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Review Article

# Evolving Textile Recycling: A Review on Technologies, Challenges and Future Outlook

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## ABSTRACT

The rapid expansion of the textile and fashion industries has led to a significant increase in global textile waste, posing serious environmental concerns. As one of the largest global contributors to waste, the textile sector urgently needs innovative, sustainable recycling solutions. This review paper critically examines recent advancements in textile recycling, including mechanical, chemical, and biochemical methods, and compares their efficiency and economic feasibility. It also highlights the role of emerging technologies such as artificial intelligence-assisted sorting, fiber regeneration through circular approaches and supportive global policy frameworks. By addressing key research gaps, this paper provides valuable insights for developing scalable and environmentally friendly textile recycling strategies. It evaluates their sustainability impact and proposes an outlook focused on circular economy, policy integration, and societal transformation. The review emphasizes for the need that integrating AI-based sorting, scalable biochemical recycling, and robust policy frameworks is essential to achieving a circular textile economy.

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# 1. Introduction

The textile industry is one of the largest contributors to global economic development, yet it remains a major source of environmental stress. The global textile industry has experienced exponential growth driven by rising consumer demand and the rapid expansion of fashion trends. However, this rapid development has led to a substantial increase in textile waste, posing significant environmental and sustainability challenges. The prevailing linear model take, make, dispose has led to excessive waste generation and unsustainable resource consumption. With approximately 92 million tonnes of textile waste generated annually, the environmental burden on landfills, water systems, and ecosystems is significant [1]. The textile industry predominantly operates under a linear model of take–make–dispose, leading to significant environmental and economic losses, with over USD 500 billion in value lost annually due to underutilization and a lack of recycling [2]. Microfibres -based textiles have been identified as another major contributor to global microplastic pollution, accounting for up to 35% of primary microplastics in marine environments [3].

From a societal perspective, the implications extend beyond environmental degradation. Textile waste management affects public health, urban infrastructure, employment patterns, and resource equity. The growing awareness of sustainability has necessitated a transition toward circular-economy models, where recycling plays a central role.

Textile waste is a major contributor to landfill overflow, with synthetic fibers shedding microplastics and chemical dyes leaching into water bodies, causing long-term harm to the ecological system. The conventional production model, such as take-make-dispose, is no longer viable, necessitating a shift toward circular economy practices in which textile recycling plays a pivotal role in reducing waste accumulation, conserving resources, and minimising pollution [4].

Despite the growing emphasis on sustainability, existing textile recycling techniques remain suboptimal, hindered by technological, economic, and logistical challenges. Mechanical recycling, one of the most widely used methods, often results in fiber degradation and loss of textile quality, making it less suitable for high-end applications. Chemical recycling, including processes such as enzymatic hydrolysis and glycolysis, holds promise in recovering monomers from synthetic fibers. Yet challenges such as high energy demands, cost barriers, and process scalability limit its widespread adoption. Recent advancements, such as Artificial Intelligence-driven waste segregation technologies and enzymatic fibre breakdown, aim to enhance recycling efficiency and bridge the gap between sustainability and economic viability.

Current textile recycling methods focus on mechanical, chemical, and biochemical approaches. Secondary sources of literature have been explored to conduct a comparative analysis of these methods in terms of efficiency, environmental impact, and economic feasibility. This study provides insights into scalable and sustainable recycling solutions. Furthermore, this article explores policy interventions that support the transition to a circular economy and also highlights global initiatives such as the European Union's Extended Producer Responsibility (EPR) framework and China's Waste-Free Cities Initiative. Given the pressing need to integrate circular economy principles at the design stage, the paper aims to identify research gaps and propose strategies for advancing sustainable textile waste management. The rapid growth of fast fashion has significantly increased textile production and waste generation, intensifying environmental pressures and challenging the effectiveness of recycling-based solutions alone [5].

This paper focuses on how technological advancements in textile recycling can contribute not only to environmental preservation but also to societal well-being and economic resilience.

