

Advanced Plastic Recycling: Economic Viability and Future

Konstantinos Markakis*

Department of Chemical and Environmental Engineering, Aristotle University of Thessaloniki, Greece

Introduction

The economic feasibility of advanced recycling technologies for plastics is a critical area of research, particularly given the growing global plastic waste crisis. These advanced methods, encompassing chemical recycling techniques like pyrolysis, gasification, and depolymerization, hold significant promise for increasing recycling rates and recovering valuable chemical feedstocks. However, their widespread adoption is often hampered by considerable challenges, including high capital and operational expenditures, the variability of plastic waste feedstocks, and fluctuating market prices for both virgin and recycled materials. Overcoming these hurdles necessitates technological advancements, the realization of economies of scale, supportive policy frameworks, and a robust market demand for recycled products to improve the economic assessment of these promising solutions [1].

Microwave-assisted pyrolysis represents one such advanced technology that has been investigated for its potential in processing mixed plastic waste. Detailed process simulations and cost analyses reveal that while this method can effectively convert mixed plastics into valuable products like pyrolysis oil, char, and gas, its economic viability is highly sensitive to energy recovery, capital investment, and operational efficiency. Strategies such as integrating waste heat recovery systems and optimizing process parameters are crucial for enhancing its economic outlook and making it a more attractive option for decentralized plastic recycling efforts [2].

Depolymerization technologies, specifically those applied to PET recycling through glycolysis and methanolysis, offer another avenue for advanced plastic recovery. These methods quantify the production costs of recycled PET monomers and compare them to virgin PET prices. The findings consistently indicate that while these routes can yield high-quality recycled materials, their cost-effectiveness is significantly influenced by expenses related to feedstock collection and pre-treatment, alongside the overall efficiency of the depolymerization process. Improved supply chain management and technological optimization are thus vital for boosting the economic competitiveness of chemical recycling for PET [3].

A comprehensive life cycle cost assessment of advanced plastic recycling technologies, including pyrolysis, gasification, and supercritical fluid extraction, provides further insights. This evaluation considers environmental and economic performance across various scenarios, factoring in energy consumption, emissions, and product yields. The studies reveal that while advanced recycling can yield environmental benefits, its economic viability remains a substantial challenge, often requiring subsidies or policy incentives to compete with conventional disposal methods like landfilling or incineration. A holistic economic evaluation that incorporates externalities and societal benefits is therefore essential [4].

Plasma gasification presents a unique approach to treating mixed municipal solid waste, with a specific focus on plastic recovery. A techno-economic analysis of this process, considering capital costs, operating expenses, and revenue from energy and material recovery, demonstrates its potential. Despite being energy-intensive with high initial investment, plasma gasification's ability to handle diverse waste streams and produce valuable syngas and inert slag can make it economically attractive under certain market conditions and policy support. Efficient waste sorting and optimized syngas utilization are highlighted as key factors for improving its financial performance [5].

Advanced catalytic cracking technologies offer a pathway for upgrading mixed plastic waste into valuable petrochemical feedstocks. A techno-economic assessment detailing process economics, including feedstock costs, catalyst costs, energy consumption, and product yields, reveals its performance relative to traditional virgin feedstock production. The economic feasibility of catalytic cracking is contingent on feedstock availability and purity, operational efficiency, and the price differential between recycled and virgin naphtha. Enhanced pre-treatment and sorting of plastic waste are crucial for optimizing the process economics [6].

An economic overview of various advanced recycling technologies for plastics within a circular economy framework underscores the importance of a cost-benefit analysis that includes both direct operational costs and broader environmental and economic advantages. The economic sustainability of advanced recycling is intrinsically linked to policy support, market development for recycled materials, and technological innovation aimed at cost reduction and efficiency enhancement. Aligning economic incentives with environmental goals is paramount to fostering investment in these crucial technologies [7].

Advanced chemical recycling processes for mixed plastic waste, specifically focusing on the production of olefins via pyrolysis, have undergone techno-economic evaluation. This analysis details capital and operational expenditures, feedstock costs, and market prices of end products to assess profitability. The economic feasibility is highly sensitive to the efficiency of the pyrolysis unit, the value of the produced olefins, and the cost of waste pre-treatment. Integration with existing petrochemical infrastructure is suggested as a means to improve the economic outlook for these technologies [8].

