International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 10, October- 2014

Biochemical Conversion of Biomass and Status of Biomass Energy in India

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Abstract- **Biomass is organic matter that is renewable over time and can be used as a source of energy. These fuels are made by a biomass conversion in three different ways: thermal conversion, chemical conversion, and biochemical conversion. In this paper biochemical conversion of biomass and power generation from biogas is described. This paper also presents the status of biomass energy in India.**

Keywords—Biomass, Biochemical conversion methods, Biogas

I. INTRODUCTION

Biomass can be defined as solid carbonaceous substance obtained from animals and plants. It may include residues of forestry and agricultural, animal throw away and unwanted materials from food processing plants. Biomass is classified as a renewable energy source. It can be defined as by-product of solar energy as plant grows by the process of photosynthesis by absorbing CO_2 from the atmosphere to form hexose(dextrose, glucose etc.). Biomass absorbs the same amount of carbon in growing plant as it releases when utilizes as a fuel, therefore biomass does not add to CO_2 to the atmosphere and hence energy produced from the biomass is 'carbon cycle neutral'.

II. CHEMICAL COMPOSITION

Biomass is a combination of organic molecules including hydrogen, usually containing atoms of oxygen, often nitrogen and also small quantities of other atoms, including alkali, alkaline earth and heavy metals.

It is carbon based and carbon used to create biomass is absorbed from the environment like carbon dioxide (CO_2) by plant life, utilizing sun as a source of energy. Plants may later eaten by animals and thus transformed into animal biomass. The primary absorption is carried out by the plants.

If plant matter is not eaten by animals it is usually either burned or broken down by micro-organisms.

- If burnt away the carbon is returned to the environment as CO_2.
- If broken down it releases the carbon back to the environment, mostly as either carbon dioxide (CO_2) or methane (CH_4), depending upon the situation and processes involved.

This process has happened for as long as there has been plants on Earth and is part of carbon cycle.

As a source of renewable energy, biomass can either be utilized directly by means of combustion for production of heat, or indirectly after transforming into various types of bio-fuel. Conversion of biomass to bio-fuel can be obtained by various methods which are broadly classified into:

- Thermal conversion methods
- Chemical conversion methods
- Biochemical conversion methods

III. BIOFUEL

Bio-fuel is a fuel that is produced from living organisms. These fuels are prepared by a biomass conversion (biomass refers to recently living organisms, most often referring to plants or plant by-product substances). This conversion of biomass results into fuels in solid, liquid, or gas form and this new form is referred as bio fuels. Some of the examples of bio fuels are-

A. Solid biofuel

- Wood Pellets
- Briquettes
- Wood chips
- Firewood

B. Liquid biofuel

- Biodiesel
- Bio ethanol
- Bio alcohols

C. Gaseous biofuel

- Biogas
- Syngas

IV. BIOCHEMICAL CONVERSION OF BIOMASS

Biochemical conversion of biomass includes utilization of bacteria, microorganisms and enzymes to break biomass into gaseous or liquid fuels, such as biogas or bio-ethanol. The most popular biochemical conversion technologies are:

- *Anaerobic* digestion (or bio-methanation)
- *Ethanol* fermentation

A. Anaerobic Digestion

Anaerobic digestion is extensively utilized for recycling and treating wet organic waste. It is a commercially proven technology. It comes in category of fermentation that transforms organic substance into biogas, which mostly consists of methane (approximately 60%) and carbon dioxide (approximately 40%) and is equivalent to landfill gas.

Anaerobic digestion is a biologically natural method of conversion that occurs when bacteria breaks into biodegradable material in the absence of oxygen, which creates biogas, a mixture of mostly methane and carbon dioxide with small quantities of other gases like hydrogen sulphide.

By this process biomass is converted into cattle dung, human wastes and other organic waste with very high moisture content into biogas (gobar gas) through anaerobic fermentation in absence of air. Fermentation occurs in two levels by two different metabolic groups of bacteria. Initially the organic material is hydrolyzed into fatty acids, alcohols, sugars, H_2 and CO_2. Methane forming bacteria then converts the product of first stage to CH_4 and CO_2 in the temperature range 30-55°C.