However, the environmental performance of different recycling technologies varies widely and depends on multiple factors. Various life cycle assessment studies suggest that climate impacts can vary significantly depending on the type of recycling process, waste composition, and system boundaries. Therefore, a critical comparison of these technologies is essential to identify the most effective strategies for achieving a circular and sustainable textile system [6].

## 2. Textile Waste and Its Impact

The current textile industry is highly resource-intensive and generates significant waste. The industry consumes approximately 98 million tonnes of non-renewable resources annually and generates around 1.2 billion tonnes of greenhouse gas emissions, making it a major contributor to climate change, whereas the production of textiles requires approximately 93 billion cubic meters of water per year, which further increases water footprints.

Textile waste is not merely an environmental issue but a socio-economic challenge. Its impact spans multiple dimensions:

- Environmental Impact: Landfills, microplastic pollution, and greenhouse gas emissions
- Public Health: Toxic dye leaching and air pollution from incineration
- Economic Loss: Underutilization of valuable raw materials
- Social Inequality: Waste dumping disproportionately affects developing regions

Currently, less than 1% of textile waste is recycled into new fibres, indicating a major limitation in existing recycling systems [7]. The environmental footprint of the textile industry extends across the entire product life cycle, from raw material to final product and its disposal. Textile waste is a multifaceted issue that contributes to landfill overflows, resource depletion, and environmental pollution. The maximum use of synthetic fibers, like polyester and nylon, in the industry further adds to the sustainability concerns due to their non-biodegradable nature and microplastic release. To fully understand the environmental challenges posed by textile waste, it is essential to assess its impact at different process stages. Table 1 outlines the major environmental repercussions associated with textile production and end-of-life handling.

**Table 1.** Environmental impacts associated with each stage of the textile lifecycle

| Process Stage | Description | Environmental Impact |
|---|---|---|
| Raw Material | Involves the extraction of natural fibers and synthesis of synthetic fibers. | High water consumption for the cultivation of natural fibers, excessive energy use, and $CO_2$ emissions for petroleum-based fiber production. |
| Clothing in Use | Textiles are actively used before disposal. | Release of microplastics during washing, chemical drain from detergents, and wastewater contamination. |
| Ultimate Disposal | Approx. 80% of textiles are discarded via landfill/ incineration. | Landfills and incineration lead to the emission of gases such as Methane and carbon dioxide, and other toxic by-products. |
| Recycling | Limited (Approx. 20%) reuse of textiles. | Reduces landfill burden and environmental pollution but often have shorter lifespans, |
| Advanced Recycling | AI-assisted segregation, Chemical/ Enzymatic recycling, and fiber-to-fiber recovery. | More efficient material sorting; environmental impact varies based on process. |

Approximately 92 million tons of textile waste is generated annually, and the existing linear consumption model is unsustainable. Fast-fashion trends accelerate disposal rates, reducing the lifespan of clothing before it is discarded. While some textiles are reused or repurposed, only 20 % undergo proper recycling, leaving the remaining 80% in landfills or incinerators.

