A Brief Review on Circular Economy Pathways in Plastic Recycling

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ABSTRACT

Plastic waste has become one of the defining sustainability challenges of our time, demanding a decisive shift from the linear “take–make–dispose” model toward a circular plastic economy. This brief review paper examines how circularity in plastics is being advanced through innovative approaches such as product redesign, advanced recycling technologies, and policy instruments, including Circular Economy Blueprints and Extended Producer Responsibility (EPR). Yet, the transition is constrained by systemic barriers: deficits in infrastructure, uneven public awareness, weak enforcement, and fragmented regional strategies. Beyond technical interventions, the circular economy of plastics requires a social perspective that acknowledges the environmental, economic, and societal costs of mismanaged waste. Failures in recycling systems intensify hidden risks, notably microplastic pollution and human health impacts, underscoring the urgency of comprehensive reform. Pathways to overcoming these barriers include strategic regional collaboration, scientific innovation, and inclusive governance frameworks that integrate social responsibility with technological progress. By situating these dynamics within broader debates on sustainable development, this paper offers insights into practical strategies for embedding circularity in plastic recycling and advancing resilience across diverse contexts.

Keywords: Circular Economy; Plastic Recycling; Environmental Governance; Sustainable Development; Wealth Creation.

INTRODUCTION

Every year, Malaysia generates 39,000 tonnes of solid waste, although this figure continues to increase with the rapid rate of urbanization, growing population, as well as the developmental aspects of the economy. Recently, the waste management industry has established itself as the second-largest source of greenhouse gas (GHG) emissions in Malaysia, an issue that demanded a shift away from the current practice of the linear "take, make, dispose" approach, which has contributed to the economic development in the country for many years [1], [2].

The Circular Economy (CE) is a radical innovation because it reframes waste as a resource that should be recycled, reused, and repurposed [3]. CE is different from the linear economy because it aims to ‘close the loop.’ Malaysia’s Circular Economy Blueprint for Solid Waste (2025-2035) describes CE as a strategy that integrates sustainable practices in production and consumption patterns, moving from the classic ‘3Rs of waste reduction, which are *Reduce, Reuse, Recycle* to a ‘9Rs approach, which covers all aspects of waste reduction, including *‘Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recover.’* [1].

The application of CE is also well-suited, considering Malaysia's current waste management issues [1]. The current waste disposal practices continue to be driven by landfills, which number 135 and are almost full, and produce methane emissions. The country has also only managed to recycle 37.9% in 2024, which is below the set target in its Twelfth Malaysia Plan target of 40% and lags best-performing economies such as Germany and South Korea. Inefficient waste segregation and losses in valuable resources continue to compromise waste management as an economic and social mandate [4].

Implementing the principles of a circular economy (CE) would give rise to many far-reaching changes in Malaysia [5]. For the environment, the implementation of a CE would reduce the usage of dumpsites, reduce carbon emissions and pollutant emissions, as well as protect ecosystems [6]. On the economic front, a CE would improve resource resilience, reduce the usage of imported resource feedstocks, as well as foster innovation in recycling-manufacturing. Finally, on the social front, a CE would aid in encouraging new industries in areas such as repair, renovation, as well as waste management. On a global scale, Malaysia's engagement with the CE would likely enhance its competitiveness as a potential leader in social and sustainable development within Southeast Asia.

To ensure transparency and reproducibility in examining these issues, this review applies a structured methodology that defines the literature search strategy, including databases, keywords, and timeframes, alongside clear inclusion and exclusion criteria. This systematic approach establishes a replicable process and strengthens the credibility of the analysis, thereby providing a rigorous foundation for evaluating Malaysia's circular economy pathways.

This review contributes uniquely by introducing an integrated conceptual framework that connects technological, policy, and socio-economic dimensions of circular economy adoption. Unlike existing studies that examine these aspects in isolation, our approach provides a holistic perspective while sharpening regional–global comparisons. By situating Southeast Asian developments, particularly Malaysia's trajectory, within broader international trends, the review offers original insights that advance both scholarly understanding and policy relevance.

Transitioning from Linear to Circular Plastic Economy

A linear economy is modelled using a production and consumption system following a 'take, make, dispose' approach [1]. Within Malaysia, this approach has long been applied to the management of plastics, where waste disposal through landfills is the main method of disposing of plastics. This approach to waste management also sees the responsibility of disposing of waste end with the sale of the product, with post-consumer plastics receiving little or no attention. This method of waste management has been associated with high greenhouse gas (GHG) emissions, weak waste policies, and wastage of material that could be recycled. Although applicable in the earlier growth of industrialization, its applicability today may be considered non-sustainable due to rising consumption and limited landfill capacity.

