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A review on the biomass energy resources and conversion technology in India

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Abstract: **-- Sustainable economic development is closely linked with the energy availability. The demand for energy continues to increase steadily from last several decades, due to rapid industrialization and globalization. Most of the world's commercial energy needs are met by fossil fuels coupled with negative environmental effects. The burning of the fossil fuels is a big contributor for increasing the level of CO_2 in the atmosphere. To combat global warming and other environmental problems associated with these fossil fuels many countries, including India, are increasingly adopting renewable energy sources. Such energy sources generally depend on energy flows through the earth's ecosystem from the insolation of the sun and the geothermal energy of the earth. India is moving toward a trend of generating electricity from renewable resources such as Solar, Wind, Biomass, etc. The total installed capacity for electricity generation in India is 310 GW as on 31st December 2016 in that Renewable power plant contributes 88.96 GW (28.69%) in particular biomass contributes 4.99 GW (1.61%). In view of this, present study has made an attempt to have a brief review on various categories of biomass and its resources available in the Indian context and its wide range of applications based on the process of conversion methods or technologies used. Study also brings various possibilities of using different biomasses and their suitability in the context of energy resource.**

***Index Terms*— Biomass, renewable energy, potential, conversion technologies.**

I.INTRODUCTION

With high economic and industrial growth, energy demand in India has increased. The major sources to fulfill the energy requirement of India are Oil and coal. India is the fourth largest consumer in the world of Crude Oil and Natural Gas, after USA, China and Russia. By 2020 India is poised to become the 3rd largest energy consumer after the USA and China. Surge in energy demand in India due to demographic and economic reasons places enormous pressure on its energy resources. The present status and future predictions indicate that the availability of fossil fuel is not certain for long period. Thus there is an utmost need of a substitute fuel which is obtained preferably from renewable resources and its use environment friendly [1][2].

Biomass is a sustainable resource for the replacement of fossil sources, especially when it comes to the production of gaseous and liquid fuels for stationary and non-stationary applications. About 32% of the total primary energy used in the country is still derived from biomass and more than 70% of the country's population depends upon it for its energy needs. Biomass is the most commonly used energy source for several small-scale industries and is used as fuel for independent power plants. Biomass materials used for power generation include sugarcane bagasse and other non bagasse materials like rice husk, straw, cotton stalk, coconut shells, soya bean husk, de-oiled cakes, coffee waste, jute waste, groundnut shells, saw dust, etc. Using sustainably grown biomass will not result in net CO_2 emissions, as the same amount of carbon released in combustion has been recovered from the atmosphere during biomass growth. The utilization of biomass-derived fuels might, however, result in CO_2 emissions from fossil fuels used for biomass production, transportation, conversion and distribution of final energy carriers. Biomass based energy carriers may also be used in these operations and reduce or even eliminate net CO_2 emissions [3].

II. AVAILABLE BIOMASS RESOURCES IN INDIA

Biomass most often refers to plants or plant-based materials that are not used for food or feed, and are specifically called lignocellulosic biomass. As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of bio-fuel. Biomass can be classified simply in the way they are available in nature as: grasses, woody plants, fruits, vegetables, manures and aquatic plants. Algae and Jatropha are also now used for manufacturing bio-diesel. The main sources of the biomass can be classified into [3]

1) Agriculture waste- such as Straws of cereals and pulses, stalks of fiber crops, seed coats of oil seed, crop wastes like sugarcane trash, rice husk, coconut shell, etc.
2) Municipal solid waste - Bio-degradable waste such as paper, green waste, kitchen waste, fiber waste, etc.
3) Industrial waste - sugarcane refiner waste mainly bagasse and molasses, paper mill waste, Food processing units waste, etc
4) Energy plantation - Plants grown in the land indentified for the energy generation. Example - Bamboo, leuceana and prosopis.

