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Application of Circular Economy Concepts in Environmental Engineering: Analysis of Waste-to-Energy Technology Pathways

With the increasing global challenges of resource depletion and environmental pollution, the traditional linear economic model is facing significant limitations. Circular economy, which emphasizes efficient resource utilization and waste minimization, has become an essential guiding principle in the field of environmental engineering. Particularly in waste management, waste-to-energy technologies enable the conversion of waste materials into valuable energy resources, thereby reducing environmental burdens and providing new green energy solutions.

Waste-to-energy encompasses a variety of technological pathways, including municipal solid waste incineration, anaerobic digestion of biomass to produce biogas, and thermochemical processes such as pyrolysis and gasification. These technologies can convert solid wastes, organic wastewater, and agricultural residues into electricity, heat, or fuels, promoting waste reduction, harmless treatment, and resource recovery. Driven by circular economy principles, waste-to-energy not only contributes to the goals of waste reduction, reuse, and recycling but also aids in pollution control and greenhouse gas mitigation.

However, the application of waste-to-energy technologies faces several challenges, including uneven technology maturity, fluctuating economic viability, insufficient policy support, and potential risks of secondary pollution. How to integrate circular economy concepts to optimize technology selection and system integration, thereby enhancing the environmental benefits and economic feasibility of waste-to-energy, remains a critical research issue in environmental engineering.

This study aims to systematically review the main technology pathways for waste-to-energy, analyze their current application status and development trends within the circular economy framework, and assess the advantages and limitations of different technologies through case studies. The research will propose optimized technology combinations and policy recommendations to provide theoretical support and practical guidance for the sustainable development of waste-to-energy solutions.