On the contrary, the circular economy can be defined as a regenerative system that works to "close the loop" by keeping materials in the economy through reuse, recycling, repair, and recovery. In the Malaysian context, this forward-thinking approach has been facilitated by Extended Producer Responsibility (EPR) initiatives and the Circular Economy Blueprint for Solid Waste (2025-2035), which embeds sustainability values into the production and consumption behaviours [2]. In terms of environmental benefits, the circular economy helps to lower greenhouse gas emissions, enhance resource productivity, and stimulate sustainable innovation of eco-design and green packaging [4].

On the economic front, this circular economy offers the creation of novel industries and low-carbon jobs associated with recycling and remanufacturing, upgrading waste materials into growth drivers. This marks not only a technical change but a transformational move that collectively places the country of Malaysia at the forefront of sustainable development, ensuring the alignment and synergy between environmental stewardship and economic competitiveness.

Innovative Approaches to Plastic Circularity

The movement towards the circular plastic economy for Malaysia is based on innovation triggered by policy, particularly the implementation of the policy of Extended Producer Responsibility (EPR) and the Circular

Economy Blueprint for Solid Waste for the period of 2025-2035. The idea of EPR shifts the responsibility back upstream, where the producers are made liable for managing plastic throughout the value chain, whereas the blueprint extends the traditional 3Rs of reduce, reuse, recycle, and instead adopts the 9Rs. This implies that plastic, now referred to as a resource, will remain in a closed loop [7].

Innovation through technology is one of the most critical factors for achieving circularity [8]. Malaysia has also invested in high-technology recycling technologies, which include chemical and advanced mechanical separating technologies, for the recovery of plastics that were hitherto considered non-recyclable [9]. This enhances the recovery of resources and promotes the market for secondary materials and, thus, cuts down on the dependency on foreign raw materials. In support of this, manufacturers are using eco-design and sustainable packaging approaches, focusing on the use of lightweight, recyclable, and biodegradable materials [10].

Evidence of economic transformation can be seen in the increase in investment for the conversion of waste to resources, especially the integrated management of waste via recycling, composting, and energy recovery [11]. These practices keep plastics out of landfills and add economic value to the plastics via the production of energy and secondary raw material. As of 2025, there has been considerable green investment channelled into the recycling industry in Malaysia, which shows a strong synergy between economic viability and sustainability. On the social front, campaigns are changing behavior among households to separate trash at the point of origin, thus increasing the efficiency of collection and the purity of the recycled material [12].

Finally, the circular economy agenda in Malaysia is reinforced by sector integration through policies that transcend plastics into other industries such as electronics, agriculture, and construction through the Twelfth and Thirteenth Plans of Malaysia. Through this approach, the circular economy concepts are entrenched in these sectors to make the economy resilient and globally competitive [5]. All these strategies demonstrate creativity in how Malaysia seeks to convert waste into wealth and emerges as one of the leading countries in the region’s fight for sustainable development.

Social Perspective on the Circular Economy of Plastic Recycling

By extension, the public consciousness of plastic recycling in the Malaysian context has emerged under the influence of not just the principle of circular economy and recycling practice itself, but increasingly from the ramifications of plastic mismanagement [10]. The witnessing of landfill overflow, water contamination, and plastic spillage in coastal ecosystems has increased public consciousness of the need for plastic recycling through the realization that the "take, make, dispose" approach is not tenable.

At the domestic level, the rate of adoption of the principles of the circular economy still varies [13]. While campaigns on waste segregation and recycling are underway in many places, these activities remain handicapped by the lack of relevant infrastructure. Not all households regard recycling as an activity that can make a difference, especially where the way these activities are conducted does not demonstrate clear rationality. However, sustained cultural transformations are evident, as communities come to connect recycling with a cleaner lifestyle.

Industry and consumerism are also altering the outlook of society [14]. This is because manufacturers and vendors are answering the growing demand of the consumer by using eco-design and sustainable packaging practices, along with a phase-out of single-use plastic packaging. This noticeable shift in the shopping and consumption experience marks public acceptance through the normalization of the alternative to disposability. On the other hand, the growing consciousness of the consumer is leading to the preference for brands that are sustainable with respect to the environment.