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India produces about 450-500 million tones of biomass per year. Biomass provides 32% of all the primary energy use in the country at present. Agriculture sector total contributed is 17.4 per cent to India's Gross Domestic Product (GDP) in 2015-16, this indicates the dependence on the agriculture sector. Due to dependence of larger part of the population of India on agriculture, this availability of biomass of diversified conditions has made possible in India villages. There are many other potential sources of energy besides agricultural residue from farm and urban areas [5]. The agro based industries, road side shrubs, plantation, vegetable market, road sweeping, etc. are the area where significant amount of biomass waste generates. As per Ministry of New and Renewable 200 million tones of agro processing and domestic wastes are generated annually in India and disposed in a distributed manner, as these areas are managed by poor farmers and the unorganized sector, rural worker and the low income small agro based industry sector [5][6].

III. BIOMASS ENERGY CONVERSION TECHNOLOGIES

Conversion of biomass to biofuel can be achieved by different methods which are broadly classified into: *bio-chemical thermal*, and *mechanical* methods [5].

Bio-chemical conversion

Biochemical conversion of biomass involves use of bacteria, microorganisms and enzymes to breakdown biomass into gaseous or liquid fuels, such as biogas or bioethanol. The most popular biochemical technologies are fermentation and anaerobic digestion (or biomethanization) [5].

Fermentation

Fermentation is a metabolic activity that converts sugar to acids, alcohol or gases. It can also be defined as anaerobic enzymatic conversion of organic compounds, especially carbohydrates, to simpler compounds mainly ethyl alcohol and carbon dioxide. Fermentation can be carried in the presence of abundant oxygen yeast cells prefer fermentation to oxidative phosphorylation, as long as sugars are readily available for consumption. When reactions begin with yeast, the initial concentration of glucose ($C_6H_{12}O_6$) will be very high. So, through diffusion, glucose enters the yeast, as reaction proceeds it will further breakdown to glycolysis. The product of glycolysis has two three-carbon sugars, called pyruvates, and some ATP (Adenosine Triphosphate), which supplies energy to the yeast and allows it to multiply. The two pyruvates are then converted by the yeast into carbon dioxide and ethanol the overall reaction is [6].

$C_6H_{12}O_6 + \text{Yeast} \rightarrow 2CH_3CH_2OH + 2CO_2$.

Anaerobic digestion

Anaerobic digestion is a collective of processes by which microorganisms break down bio-degradable material in the absence of oxygen, these microorganisms are able to progressively transform organic materials into biogas consisting of methane, carbon dioxide and some trace of contaminates such as hydrogen sulphide. Natural anaerobic digestion can be observed in the lake, sumps and ocean basin sediments. By simulating appropriate conditions, the microorganisms can be cultivated in the controlled conditions in the closed chamber called as digester. Anaerobic digestion is commercially proven technology and it is used for treatment of high moisture content organic waste, i.e. is 80-90% moisture. The energy content of the biogas will be about 20–40% of the lower heating value of the feedstock. The heating value of the biogas is approximately 18-25MJ/m^3 depending on the concentration of methane and carbon dioxide, which is 30-40% lower than compressed natural gas (CNG). Further it can be upgraded to bio-CNG by scrubbing out carbon dioxide, water and traces of other gases. But before utilization of biogas energetically the necessary steps to clean the gas should be carried out, one of the most important step is to remove the hydrogen sulfide, which is more toxic and corrosive in nature [7][9].

Thermo-Chemical

Thermo-chemical conversion processes are pyrolysis, gasification, and liquefaction. Bio renewable feed stocks can be converted into liquid or gaseous forms for the production of electric power, heat, chemicals, or gaseous and liquid fuels

Pyrolysis

Pyrolysis is the conversion of biomass to liquid, solid and gaseous fraction when it is exposed to high temperature (400-500^{0}C) in the absence of oxygen. The output can be condensed to ambient temperature lead to water and some complex oxygenated hydrocarbons in the form of liquids and permanent gases like CO, H_2, and CO_2 and CH_4, there is some solid residue in the form of char.

