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RENEWABLE ENERGY CONVERSION FROM BIOMASS

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***Abstract* - The global impacts of fossil fuels have driven governments and companies to investigate other methods of energy production for the benefit of society. The utilization of biomass in energy validates the possibility to replace non-renewable sources of energy. Bioenergy is obtained from a wide variety of sources, including rice husks, bagasse, wood chippings, and sawdust. This article presents an examination of the techniques employed in the conversion of biomass into energy that is suitable for practical applications, ecologically friendly and also the rates at which biomass power is consumed worldwide.**

Keywords—*biomass, bioenergy, feedstock, pyrolysis, torrefaction, combustion*

I. INTRODUCTION

The growing focus on achieving environmental sustainability has encouraged extensive research on the utilisation of biomass in various sectors, such as construction [1,2] aviation [3], packaging [4], medicine [5], energy storage [6], and biofuels [7,8]. The utilisation of biomass for energy production dates back to the earliest humans. Since ancient times, the issue of greenhouse gas emissions has gained increasing significance, particularly in efforts to mitigate their impact [9]. The usage of cleaner sources of energy, such as biomass energy, has emerged as a more viable option to the utilisation of fossil fuels for the purpose of generating heat or electricity. Biomass covers a range of molecular and macromolecular chemicals derived from plant matter, agricultural produce, forestry resources, and residual materials [10]. The combustion of fossil fuels has made a substantial impact on the degradation of atmospheric gases, such as the ozone layer. In consideration of the depleting reserves of fossil fuels, biomass energy emerges as a more viable alternative, owing to recent advances in renewable energy technologies. In order to optimise the consumption of bioenergy, it is vital that the conversion process be environmentally sustainable.

II. BIOMASS CONVERSION PROCESSES

The four major types of conversion technologies currently available include thermal, thermochemical, biochemical, and chemical conversion.

A. Thermal conversion

Thermal conversion refers to the process of converting energy from one form to another through the utilisation of heat. The process is widely employed as the prevalent approach for converting biomass into renewable energy. It is categorised into three distinct methods; Pyrolysis, Gasification, and combustion [11].

Pyrolysis: Pyrolysis involves subjecting biomass to temperatures usually above 500°C in an oxygen deficient environment leading to the decomposition of the biomass feed stock into biofuels. By carefully selecting the rate at which heat is applied, the temperature at which pyrolysis occurs, and effectively removing the product from the reaction area, it is possible to enhance the maximum production of organic liquid (referred to as pyrolytic oil or bio-oil) from thermal decomposition combustion [12]. This improvement can lead to yields as high as 80%, calculated based on the weight of the material post-drying [13]. Fig. 1 shows the process of pyrolysis. The pyrolysis process can be categorized into three subtypes: conventional pyrolysis, fast pyrolysis, and flash pyrolysis.

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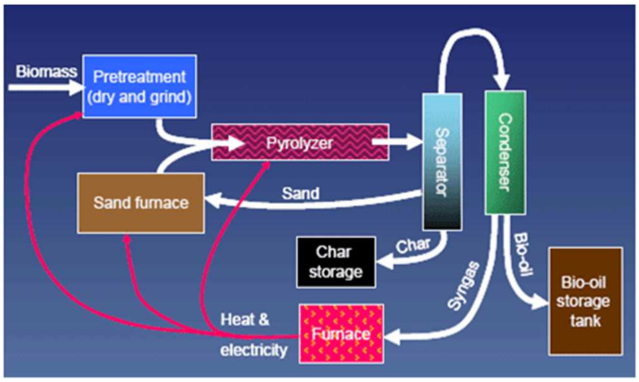

Fig.1. Schematic of pyrolysis combustion [14].

Torrefaction: The process of torrefaction of biomass involves the decomposition of biomass by heating at temperatures usually within the temperature range of 200 to 320°C [15]. Consequently, all moisture is removed as well as a fraction of the volatile matter from the dried biomass [16]. Torrefaction modifies the properties of biomass to enhance its fuel quality for applications in combustion and gasification. Generally, the torrefaction process results in a mass loss (on a dry basis) of 20-30% and an energy loss of 10-15%. The process of torrefaction is shown in Fig.2.