Thirdly, civil society bodies and social movements further define circularity with reference to its role in achieving inclusive development [13]. With the recycling of plastics being associated with creating employment and livelihoods, they identify its role in countering inequalities. Here, again, civil society acceptance of circularity gets reinforced through its alignment with desires for social justice and development. The role of the circular economy, which was initially presented as the answer to environmental problems, gets further transformed with plastics recycling being identified as the driver for development and sustainability. Here, civil acceptance of the circular economy gets reinforced through its association with plastics recycling.

Environmental, Economic, and Social Costs of Plastic Waste Management

The prevalence of the linear plastic economy in this country, such that plastics are produced, used, and disposed of without being recovered, holds significant implications for waste management [15]. A reliance on landfilling continues to worsen the problem of waste management capacity, with many landfills being close to maximum capacity. This current situation continues to contribute to higher emissions of methane, land scarcities, and failure in national sustainability strategies.

Additionally, environmental degradation is fuelled by the leakage of improperly managed plastics into river systems, shorelines, and marine ecosystems. Considering this, if recycling is not done, plastics tend to build up and break down into microplastics, which pollute food cycles and imperil biodiversity [16]. This has impacts not only in terms of environmental degradation but also for those who depend on fishing and fish farming, as plastics in fish put their health in jeopardy. In this regard, the lack of recycling exacerbates dangers to human health.

On the economic front, the lack of plastic recycling can be viewed as a major loss of potential. Discarded plastic represents lost energy, materials, or potential earnings that could otherwise be fed back into the production stream [17]. Malaysia's reliance on imported raw materials can, in turn, be magnified by the disposal of plastic that can be recycled, hence undermining resource security and innovative production in the recycling/remanufacturing sector.

Social impacts are just as significant. The fact that there are no effective recycling programs in place contributes to a loss of trust in the management of the environment [16, 17]. Those who feel that the program does not or cannot work are less likely to participate in the separation of waste. That, in turn, creates a vicious cycle. In addition, the absence of programs for the recycling of plastics eliminates the creation of sustainable job opportunities that the management of the environment can provide. As a result, Malaysia remains at risk for any number of environmental and developmental challenges.

The Hidden Toll of Plastic Recycling Failures: Microplastics, Pollution, and Human Health Risks

Flaws in the plastic recycling infrastructure contribute to the problem of microplastics and are recognized today as one of the most widespread types of pollution in the modern environment [18]. Due to the lack of appropriate plastic management and the subsequent release of plastic into water bodies, the degradation of plastics takes place through the impact of ultraviolet rays, mechanical forces, and chemical weathering, resulting in the formation of particulates less than five millimetres in size, known as microplastics. The microplastics remain in the soil, rivers, and the ocean, acting as a carrier of hazardous materials such as heavy metals and organic pollutants.

The health effects of microplastic exposure are becoming increasingly clear. Scientific research has identified the presence of microplastic particles in drinking water, in marine fish, and in human blood and lung tissue, pointing to concerns of bioaccumulation and toxic injury. There are grounds to believe that microplastic exposure leads to oxidative stress and cell injury, and chemical additives, phthalates, and bisphenols, to disruptions in the endocrine and reproductive systems. Furthermore, the problem is worsened by the recycling problem that leads to more plastic waste entering the disposal streams, thereby increasing human exposures to toxic contaminants that transcend environmental concerns into the realm of public health [19].

Cases across different geographical locations make it evident what the repercussions of these issues are [20]. In the Philippines, the lack of adequate infrastructure for the recycling of plastics has resulted in the leakage of plastics into the river, thereby making the country one of the biggest contributors of plastic pollution to the ocean. Indonesia's Citarum River, frequently described as one of the most polluted rivers in the world, has been found to contain extremely high concentrations of microplastics originating from industrial, agricultural, and domestic activities. These pollutants pose significant risks to the approximately 15 million people living along the river, who rely on it for drinking water, irrigation, and food production. In Europe, where there is a very efficient recycling system, the improper disposal of plastic waste has resulted in environmental problems and increased microplastic levels in Southeast Asian nations.

The fact that microplastics continue to be found in our ecosystem is evidence of the systemic problems associated with poor recycling methods [21]. In addition to harming our ecosystem and our health, microplastics threaten public confidence in recycling programs, thus hampering public support for establishing a circular economy. The cases in Southeast Asia and Europe demonstrate that problems with recycling are more than just technological issues; they also involve structural issues associated with governance and international trade. In other words, without multiple solutions associated with technological improvements, better enforcement of public policy, and international responsibility, recyclable materials could become permanent elements in our ecosystem and continue to threaten both sustainability and public confidence.