All the products of the pyrolysis depend on the rate of the temperature raise and maximum temperature it is raised. Typical range of the pyrolysis is in the range of the 300 to

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500^0C. Methods of controlled heating by combining the heating rate with the temperature to which the biomass is raised leads to chars of different fractions and quality. Slower heating rates and achieving high temperatures leads to much larger fraction of gases. Slow pyrolysis is a standard process used to produce charcoal. Pyrolysis can be used to produce predominantly bio-oil if, flash pyrolysis is used, enabling the conversion of biomass to bio-crude with an efficiency of up to 80%. These liquids can be directly used for combustion applications or they can become a feedstock for conversion to straight hydrocarbons in another process. The bio-oil can be used in engines and turbines and its use as a feedstock for refineries is also being considered. But there are some problems which are still there to overcome such as corrosivity, less thermal stability, etc [6].

Combustion

Combustion is a process by which biomass combined with air or oxygen is reacted after suitable ignition to lead to conversion of chemical energy stored in the biomass to heat energy, mechanical energy in some cases it is converted into electrical energy by different process and devices for example furnace, boilers, steam turbines and stoves. It is reported that the biomass appears in wide range of physical conditions - moisture, density, shape, ash content, all these physical properties have significant impact on the combustion process. The feasible range of moisture content in the biomass is less than 50%, high moisture content biomass are more suitable for biological conversion process. Net bio-energy conversion efficiencies for biomass combustion power plants range from 20% to 40%. The higher efficiencies are obtained with systems over 100 MWe or when the biomass is co-combusted in coal-fired power plants [5][6].

Gasification

Gasification is the processes of converting solid biomass into gaseous fuel by partial oxidation at high temperature typically in the range of 900-1100C. The product of gasification is however a fuel gas. It can be further used for combustion purposes either locally in a furnace or at a distance from the location of gasification in a wider variety of applications like reciprocating or gas turbine engines, fuel cell or as a feedstock for conversion to liquid fuels like methanol or biodiesel. The gasification is used to produce electricity in the range of few kWe to few MWe from reciprocating engine. The gasification process itself have the conversion efficiency of solid to gaseous fuel in the range of 70 to 85%. The overall from biomass gasification- reciprocating engine power generation conversion efficiency are of the range of 20 to 25%, which implies the specific biomass consumption of 1 to 1.3kg/kWh. The produced syngas from biomass is used for the production of methanol and hydrogen, which can be considered as fuels for transportation and others. The gasification process can be carried out air, oxygen -steam mixture, or air-steam mixture for different objectives. The gaseous fuel composition from air gasification process on dry bases will be - CO and H_2 is about 18 to 20%, CH_4 is about 1 to 20%, CO_2 is about 11 to 12.5%, balance is N_2, this gas is called as Producer gas. Gasification process with oxygen/steam mixture leads to the gas composition of 30 to 50% of H_2, CO is about 15 to 30%, CH_4 is about 2 to 5%, and rest is CO_2, this gas is called as Synthesis gas (Syngas). The lower calorific value of producer gas is 4.5±0.5 MJ/kg [6].

Mechanical extraction

Extraction is a mechanical conversion process used to produce oil from the seeds of various biomass crops, such as oilseed rape, cotton and groundnuts. The process produces not only oil but also a residual solid or 'cake', which is suitable for animal fodder. Three tons of rapeseed are required per ton of rape- seed oil produced. Rapeseed oil can be processed further by reacting it with alcohol using a process termed esterification to obtain. The chemical reaction that converts a vegetable oil or animal fat to biodiesel is called "transesterification.", chemically reacting a vegetable oil or animal fat with an alcohol such as methanol or ethanol. In words, the reaction is as follows [3][8],

Oil + alcohol → biodiesel + glycerin

IV. CONCLUSION

For a country like India, The suitability and choices of region-specific biomass feedstock need to be established along with process parameters, yields, etc. for both the thermo-chemical as well as bio-chemical platforms on a pilot scale. Considering the huge potential for bio-fuels and bio-based products in India, bio-fuels have special significance due to energy security, contribution to rural economy and employment generation.

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