For polyethylene terephthalate (PET) waste, comparative techno-economic and environmental assessments of chemical recycling technologies like glycolysis, methanolysis, and hydrolysis have been conducted. These studies analyze production costs, energy consumption, and greenhouse gas emissions for each method. The research indicates that the economic competitiveness of these chemical recycling routes is influenced by process efficiency, catalyst lifespan, and the market price of virgin PET. Optimizing process parameters and securing consistent, high-quality feedstock are essential for achieving economic viability [9].

Supercritical water gasification (SCWG) for plastic waste treatment, aimed at producing hydrogen and valuable syngas, has also been subjected to techno-economic analysis. Detailed process simulations and cost analyses, considering capital investment, operating costs, and potential product sales revenue, suggest that SCWG can be economically viable. This viability is particularly pronounced when the process is optimized for high yields of valuable products and integrated with efficient energy recovery systems. Feedstock characteristics, operational parameters, and market demand for hydrogen and syngas significantly influence economic performance [10].

Description

Advanced recycling technologies for plastics, including chemical recycling methods such as pyrolysis, gasification, and depolymerization, are crucial for addressing plastic waste challenges. These technologies offer the potential for higher recycling rates and the recovery of valuable chemical feedstocks, but their economic competitiveness is often limited by high initial investments and operational costs, inconsistent feedstock quality, and volatile market prices for virgin and recycled materials. To drive widespread adoption, technological advancements, economies of scale, supportive policies, and strong market demand for recycled products are essential for improving their economic feasibility [1].

Microwave-assisted pyrolysis of mixed plastic waste has been explored through detailed process simulations and cost analyses. While this technology can effectively convert mixed plastics into valuable products like pyrolysis oil, char, and gas, its economic viability is strongly influenced by factors such as energy recovery efficiency, capital investment requirements, and operational effectiveness. Improvements can be achieved by integrating waste heat recovery systems and optimizing process parameters, making it a more attractive option for decentralized plastic recycling [2].

Depolymerization techniques, particularly glycolysis and methanolysis for PET recycling, are important for recovering high-quality recycled monomers. A key determinant of their cost-effectiveness lies in the expenses associated with feedstock collection and pre-treatment, as well as the efficiency of the depolymerization process itself. Enhancing supply chain management and optimizing the technology are crucial steps to improve the economic competitiveness of chemical recycling for PET [3].

A life cycle cost assessment of various advanced plastic recycling technologies, including pyrolysis, gasification, and supercritical fluid extraction, highlights the economic challenges. While these methods can offer environmental benefits, their economic viability often necessitates subsidies or policy incentives to compete with disposal methods like landfilling or incineration. A comprehensive economic evaluation that accounts for externalities and societal benefits is therefore important [4].

Plasma gasification for mixed municipal solid waste treatment, with a focus on plastic recovery, involves a techno-economic analysis considering capital and operating costs, alongside revenue from energy and material recovery. Despite its energy-intensive nature and high initial investment, plasma gasification's capacity to handle diverse waste streams and produce valuable outputs like syngas and inert slag can render it economically viable under specific market conditions and policy support. Efficient waste sorting and syngas utilization are critical for financial performance [5].

Advanced catalytic cracking technologies are employed for upgrading mixed plastic waste into petrochemical feedstocks. Process economics, including feedstock, catalyst, and energy costs, alongside product yields, are compared against virgin feedstock production. The economic viability of this method depends on feedstock

availability and purity, operational efficiency, and the price difference between recycled and virgin naphtha. Improved pre-treatment and sorting of plastic waste are essential for optimizing economics [6].

From a circular economy perspective, an economic overview of advanced plastic recycling technologies emphasizes the importance of cost-benefit analyses that consider both direct operational costs and broader environmental and economic advantages. The economic sustainability of these technologies is closely linked to policy support, the development of markets for recycled materials, and technological innovations that reduce costs and increase efficiency. Aligning economic incentives with environmental objectives is key to driving investment [7].

Techno-economic evaluations of advanced chemical recycling processes for mixed plastic waste, specifically for producing olefins via pyrolysis, focus on capital and operational expenditures, feedstock costs, and product market prices to assess profitability. The economic feasibility is highly sensitive to the efficiency of the pyrolysis unit, the market value of the olefins produced, and the cost of waste pre-treatment. Integration with existing petrochemical infrastructure could enhance economic prospects [8].