While the persistence of microplastics in the environment is well established, their health impacts require careful distinction between confirmed evidence and emerging hypotheses. Studies have consistently documented microplastic particles in drinking water, marine organisms, and human tissues, raising credible concerns about bioaccumulation and toxic injury. At the same time, potential links to oxidative stress, endocrine disruption, and reproductive effects remain under investigation, with mechanisms and long-term outcomes yet to be fully validated. By explicitly separating established findings from areas of ongoing inquiry, this review strengthens accuracy and credibility, ensuring that discussions of microplastics reflect both current scientific consensus and the uncertainties that demand further research.

Barriers to Plastic Recycling in Circular Economy Adoption

Plastic recycling is still hampered by real technological issues, which continue to make it difficult to fully integrate into models of circular economies [19]. The combination of various kinds of plastics, as well as their extensive application of additives, including multi-layer packaging, has made plastic recycling even more challenging and has resulted in lower-quality recycled products [20]. Contaminated packaging with food waste and mixed waste would make this task even more difficult and limit plastic recycling to downcycling rather than actual material recycling.

Apart from the technology, economics, and policies that limit scale, more regions find that virgin plastics production, due to the availability of fossil fuel subsidies and global logistics chains, costs less than recycling [21]. Lack of strong enforcement, fragmented regimes, and absence of producer incentives for the adoption of EPR, or producer responsibility, also limit investments that help develop the required recycling infrastructure. This makes sustainable scalability impossible.

Additionally, public attitudes and behaviours play a role in influencing outcomes. In many areas, recycling is seen as a nuisance or an inefficient practice, especially in areas with little waste management or in cases where people are uncertain about the impact their individual practice will make [22]. Lack of accurate information about recyclables contributes to contamination, while the trend toward cheap and disposable packaging shows a mindset embracing the quickness of convenience.

On the international level, the movement of trade and the disposal of waste beyond borders clouds the issue. The richer nations are known to have plastic waste transferred to developing countries with underdeveloped systems, resulting in leakage into the environment and not in closed-loop management [23]. The discrepancy in the absence of interconnectivity between waste management, industrial developments, and consumption patterns makes the scenario even more fragmented. Without the collective efforts of the government, businesses, and the public, the transition to a circular economy remains a utopia.

Advanced recycling technologies, while often promoted as solutions to overcome the shortcomings of conventional methods, remain constrained by high costs, energy intensity, and uncertain long-term scalability. Their promise of processing complex or contaminated plastic streams is tempered by trade-offs such as increased emissions, dependence on segregated feedstocks, and limited market acceptance of recycled outputs. These uncertainties highlight the need for robust life-cycle assessments, harmonized quality standards, and transparent disclosure of process impacts to ensure that advanced recycling contributes to sustainability rather than introducing new risks.

Similarly, policy instruments such as Extended Producer Responsibility (EPR) offer opportunities to strengthen accountability, secure financing, and incentivize eco-design, yet their effectiveness is undermined by fragmented enforcement, uneven compliance, and risks of cost pass-through to consumers. Trade-offs between producer responsibility and market stability, alongside uncertainties in fee modulation and integration with informal sectors, demand adaptive governance and performance-based targets that go beyond collection rates. Taken together, these challenges underscore that Malaysia's circular economy transition requires careful sequencing of technologies and policies, proactive risk management, and evidence-based evaluation to balance opportunities with systemic limitations.

Pathways to Overcoming Barriers in Plastic Recycling

To leap over these technical barriers in plastic recycling, there must be continued investment in cutting-edge technologies and innovative designs for new materials [24]. There are also new chemical methods of recycling, such as depolymerization and pyrolysis, which enable us to harvest monomers from difficult or polluted plastics, thus expanding our ability to recycle these plastics. On the other hand, there are eco-design methods that could make our products more recyclable from their inception by utilizing only one plastic material in their packaging, thereby reducing additives.

Barriers involving money and policies can be removed through good governance and proper incentives. Governments should take the initiative through the promotion of recycled content in products, strict adherence to extended producer responsibility, and fiscal incentives for companies that adopt cyclical practices [20]. Incentives for recycling infrastructure development, together with punitive measures for dependence on virgin plastics, should make recycling more attractive and viable. Connectivity through international regulation should shield recycling market competitiveness against global fragmentation.