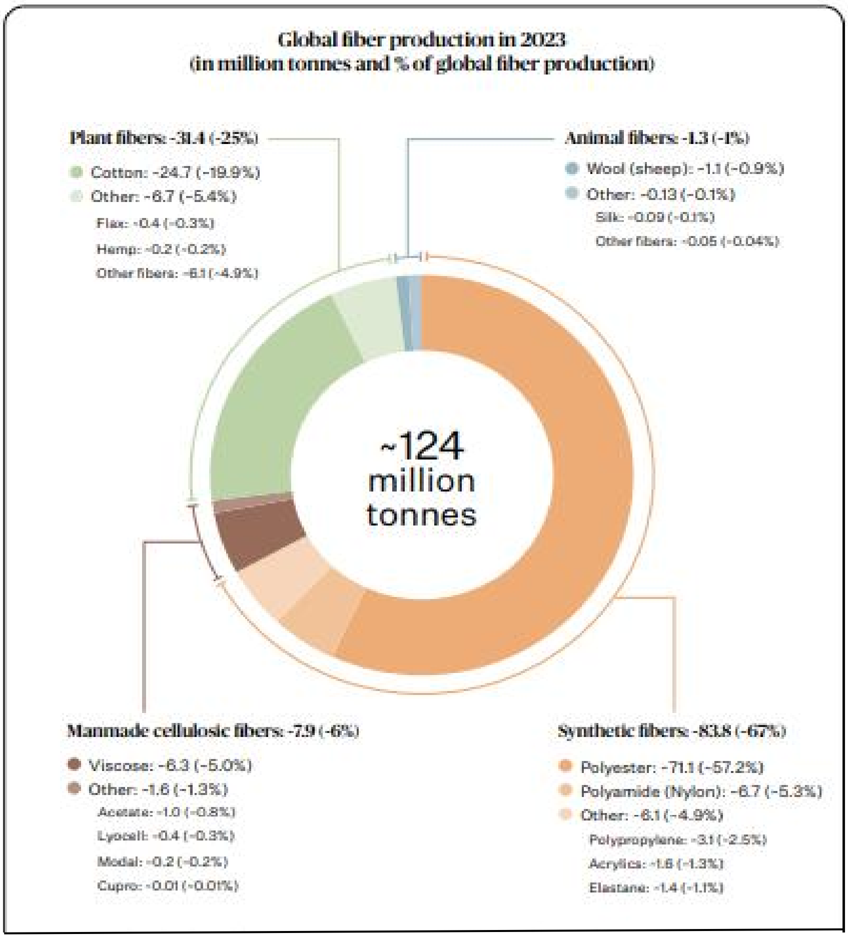

**Figure 1.** Global fiber production

Figure 1 illustrates global fibre production in 2023. It shows the prevalence of synthetic fibers like polyester, which present unique recycling challenges, as synthetic fibers like polyester can take up to 200 years to decompose, while natural fibers, though biodegradable, often contain chemical dyes and finishes that leach into the environment, causing pollution. The urgency of innovating textile waste management has led to a growing interest in advanced recycling solutions. Artificial intelligence-driven material segregation, chemical depolymerization, and biochemical processes for fiber recovery are emerging as more promising strategies for reducing landfill dependency and fostering a circular textile economy. However, these approaches face challenges in scalability, economic viability, and regulatory alignment, which necessitate further research and policy intervention [8].

## 3. Textile Recycling Technologies

Given increasing concerns about textile waste generation, accumulation, and environmental impacts, recycling has emerged as a key strategy for advancing circular economy principles in the textile industry. Conventional disposal methods, such as landfilling and incineration, contribute to greenhouse gas emissions, resource depletion, soil and water contamination. In context, recycling technologies optimizes raw material usage, reduce carbon footprints, and minimize waste generation. However, each recycling method presents unique challenges, such as fiber degradation, contamination, processing costs and initial capital investment.

### 3.1. Mechanical Recycling

Mechanical recycling is the most widely used method, primarily involving the physical breakdown of textile waste into fibers, which are then processed into new yarns and fabrics. This method is particularly effective for natural fibers like cotton and wool, but its application to synthetic textiles is limited due to fiber quality degradation. It typically involves the shredding, carding, and re-spinning of textile waste. Studies suggest that mechanically recycled fibers require up to 50 % less energy than virgin fiber production, making it an energy-efficient solution. Mechanical recycling processes often reduce polymer quality, with studies reporting up to a 30% decrease in PET melt viscosity due to thermal and mechanical degradation during reprocessing.

However, key challenges include:

- Short-length fibres – Each recycling cycle weakens the fibre structure, limiting its lifespan.
- Microfiber shedding – the mechanical breakdown process generates a high amount of microplastics, especially in synthetic blends.
- Colour contamination – different coloured textiles complicate dye removal and fiber reuse.