Fermentation occurs in a sealed tank called 'digester' where the sludge is left behind is used as enriched fertilizer**.**

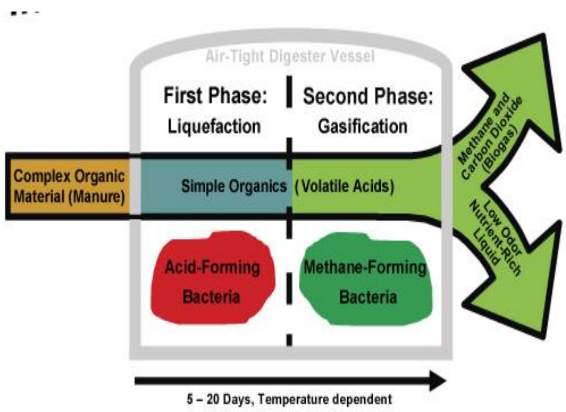

Fig.1. Working of Anaerobic Digestion Process

TABLE I. CHARACTERISTICS OF ANAEROBIC DIGESTION[1]

Characteristic	**Anaerobic**
Reaction	$C_6H_{12}O_6 \rightarrow CO_2 + 3CH_4$
Energy Release	ΔG°' = -393 kJ/mol glucose
Carbon Balance	95% → $CO_2 + CH_4$ (= biogas)5% → biomass
Energy Balance	90% retained in CH_4 5% → biomass 5% → heat production
Biomass Production	Slow growth of biomass

Anaerobic digestion plant produces two products, biogas and digestate both can be further processed or used to produce secondary products. Biogas can be used for producing electricity and heat, as a natural gas substitute and also a transportation fuel. Biogas can also be upgraded and used in gas supply networks.

Digestate can be further processed to produce liquor and a fibrous substance. The fibre, which can be processed into compost, is a bulky material with low levels of nutrients and can be used as a soil conditioner or a low level fertilizer. A high proportion of the nutrients remain in the liquor, which can be used as a liquid fertilizer. [2]

B. Ethanol Fermentation

Ethanol can be produced by decomposition of biomass containing sugar like sugarcane, cassava sweet sorghum, beet, potato, corn, grape, etc. into sugar molecules such as glucose ($C_6H_{12}O_6$) and sucrose ($C_{12}H_{22}O_{11}$).

Ethanol fermentation involves biological conversion of sugar into ethanol and CO_2.

$$C_{12}H_{22}O_{11} + H_2O \Longrightarrow 2C_6H_{12}O_6$$
$$C_6H_{12}O_6 \Longrightarrow 2C_2H_5OH + 2CO_2$$

Ethanol is emerged as the major alcohol fuel and is blended with petrol.

V. BIOGAS

Biogas typically refers to a gas produced by the breakdown of organic matter in the absence of oxygen. It is a renewable source of energy, like solar and wind energy. Furthermore, biogas can be produced from regionally available raw material such as recycled waste and is environmentally friendly [3].

Biogas is produced by anaerobic digestion with anaerobic bacteria or fermentation of biodegradable materials such as manure, sewage, municipal waste, green waste, plant material, and crops.

Biogas is a fuel gas, a mixture consisting of 65% methane (CH_4) and of 35%CO_2. It is a renewable energy resulting from biomass. Biogas is characterized based on its chemical composition and the physical characteristics which result from it. However the name "biogas" gathers a large variety of gases resulting from specific treatment processes, starting from various organic waste- industries, animal or domestic origin waste etc.

VI. POWER GENERATION FROM BIOGAS: BIO POWER

There are three methods for this:

- Direct method
- Gasification
- Landfill

A. Direct method

For decades, the only commercial options available for the production of electricity are wood, wood residues and other solid. In the method biomass is directly combusted and coupled to a steam turbine – that is, burning biomass in a boiler to produce hot gases, producing steam from the hot gases via a heat exchanger, and then generating power from the steam using a steam turbine.