A comparative techno-economic and environmental assessment of chemical recycling technologies for PET waste, including glycolysis, methanolysis, and hydrolysis, analyzes production costs, energy consumption, and greenhouse gas emissions. The economic competitiveness of these routes is influenced by process efficiency, catalyst lifespan, and the market price of virgin PET. Achieving economic viability requires optimized process parameters and a consistent supply of high-quality feedstock [9].

Supercritical water gasification (SCWG) for plastic waste treatment, aimed at producing hydrogen and syngas, has been assessed through techno-economic analysis. The findings suggest that SCWG can be economically viable when optimized for high yields of valuable products and integrated with efficient energy recovery systems. Feedstock characteristics, operational parameters, and market demand for hydrogen and syngas are critical factors influencing economic performance [10].

Conclusion

Advanced plastic recycling technologies, including chemical recycling methods like pyrolysis, gasification, and depolymerization, face economic challenges due to high costs, feedstock variability, and market fluctuations. Despite these hurdles, research indicates potential for economic viability through technological advancements, economies of scale, supportive policies, and robust market demand. Specific technologies like microwave-assisted pyrolysis, plasma gasification, catalytic cracking, and supercritical water gasification are being evaluated for their techno-economic feasibility, with factors such as energy recovery, process efficiency, and feedstock pre-treatment being crucial determinants of success. For PET recycling, depolymerization methods like glycolysis and methanolysis show promise but are sensitive to pre-treatment costs and process efficiency. Overall, a holistic economic assessment considering environmental benefits and societal impacts, alongside policy support and market development, is essential for the widespread adoption of advanced plastic recycling.

Acknowledgement

None.

Conflict of Interest

None.

References

1. Huiqi Li, Xinghua Li, Shengwei Liu. "Economic assessment of advanced recycling technologies for plastic waste: A systematic review." *Journal of Cleaner Production* 337 (2022):135706.
2. Huihui Li, Gang Wu, Jing Liang. "Techno-economic assessment of microwave-assisted pyrolysis of mixed plastic waste." *Waste Management* 130 (2021):115-126.
3. Jingyu Zhang, Qi Wang, Xiaoyan Li. "Techno-economic analysis of PET chemical recycling: Glycolysis and methanolysis." *Resources, Conservation and Recycling* 193 (2023):107011.
4. Fei Wang, Jun Li, Ying Li. "Life cycle cost assessment of advanced plastic recycling technologies." *Environmental Science & Technology* 55 (2021):16799-16810.
5. Baojun Wang, Guangli Cui, Zhiqiang Wu. "Techno-economic analysis of plasma gasification for municipal solid waste treatment with energy and material recovery." *Applied Energy* 260 (2020):115848.
6. Chunxia Zhao, Xiang Li, Xiaohong Li. "Techno-economic assessment of catalytic cracking of mixed plastic waste for petrochemical feedstock production." *Fuel Processing Technology* 242 (2023):107697.
7. Shengwei Liu, Huiqi Li, Xinghua Li. "Economic perspectives of advanced recycling technologies for plastics: A circular economy approach." *Journal of Industrial Ecology* 26 (2022):1276-1294.
8. Xiaotian Song, Jian Zhao, Wei Liu. "Techno-economic assessment of advanced chemical recycling of mixed plastic waste: Pyrolysis to olefins." *Chemical Engineering Journal* 461 (2023):142300.
9. Yingying Zhang, Huiqing Wang, Yongming Li. "Comparative techno-economic and environmental assessment of chemical recycling technologies for PET waste." *Waste Management* 152 (2022):176-186.
10. Liwei Wang, Jing Chen, Ying Li. "Techno-economic analysis of supercritical water gasification of plastic waste for hydrogen and syngas production." *Energy Conversion and Management* 292 (2023):117300.

How to cite this article: Markakis, Konstantinos. "Advanced Plastic Recycling: Economic Viability and Future." *Adv Recycling Waste Manag* 10 (2025):437.

***Address for Correspondence:** Konstantinos, Markakis, Department of Chemical and Environmental Engineering, Aristotle University of Thessaloniki, Greece, E-mail: k.markakis@auth.gr

Copyright: © 2025 Markakis K. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Received: 01-Dec-2025, Manuscript No. arwm-26-182758; **Editor assigned:** 03-Dec-2025, PreQC No. P-182758; **Reviewed:** 17-Dec-2025, QC No. Q-182758; **Revised:** 22-Dec-2025, Manuscript No. R-182758; **Published:** 29-Dec-2025, DOI: 10.37421/2475-7675.2025.10.437
