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## A Comprehensive Analysis in Pyrolysis Technology for Sustainable Fuel Production

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**Abstract:** [2] The escalation of plastic waste has become one of the most pressing ecological crises of our time. With millions of tons of plastic flooding landfills, oceans, and ecosystems annually, traditional recycling systems seem inadequate—struggling against the complex, mixed, and contaminated nature of discarded plastics. Amidst this environmental chaos, pyrolysis has emerged as an innovative, albeit intricate, solution: a high-temperature, oxygen-free process that fractures plastic polymers into a spectrum of valuable, albeit sometimes volatile, products.

In this review, we delve into the multi-faceted world of pyrolysis, a thermochemical reaction that transforms waste plastic into an array of fuels, gases, and solid byproducts. The volatile interplay between feedstock types—ranging from ubiquitous polyethylene (PE) and polypropylene (PP) to stubbornly resistant polystyrene (PS) and polyethylene terephthalate (PET)—determines the efficiency and nature of the products. Pyrolysis products generally fall into three categories: the liquid fuel (a complex cocktail of hydrocarbons), gaseous byproducts (methane, ethylene, propane), and the solid char, often a carbonaceous material with applications ranging from industrial processes to carbon black production.

[7] Recent strides in technology have injected new life into this ancient process. Catalytic pyrolysis, employing zeolites and metal oxides, seeks to lower the reaction temperatures and boost the yield of liquid fuels while curbing the formation of byproducts. Fast pyrolysis, with its lightning-fast heating rates, promises a quantum leap in liquid yields. Moreover, the integration of pyrolysis with other technologies, such as waste-to-energy systems, aims to maximize energy recovery and make the entire process more resource-efficient.

[8] However, the promise of pyrolysis is far from unblemished. From the unpredictable variability of plastic waste feedstocks to the significant energy consumption, the road to mass adoption is riddled with technical, economic, and environmental hurdles. Moreover, while pyrolysis may offer a cleaner alternative to landfilling and incineration, its byproducts—particularly gases—demand stringent emission controls to avoid unleashing harmful pollutants. Thus, while pyrolysis holds immense potential to help solve the global plastic waste problem, it requires more than just scientific ingenuity; it demands a concerted effort to innovate, optimize, and scale sustainably.

**Keywords:** Pyrolysis, Plastic waste management, Waste-to-energy, Plasticrecycling, Circular economy, Feedstock variability