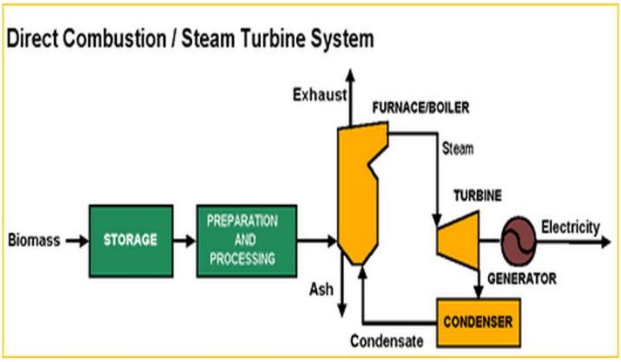

Fig.2 :Direct method

Combustion of the fuel produces steam in the boiler that powers a turbine/generator to generate electricity. The steam is then returned to the liquid state in a condenser by circulating cooling water around the condenser tubes containing the steam. The condensed water is then re-circulated to the boiler to be heated again into steam.

1) Combined Heat and Power

Combined heat and power or CHP, also called cogeneration or distributed generation, is the simultaneous production of two types of energy – heat and electricity – from one fuel source, often natural gas.

a) Cogeneration with Biogas

Biogas from Regenerative Raw Material and Biogas Plants: Biogas is the product of the anaerobic fermentation of organic material in a fermenter. This gas has a CH_4 methane content of 45-70 percent. During the combustion, the amount of emitted CO_2 merely corresponds to the amount the substrates absorbed during growth. Cogeneration plants, that produce power using biogas prevent emissions that would otherwise be emitted during the combustion of fossil fuels.

A typical CHP system has an electric generator, which can take the form of a gas turbine, steam turbine, or combustion engine. In addition to this electric generator, a waste heat exchanger is installed, which recovers the excess heat or exhaust gas from the electric generator to in turn generate steam or hot water.

B .Gasification Technology

Gasification plants consist of several process steps, which are shown in figure below. The solid biomass fuel delivered needs to be adjusted (fuel conditioning and handling) to the fuel characteristics (particle size, water content) required for the gasification process. The conditioned fuel enters the gasification process, which produces raw product gas. The raw product gas quality needed for further utilization. The cleaned product gas is used for the production of electric power, heat and fuel based on different technologies. [4].