Despite these limitations, blended fiber reinforcement techniques and closed-loop recycling models are improving the feasibility of mechanical recycling.

**Societal relevance:**

- Generates employment in sorting and processing sectors
- Supports low-cost recycled products
- Promotes decentralized recycling models

**Limitations:**

- Fiber degradation
- Limited application for blended textiles
- Reduced product quality

## 3.2. Chemical Recycling

Chemical recycling involves breaking down complex textile polymers into smaller monomers, which can then be repurposed into high-quality raw materials. This method is particularly effective for synthetic fibers like polyester, nylon, and polyurethane, as well as blended textiles that are unsuitable for mechanical recycling. Chemical recycling involves:

### 3.2.1. Enzymatic Hydrolysis

Enzymatic recycling has emerged as a promising advanced technology, with engineered enzymes capable of efficiently depolymerizing polyethylene terephthalate (PET) into its high quality monomers under mild conditions [9].

Enzymatic hydrolysis uses biocatalysts to degrade textile fibers, particularly cotton-polyester blends. Research shows that optimized pretreatment techniques (e.g., alkaline soaking, enzymatic concentration, etc.) have improved hydrolysis efficiency to over 89 % [10]. However, key challenges include:

- Enzyme stability and cost – Large-scale application remains limited due to high enzyme production costs and short operational lifespans.
- Fiber separation limitations – The process struggles to achieve complete polymer recovery without additional chemical treatments.

In a practical demonstration, enzymatic hydrolysis was used to completely degrade cotton from polyester-cotton blends. The resulting polyester retained its mechanical properties and was reused in towel production, validating a circular recycling loop. Similar enzymatic digestion of wool in wool/polyester blends has also yielded recyclable polyester fibers. This suggests that, enzymatic hydrolysis is a promising solution for sustainable textile recycling, especially when integrated with AI-assisted sorting technologies.

### 3.2.2. Glycolysis

Glycolysis is a thermochemical process that breaks down polyester fibers into monomers using high-temperature glycol-based solvents. Catalysts such as zinc oxide (ZnO) nanoparticles enhance the conversion efficiency, leading to higher monomer recovery rates [11]. Notable advancements include:

- Microwave-assisted glycolysis, which reduces reaction times and improves polymer recovery efficiency.
- Selective depolymerization techniques, which allow for precise monomer extraction, minimizing secondary waste production.

However, glycolysis requires strict process control and high energy input, impacting cost-effectiveness and environmental benefits.

### 3.2.3. Ammonolysis

Ammonolysis is an emerging chemical recycling method that uses ammonia to depolymerize polyester-based textiles, particularly polyethylene terephthalate (PET). A related technique, aminolysis, uses amines or alkanolamines to convert polyurethane (PU) waste into reusable polyols or monomers. Ammonolysis shows particular promise in separating and recovering PET from textile blends that combine synthetic fibers with natural ones like cotton. These blends are notoriously difficult to recycle due to the physical entanglement and chemical incompatibility of their constituents.

However, research has demonstrated that ammonolysis can selectively break down the polyester component into monomers such as bis(hydroxyethyl) terephthalate (BHET), while leaving the cotton fraction intact. Compared to conventional chemical recycling methods like hydrolysis and glycolysis, ammonolysis can operate under comparatively milder conditions, thereby reducing the generation of secondary chemical waste and minimizing environmental impact. This makes it a more sustainable option for tackling complex textile waste streams, especially those composed of multi-material blends.

Recent studies have demonstrated that mixed textile waste which includes polyester, cotton, nylon, and spandex, can also be efficiently processed through microwave-assisted chemical recycling, achieving rapid depolymerization and material separation within short reaction times (~15 minutes), highlighting its strong potential for scalable industrial applications [12].

## 4. Advanced Textile Recycling Technologies

One of the major challenges in textile recycling is efficient sorting of mixed textile and composite materials which often requires advanced automated technologies [13].