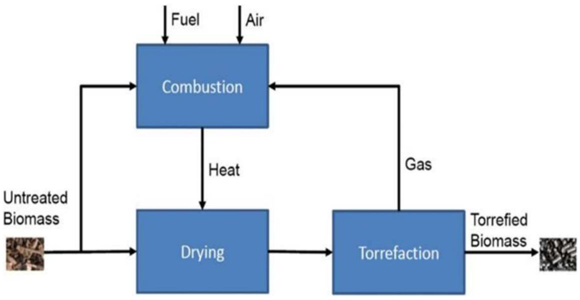

Fig. 2. Diagram of torrefaction process [12].

Combustion: During combustion, biomass is burned in the presence of oxygen to produce heat which can then be used for hot water, heating, or to generate electricity via a steam turbine using a waste heat boiler. When the biomass is combusted, it typically drops its moisture at temperatures reaching up to 100°C [17]. As the particles dry out, they begin to heat up and release volatile gases that include hydrocarbons, CO, CH4, and various other gaseous elements [18]. Approximately 70% of the heating value of the biomass during combustion is attributed to these gases. Finally, the remaining char undergoes oxidation,resulting in the formation of ash [19]. A representation of the stages of combustion of biomass is shown in Fig. 3.

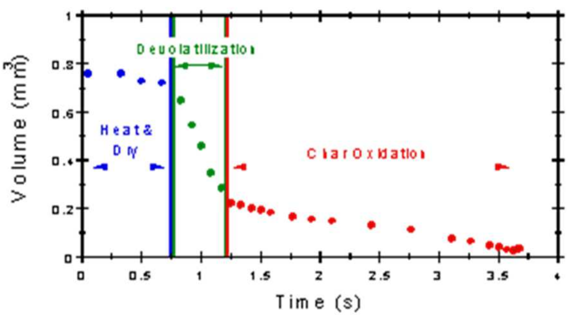

Fig. 3. Graph showing distinct stages of combustion of biomass heating and drying, (2) devolatilization and (3) char oxidation. [20]

B. Thermochemical conversion

Thermochemical conversion pathways involve the breaking down of bonds among neighboring carbon, hydrogen, and oxygen molecules, releasing the stored chemical energy that was produced during the process of photosynthesis [21]. The four main types of thermochemical conversion are combustion, pyrolysis, liquefaction, and gasification [22].The generated syngas undergoes purification and conditioning to produce a gas free from contaminants with the appropriate hydrogen-carbon monoxide ratio before the catalytic conversion stage. During the cleanup process, various contaminants such as tars, acid gas, ammonia, alkali metals, and other particulates are eliminated. Subsequently, the syngas is conditioned, reducing hydrogen sulfide levels through sulfur polishing, and adjusting the hydrogen-carbon monoxide ratio through water-gas shift. A simple representation of thermomechanical conversion is shown in Fig. 4.

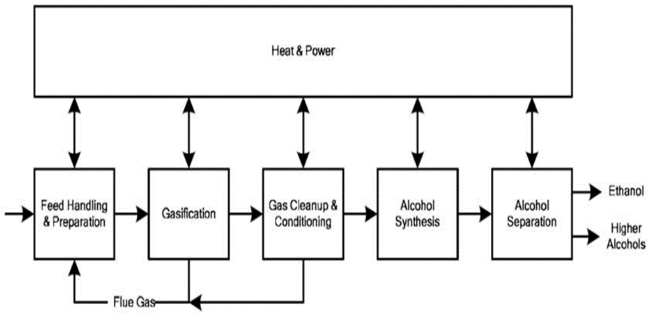

Fig. 4. Simplified pictorial representation of thermochemical conversion of biomass [23]

C. Biochemical conversion

Biochemical conversion encompasses the breakdown of biomass to make its carbohydrates available for processing into sugars. These sugars can be converted into biofuels and bioproducts through the utilization of microorganisms and catalysts. The most widely adopted biochemical technologies are anaerobic digestion, often referred to as biomethanation and fermentation [24,25]. Anaerobic digestion is a natural biological process that stabilizes organic waste in the absence of air converting it to biofertilizer and biogas (Fig. 5). Anaerobic digestion plants generate two outputs, namely biogas and digestate. These outputs can further be processed or be utilized for the production of secondary outputs. Biogas has the potential to be used for the production of electricity and heat, comparable to natural gas.