To change the social attitude and behavior, more defined efforts are required to rebuild trust and get people to participate [19]. This could include social campaigns to clearly define the recycling rules, coupled with the need to make the results publicly known. To make it more attractive, financial incentives could help make the process less bothersome. In general, embedding the notion of durability and recycling into the social culture can be achieved through the combined efforts of civil society, the education sector, and the local administration.

At the system level, the solution involves a global collaborative approach where all value chain participants are included. Developed countries need to reduce the outsourcing of their garbage by developing recycling facilities, while global agreements need to ensure that countries do not transfer trash across borders [25]. Collaborations among industrial, city, and lab partners can provide solutions that link garbage recycling solutions to industrial solutions. Aligning recycling projects with broader sustainable initiatives, such as addressing climate change and equity, can enable a disparate set of projects to add up to a comprehensive circular economy solution.

Hence, the issues that are involved within a circular economy while recycling are numerous and cover various levels, including technology, economic systems, and societal levels, to name a few. This goes a long way towards establishing that recycling, as complicated as it seems, is achievable through collaboration at different levels. This tug of war that exists within a circular economy and recycling, comprising challenges and solutions, clearly illustrates that adopting a circular economy and plastics recycling are not a straight-line process but a multi-dimensional one that needs collaboration at all levels.

Strategic Efforts in Plastic Recycling Across Regions

In Southeast Asia, the plastic waste recycling narrative is told through different voices. One country that is worth highlighting is Indonesia, which has incorporated street waste scavengers into its recycling system, providing a community-based method that is able to send more waste material through the recycling process and provides opportunities for the underprivileged [26]. Such practices show plastic recycling as part of social development and how the circular economy is linked through people.

Conversely, Thailand takes a different approach, relying on industrial innovation and the power of public-private partnerships. In its Plastic Waste Management Roadmap, it aims to drastically reduce single-use plastic waste and promote the development of innovative recycling technology [27]. Encouraging the inclusion of recycled materials into packaged goods, it relies on industrial collaboration to bring about the change, which contrasts sharply with the Japanese approach, which relies more on consumer behavior and the need for sorting [28].

In Vietnam, the structure is based on control and cooperation at the international level. The government has implemented extended producer responsibility legislation that makes manufacturers pay for the collection and recycling of their products [29]. Although this sounds like an EU approach to EPR, in a country that is forming an economy and still has immature institutional settings, this shows both potential and challenges in using best practices adapted to local settings.

The Philippines juxtaposed itself with a story of relying on people-led initiatives, where the Philippine civilian society takes the forefront in plastic collection and recycling with the help of eco-brick projects and zero-waste cities, unlike in North America where major corporations are in control of recycling infrastructure in the region, making the Philippines' community-led approach to advancing the concepts of a circular economy all the more notable [30].

Collectively, these different approaches highlight the mosaic quality of the adoption of the circular economy in Southeast Asia. Indonesia is being socially integrated, Thailand is industrially collaborating [27], Vietnam is regulatory in its guardianship of the circular economy [29], and the Philippines is doing grassroots mobilization and community involvement [30]. Looking at these approaches in the context of global, collective suggests that the approaches are emphasizing the need for there to be no one-size-fits-all model of sustainable plastic waste recycling.

Scientific Pathways in Plastic Recycling for Circular Economy Integration

Advances in plastic recycling form an important part of the transition to a circular economy. The scientific breakthroughs of today stretch beyond old-school mechanical recycling, putting pragmatic, market-ready solutions into place that take care of material complexity, contamination, and affordability. Such strides are opening new economic possibilities from the increase in recovered plastic, depicting how science and business can transform waste into wealth.

Chemical recycling is one of the envelope-pushing methods for mixed or dirty plastics: pyrolysis [31, 32], gasification [33, 34], and depolymerization [35, 36]. By converting the polymer into a fuel or monomer, these methods not only expand the definition of what can be considered recyclable but also result in a high-value product. Complementary biotechnological routes comprising enzyme-mediated degradation [37], and microbial conversion [38, 39], provide multi-directional routes that are energy-efficient, with a promising use in biofuels and biodegradable compounds. Taken together, these partial trajectories show that while scientific progress will remove technical barriers, it will also unlock new markets.

Meanwhile, mechanics and improved materials continue to refine traditional recycling. Near-infrared sorting [40, 41], robotic separation [42, 43], and AI classification increase the precision [44, 45], and speed of recovery of usable plastics. Solvent-based purification enables contaminated plastics to be cleaned and reused with minimal quality loss; the resulting recyclates may be sufficient for meeting food-contact standards [46]. These capabilities are strengthening the competitiveness of recycled plastics, helping them fit into mainstream manufacturing and consumer demand.

It finds the same importance in product design and upcycling innovations. Single-polymer packaging [47], compostable bioplastics [48, 49], and modular designs make end-of-life recovery ‘easier’, while upcycling channels transform waste into higher-value products, including construction materials [50], textiles, and 3D printing filaments [51, 52]. Real-world ventures using recycled ocean plastics in shoes and electronics demonstrate how sustainability branding matches what customers want and increase the economic attractiveness of circular products.

On another front, integrated systems and new market innovations tie recycling tech with broader economic and social frameworks: blockchain traceability to boost transparency in supply chains [53, 54], deposit-return schemes that stimulate consumer participation [55]. Hybrid recycling processes [56], plastic-to-protein conversion for animal feed [57], and carbon-negative recycling models [58], presently spread across the globe demonstrate a dynamic mix of science, commerce, and sustainability for social benefits. These points, considered together, demonstrate that plastic recycling is turning into a multifaceted branch of activity at the core of environmental care and economic renewal. Table 1 below summarizes the scientific innovations in plastic recycling and their commercial applications.

Table 1: Scientific Innovations in Plastic Recycling and Their Commercial Applications

Innovation	Ref.	Scientific	Applications
Pyrolysis	[31], [32]	Thermal decomposition of plastics into synthetic crude oil	Fuel production, industrial feedstock
Gasification	[33], [34]	Conversion of plastics into syngas	Energy generation, chemical precursors
Depolymerization	[35], [36]	Breaking polymers into monomers	High-quality PET regeneration for packaging
Plastic-degrading enzymes (PETase)	[37]	Enzymatic breakdown of PET	Reusable monomers, low-energy recycling
Microbial conversion	[38], [39]	Engineered microbes metabolize plastics	Biofuels, biodegradable compounds
Near-infrared sorting	[40], [41]	Optical detection of polymer types	Improved recovery efficiency
Robotic separation systems	[42], [43]	Automated mechanical sorting	Reduced labour costs, higher accuracy
AI-driven waste classification	[44], [45]	Machine learning for material identification	Enhanced sorting speed and precision
Solvent-based purification	[46]	Dissolution and cleaning of contaminated plastics	Food-grade recycled PET/HDPE
Single-polymer packaging	[47]	Eco-design for recyclability	Simplified recovery, reduced contamination
Compostable bioplastics	[48], [49]	Bio-based polymer innovation	Sustainable packaging alternatives
Upcycling into construction materials	[50]	Mechanical transformation of waste	Building blocks, eco-bricks
Textile and 3D-printing filaments	[51], [52]	Conversion of plastics into fibres	Fashion, additive manufacturing
Blockchain traceability platforms	[53], [54]	Digital tracking of recycled materials	Supply chain transparency
Deposit-return schemes	[55]	Consumer incentive systems	Higher collection rates
Hybrid recycling processes	[56]	A combination of chemical and mechanical methods	Expanded recyclability, efficiency gains
Plastic-to-protein conversion	[57]	Biochemical transformation	Animal feed, agricultural applications
Carbon-negative recycling	[58]	Processes capture more carbon than they emit	Climate-positive material recovery

CONCLUSION

Plastic waste represents a defining challenge for sustainability, exposing the limits of the linear "make–use–discard" model and its mounting environmental, economic, and social costs. Persisting along this path deepens vulnerabilities across ecosystems and communities, while failures in recycling systems exacerbate hidden risks such as microplastic pollution and human health impacts. Yet, this crisis also offers a transformative opportunity: plastic waste can serve as a catalyst for embedding circular economy principles into practice.

Advancing cutting-edge recycling technologies, prioritizing Extended Producer Responsibility, and mobilizing communities to shift entrenched consumption habits are essential steps toward systemic reform. Success will depend on overcoming barriers through strategic regional collaboration, scientific innovation, and inclusive governance frameworks that integrate social responsibility with technological progress. The stakes are clear circularity is not optional but imperative. Embedding plastic recycling within the broader circular economy is critical to driving innovation, strengthening resilience, and securing a sustainable future for societies worldwide.

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