To overcome the challenges and limitations of conventional recycling and improve its efficiency and scalability, emerging technologies such as AI-driven sorting, automated material recovery, and biochemical treatments are being integrated into textile waste management.

### 4.1. Artificial Intelligence (AI) based Textile Sorting

Accurate fibre identification remains the weakest link in most recycling chains. Modern sorters pair near-infra-red or hyperspectral cameras with machine-learning classifiers [14-17]. The sensor captures a spectral “fingerprint,” the model assigns a label (cotton, wool, PET, poly-cotton, etc.), and air jets or robotic grippers divert each item accordingly. Pilot studies report more than 95 % mass-based purity, a sharp jump from the approximate 65 % typical of manual picking, with corresponding gains in overall fibre yield [18].

A few-commercial examples include:

- **Kosha.ai** (India) – KOSHA.ai builds IoT and AI tools that help verify handloom authenticity and bring accuracy to textile recycling in India. The device employs near-infrared spectroscopy paired with AI-driven chemometric modelling to identify fibre composition in seconds. By projecting near-infrared light onto a textile sample, it detects unique absorption and reflection patterns, essentially creating a “molecular signature” for each fibre. This device is a hand- held scanner for collection centres and laboratory tests show 96 % accuracy in natural verses synthetic detection and loom- type authentication [19].

- **Fibersort®** (Valvan Baling Systems) – Valvan Baling Systems and Wieland Textiles proudly launched Fibersort. For the first time in the history of textile recycling, this optical sorting technology enables the quick and efficient scanning and sorting of numerous stacks of garments into uniform categories of fibers with specified compositions, colours and/or structures. This paves the way for a circular revolution in the textile industry: a cost-efficient recovery of highly valuable raw materials from discarded garments for the production of new clothes. Fibersort is able to sort 900 kilograms of post-consumer textiles per hour and sorts more than 40 fibre/colour fractions. Independent validation found 94 to 97 % purity across cotton, polyester and wool streams [20].
- **AUTOSORT Textiles** (TOMRA) – TOMRA Sorting is a global leader in sensor-based sorting solutions. It is capable of efficiently identifying and separating different types of fibers and textile materials for high-quality recycling. Field trials in Norway and Germany recorded 98 % identification accuracy for polyester and cotton and throughputs up to 2.5 tons per hour [21].
- **Refiberd** (USA) – Advanced material detection via AI-based hyperspectral imaging.  technology combines a hyperspectral imaging system with artificial intelligence to accurately detect fiber composition and contaminant presence in textile waste. Hyperspectral imaging plus deep learning predicts polyester/cotton blend ratios more or less 3 % absolute error in  less than 2 seconds [22].
- **PICVISA “Textil Selector”** (Spain) – PICVISA's Textil Selector (Spain) utilizes the Specim FX17 NIR hyperspectral sensor to achieve automated textile sorting, capacity for over 10 tons per day. Industrial data indicates this system achieves 95% purity for seven major fiber types, covering composition and color identification. It enables efficient, large-scale textile recycling, processing up to 5,000 tons annually [23].

Recent advancements in spectroscopy-based textile sorting also show strong potential. For instance, a Raman spectroscopy-based system integrated with machine learning models (e.g., PCA, SVM, CNN) achieved over 95% accuracy and processed 1 item per second, effectively distinguishing six fiber groups. Another noteworthy example is an AI-enabled industrial textile sorting pipeline utilizing robotics and spectral imaging, integrated with a digital twin system to assess both technical and economic feasibility. This setup demonstrated scalable and accurate sorting aligned with Industry 4.0 goals [24]. Despite these gains, three hurdles still slow wider roll- out:
(i) the capital cost of sensor arrays,
(ii) the need to retrain algorithms as new fabric chemistries appear, and
(iii) the extra mechanics required to match high- speed scanning with robotic picking.

How quickly these barriers are addressed is likely to dictate the pace at which AI- based segregation underpins truly circular, fibre- to- fibre recycling.

**Key benefits of AI-based Textile Sorting**

- