

Chapter 6

Biofuels and Biomass Conversion Technologies

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ABSTRACT

The escalating global awareness of climate change and the imminent depletion of fossil fuel reserves have spurred an urgent search for sustainable energy alternatives and eco-friendly chemical processes. Biofuels and biomass conversion technologies have emerged as pivotal solutions in this critical endeavor, offering pathways to reduce greenhouse gas (GHG) emissions, foster green chemistry principles, and enhance energy security. Biofuels, derived from renewable biological sources such as plants, algae, and agricultural waste, present a compelling alternative to fossil fuels. Biomass conversion technologies, including thermochemical, biochemical, and hybrid approaches, transform biomass into valuable products. These technologies, when integrated with green chemistry principles, minimize waste, conserve energy, and facilitate the development of bio-based chemicals and materials. Challenges such as feedstock availability, process efficiency, and economic competitiveness need to be addressed through advancements in biotechnology, process engineering, and material science.

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1. INTRODUCTION

The increasing cost of fuel, energy consumption, CO₂ emissions, other greenhouse gas emissions which contribute to climate change, water and air pollution, land degradation, and the expanding demand for fossil fuels are the main factors driving the need for alternative energy sources. Currently, the main energy source is fossil fuels, which account for about 88% of global energy production. Additionally, the scarcity of fossil fuels and environmental concerns have also prompted scientists and researchers to look for sustainable resources as alternatives to meet the increasing energy demand. The generation of renewable energy sources is necessary to reduce greenhouse gas emissions and improve the security of the newly identified renewable energy sources (Ashfaq et al., 2024; Yaashikaa et al., 2019).

In this point of view, the most significant and alternative renewable energy source that can lower greenhouse gas emissions and pollutants in the environment is biomass fuel. Since biomass is predicted to provide 10–14% of the world's power supply, it is currently attracting a lot of attention as an environmentally beneficial renewable energy source (Díaz-Rey et al., 2015; Peres et al., 2013). This is because it can reduce the overreliance of fossil fuels, emit the same amount of carbon into the atmosphere as was absorbed by plants during their life cycle (carbon neutral), and decreases landfill disposal costs and land requirements. Moreover, the fossil fuel extraction needs significant capital investment, such as oil rigs, gas pipelines, and fuel collection. While biomass technology is far less expensive. Manufacturers and manufacturers can increase earnings despite producing less (USDOE, 2016).

In order to develop renewable energy from biomass conversion with better efficiency, it is crucial to have a thorough insight of its working principles. To date, thousands of biomass materials have been investigated annually, for the past 50 years by appropriate choice of raw materials, feedstock, and different method/reaction conditions (**Figure 1**). Due to their advantages as renewable sources, the conversion of biomass to fuel, energy and chemicals can be formulated efficiently to achieve maximal production rate based on the analysis from research that has been conducted previously. Thus, this chapter will focus on the biomass process, the feedstocks used in biomass conversion, and comparison between the technologies used for the conversion of biomass such as thermochemical (pyrolysis, gasification, and combustion), biochemical (fermentation, enzymes), hybrid processes, and the products or by-products generated from the biomass conversion processes. Besides that, the challenges and issues that play around in feedstock availability, supply chains logistics, process efficiency, technological scalability, and economic competitiveness, and future directions will also be discussed in this chapter.

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