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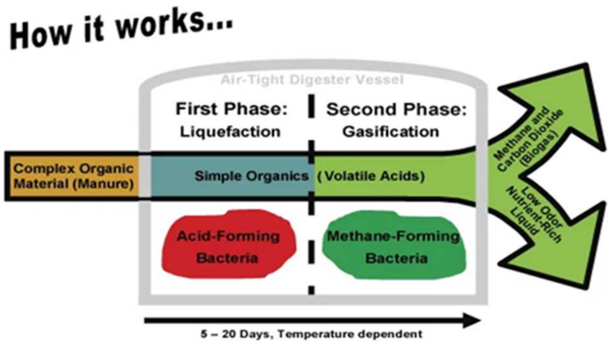

Fig. 5. Schematics of aerobic digestion of biomass [26]

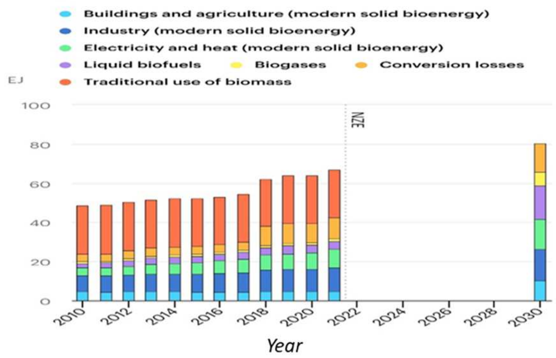

Fig. 6. Global bioenergy consumption [30]

D. *Chemical conversion*

Chemical conversion includes the utilization of chemical agents to facilitate the conversion of biomass into liquid fuels, predominantly in the form of biodiesel. The utilization of inorganic catalysis in the conversion of raw biomass feedstock into valuable products has demonstrated certain economic advantages compared to acid catalysis. Acid catalysis is widely utilized in biomass valorization due to its exceptional capacity for molecular deoxygenation through various chemical reactions [27]. In the past, the pulp and paper industry utilized chemical conversion technologies of biomass. Transformation of biomass through chemical processes, such as hydrolysis, transesterification, hydrotreatment, and catalytic applications. Chemical conversion technologies involve the utilization of the significant heat generated during oxidation either for direct application or for the generation of power. Hemicellulose exhibits significant decomposition at temperatures below 300°C. Cellulose exhibits the ability to undergo decomposition within the temperature range of 300–350°C. When the temperature exceeds 500°C, the process of lignin decomposition initiates. This particular technology has an extended historical background and is characterized by its relatively affordable cost. Nevertheless, the process produces a substantial amount of greenhouse gases, including sulfur dioxide (SO2) [28].

III. STATISTICS

About 85% of the domestic supply was from solid biomass sources including wood chips, wood pellets and traditional biomass sources. Liquid biofuels accounted for 8%, municipal and industrial waste sectors accounted for 5% followed by biogas at 2%. In 2020, 1.93 billion m^3 of wood fuel was produced globally. According to the United States Energy Information Administration, nearly 5000 trillion British thermal units and equal to about 5% of total energy consumption in 2021 was provided with biomass energy [29,30].

IV. CONCLUSION

The present study examines four distinct biomass conversion methods, including thermal, thermomechanical, biochemical, and chemical conversions. The thermal process is employed to convert energy from one form to another by utilising heat. Thermomechanical processes involve the breakdown of bonds between adjacent carbon, hydrogen, and oxygen molecules, thereby releasing the stored chemical energy that was produced during photosynthesis. Biochemical processes, on the other hand, break down biomass to make carbohydrates accessible for further processing into sugars. These sugars are then converted into biofuels and bioproducts using microorganisms and catalysts. Lastly, chemical conversion involves the utilisation of the substantial heat generated during oxidation, either for direct application or for power generation purposes. The quantity of gases released during the combustion of fuels is subject upon various factors, including the specific fuel type, the combustion technology employed, the level of maintenance, and the operational practises implemented. The production of renewable fuel has experienced substantial growth, with an estimated increase from 9 billion gallons in 2008 to a projected 36 billion gallons in 2022. Biomass exhibits potential as a viable energy source for the future due to its reduced carbon dioxide emissions, abundant availability, and renewable nature.

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