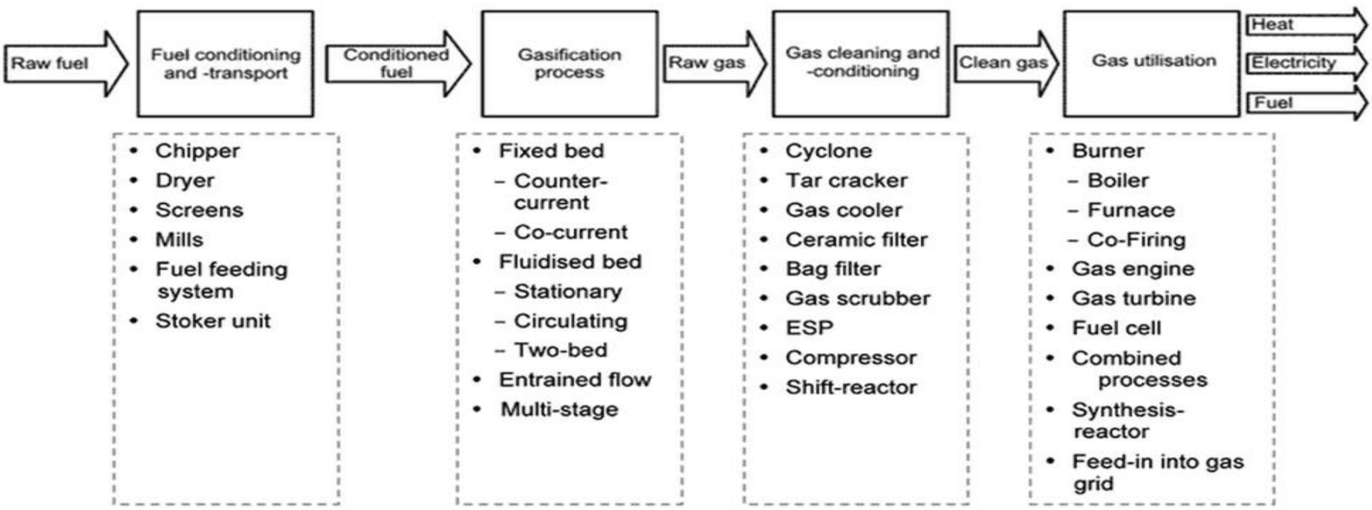

Fig.3: Processes involved in gasification

C. Landfill

Generally , during anaerobic conditions, the composition of landfill gas is approximately 50 percent methane and 50 percent carbon dioxide with trace amounts of nitrogen, oxygen, hydrogen sulphide , hydrogen, and non-methane organic compounds (NMOCs). The more organic waste and moisture present in a landfill, the more landfill gas is produced by the bacteria during decomposition [5].

The process involves covering or "capping" a section of the landfill with clay, drilling vertical wells into the waste and connecting them with underground piping. Vacuum compressors then capture the gas and pipe it to a blower/flare station, where it is either piped to the power generation facility or combusted in a flare. During the combustion process the methane is converted to carbon dioxide, a less harmful gas. While effective at reducing methane gas emissions, ending the process at this point makes no use of the heat energy that is produced during the conversion. After the gas is collected, it will be piped to a power generation facility and combusted in engine generator sets to generate electricity

VII. BIOGAS DEVELOPMENT

Biogas is a clean, non-polluting and low - cost fuel. It contains about 55 to 75 per cent methane, which is inflammable.

The Ministry of Non-Conventional Energy Sources has taken up following programmes for development and harnessing of biogas potential in the country:-. [6].

National Project on Biogas Development (NPBD) for setting up of family type biogas plants. Started in 1981-82 to provide fuel for cooking purposes and organic manure to rural households through biogas plants, to mitigate drudgery of rural women, reduce pressure on forest and accentuate social benefits and to improve sanitation in villages by linking toilets with biogas plants.

Community, Institutional and Night Soil based Biogas Plants (CBP/IBP/NBP) Programme. Started in 1982-83 and later on in 1993-94, a scheme of setting up of large sized biogas plants lined with community toilet blocks was added.

VIII. BIOMASS ENERGY IN INDIA: STATUS

In India primary energy contribution of biomass is one third of the total. They are largely used for heating water, cooking purposes in rural areas and is also used by traditional and artisan industries. It also delivers the majority of the energy for the domestic use (rural - 90% and urban - 40%) in India (NCAER, 1992)[7].

Wood fuel contributes 56 percent of total biomass energy (Sinha et. al, 1994). Consumption of wood has grown annually at 2 percent rate over past two decades. [8]

TABLE II. CONSUMPTION OF FUEL WOOD (1996)

Consumption of Fuel-wood	**Million Tons**
1. Household	
(a) Forested Rural	78
(b) Non Forested Rural	74
(c) Urban Areas	10
Sub Total	162
2. Cottage Industry	25
3. Rituals	4
4. Hotels etc.	10
Total	201

TABLE III. CONSUMPTION OF FUEL WOOD (2004) [9]

Consumption of Fuel-wood	**Million Tons**
1. Household	
(a) Forested Rural	83
(b) Non Forested Rural	65
(c) Urban Areas	17
Sub Total	165
2. Cottage Industry	22
3. Rituals	4
4. Hotels etc.	14
Total	205

TABLE IV. BIOMASS CONSUMPTION (2004) [9]

Fuel	**Million Tons**
1.Fuel-wood	205
2.Crop-residue	116
3.Dry Dung	35
Total	356

IX. MODERN BIOMASS TECHNOLOGY IN INDIA: EXPERIENCES

India has a decade of experience with modern biomass technologies for thermal, motive power and electricity generation applications.

Gasifier technology has entered the applications such as village electrification, captive power generation and process heat generation in industries producing biomass waste. More than 1600 gasifier systems, having 16 MW total capacity, have generated 42 million Kilo Watt hour (KWh) of electricity, replacing 8.8 million litres of oil annually[10].

