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Complementary Roles of Chemical and Mechanical Recycling in Achieving Circular Waste PET Management Systems

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Introduction and Research Rationale

Polyethylene terephthalate (PET) plays a critical technological role in modern materials but presents persistent sustainability issues. Mechanical recycling, although efficient, cannot handle all PET waste streams, particularly those involving textiles or complex contamination[1]. Chemical recycling, while capable of treating these streams, is often associated with higher environmental burdens[2]. This study applies Life Cycle Assessment (LCA) to a microwave-assisted chemical recycling process and investigates its systemic role within future PET waste management scenarios in Europe, evaluating how combinations of recycling technologies affect environmental performance and circularity[3].

Results

The scenario analysis models the European PET market in 2040, exploring three configurations: one in which chemical and mechanical recycling are used in combination, a second where chemical recycling capacity is reduced, and a third that relies exclusively on mechanical recycling. The results show that when both technologies are integrated, greenhouse gas (GHG) emissions are lowest, with emissions amounting to 3505.6 kilotons of CO_2-eq under ideal mechanical recycling conditions. Eliminating chemical recycling leads to increased reliance on incineration and landfill, resulting in a steep increase in GHG emissions to over 8600 kilotons of CO_2-equivalent. This trend is exacerbated when accounting for the limited efficiency of mechanical recycling. Circularity indicators reinforce these findings: the first scenario achieves 65% material recovery, while the last falls to 49%. The data indicate that removing chemical recycling not only raises emissions but also reduces the system's ability to reintegrate PET, undermining both sustainability and circularity objectives.

Conclusions

The integration of chemical and mechanical recycling is critical to achieving low emissions and high circularity in PET waste management. The exclusion of chemical recycling leads to significantly higher environmental impacts and increased virgin PET dependency. This study demonstrates that a balanced, systems-oriented approach can effectively align environmental sustainability with circular resource use.

References

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