertilizer.

BIOGAS

- Biogas is produced in a biogas digester.
- It is called as digester because it is a large tank filled with bacteria that eats (or digests) organic waste and gives a flammable gas, called biogas.
- Biogas systems make use of a relatively simple, well-known, and mature technology. The main part of a biogas system is a large tank, or digester.
- Inside this tank, bacteria convert organic waste into methane gas through the process of anaerobic digestion. Each day, the operator of a biogas system feeds the digester with household by-products such as market waste, kitchen waste, and manure from livestock. The methane gas produced inside biogas system may be used for cooking, lighting, and other energy needs. Waste that has been fully digested exits the biogas system in the form of organic fertilizer.

BIOGAS

- **Factors Affecting biogas production capacity**

C/N Ratio:

Ratio of carbon to nitrogen present in the organic matter (the feed provided to biogas digester). The maximum amount of biogas is produced for a particular value of C/N ratio.

Gas production is optimum at C/N ratio 20 - 30. C/N ratio of cow/buffalo dung ~ 25 and hence ideal for biogas production. C/N ratio can be brought within the optimum range by mixing different inputs (in certain ratios).

BIOGAS

- **Factors Affecting biogas production capacity**

pH: Is the measure of acidity/alkalinity of the input. A pH of 7 is neutral; pH less than 7 is acidic and higher than 7 is alkaline. Optimum gas production occurs when the pH value of the input is 6 to 7.

BIOGAS

- **Factors Affecting biogas production capacity**

Digestion temperature

Optimum gas production occurs at temperature of 35-degree Celsius. Below 20 ^{o}C gas production is significantly reduced. Hence, this technology in its simple form is not viable in cold climates. If the ambient temperature is 10 degree C or lower, gas production stops. Even a sudden fall of temperature by 2 to 3 degree C significantly reduces gas production. Insulation of the digester helps to increase gas production in the cold climates

BIOGAS

- **Factors Affecting biogas production capacity**

Hydraulic Retention time

Hydraulic retention time (HRT) is the average length of time the liquid influent (organic matter which is mixed with water and supplied to digester) remains in the digester for treatment.

This means that before the biogas is usable, the organic matter which is mixed with water is allowed to decompose inside the digester before the biogas is usable.

It is done to create enough pressure inside the digester.

It is a function of the type of input and the ambient temperature. For cow/buffalo dung input BSP recommends a retention time of 70 days in the hills and 55 days in the Terai (warmer climate). Since human excreta contain more pathogens (disease vectors) than most animal dung, 90 – 100 days retention time is recommended

BIOGAS

Benefits of Biogas

- Saving of Fuelwood and Kerosene: Biogas replaces the use of fuelwood and Prevents deforestation and saves time
- Health Improvement: Being smokeless biogas reduces respiratory and eye infection in women and children. Toilet connection to Biogas Plants improve sanitation and environment
- Reduces water borne diseases - diarrhea, dysentery
- Replacing kerosene by biogas lamps improves in-house pollution
- Saving of Time: Cooking with biogas saves time for firewood collection
- Possibility of using saved time in income generating activities, recreation, childcare and social activities
- Availability of High-Quality Manure: Biogas slurry (Bio-slurry) is an excellent organic fertilizer
- Reduction of Women’s Workload: Study showed that women can save nearly 2.8 hours a day due to biogas installation

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