About 90 MW capacity is under construction and nearly 55 MW of grid connected biomass power capacity is already commissioned. Enhanced scale has improved economics as well as the technology of biomass power generation. Technology improvement is also derived from joint ventures of Indian firms with leading international manufacturers of turbines and electronic governors.

X. A CASE STUDY: BIOGAS BOTTLING IN INDIA

Energy is the key input for socio-economic development of any Nation. The rapid industrialization and urbanization in addition to mechanized farming have generated a high demand of energy in all forms i.e. thermal, mechanical and electrical. To meet this ever-increasing demand, fossil fuels such as coal, oil and natural gas have been overexploited in an unsustainable manner which is a serious environmental problems such as global warming and climate change.

Biogas plants in addition to gaseous fuel also provide high quality organic manure with soil nutrients which improves its fertility required for sustainable production and improving productivity. Thus, there is a huge potential for the installation of medium size biogas plants in the country.

The potential can be translated to an aggregated estimated capacity of 8165 MW per day power generation or 22,06,789 LPG cylinders and 21304 lakh kg of urea equivalent or 3974 lakh tones of organic manure/fertilizer per day [14].

CNG technology has already become easily available and therefore, bio-methane (enriched biogas) which is nearly same as CNG, can be used for all applications for which CNG are used. Purified/enriched biogas (bio-methane) has a high calorific value in comparison to raw biogas.

During the year 2008-09, a new initiative was taken for demonstration of Integrated Technology-package, in entrepreneurial mode, for installation of medium size mixed feed biogas fertilizer plants (BGFP) for generation, purification/ enrichment, bottling and piped 2 distribution of biogas under RDD&D policy of MNRE [11].

Installation of such plants aims at production of CNG quality of Compressed Biogas (CBG) to be used as vehicular fuel in addition to meeting stationary & motive power and electricity generation needs in a decentralized manner through establishment of a sustainable business model in this sector. There is a huge potential of installation of medium size biogas-fertilizer plants in various villages and other areas and agro/ food processing industry of the country.

The main components of biogas bottling projects (BGFP) are given below:

- Pre-treatment system
- Biogas generation system
- Biogas Storage system
- Biogas purification system
- Biogas Bottling system
- Slurry handling system etc.

The first biogas bottling project sanctioned to Ashoka Biogreen Pvt. Ltd. of 500 m3/day capacity at Vill.-Talwade, Dist.-Nashik (Maharashtra) was commissioned on 16.03.2011 after obtaining license for filling and storage of compressed biogas in CNG cylinders from Petroleum & Explosives Safety Organization (PESO) [11].

The second biogas bottling plant was commissioned on 17.11.2011 after obtaining license for filling and storage of compressed biogas in CNG cylinders from Petroleum & Explosives Safety Organization (PESO).This biogas bottling project was of 600 cubic meter per day capacity for generation, purification/enrichment, bottling of biogas has sanctioned by the MNRE with Rs. 45.50 lakh CFA during the year 2009-10 to Anand Energy at Vill.-Kalatibba, Teh.- Abohar, Dist.- Ferozepur (Punjab).

The purity of biogas is about 98% Methane and this has being corroborated through tests conducted by NABL and compressed to 150-bar pressure for filling in cylinders. The purified biogas is equivalent /similar to CNG.

The upgraded biogas is filled in CNG cylinder and supplied to mid-day meal scheme for cooking food of over 18000 school students in Abohar and its adjoining areas. The slurry/manure of biogas plant is being sold to the farmers and used in liquid form by them in Kinoo plants. The field trials have indicated the excellent growth in agro-production and substantial improvements in the quality. Further, minimum dropping of fruits was reported after using biogas slurry (bio-manure) [11].

This biogas bottling project will be able to replace fuel & manure worth of about Rs. 40 lakh annually. The full cost of the project would be recovered within four to five years. The separation and bottling of CO2 and extraction of Humic acid from slurry would further improve viability of biogas bottling plants.

The biogas bottling project (BGFP) provide three-in-one solution of gaseous fuel generation, organic manure/fertilizer production and wet biomass waste disposal.

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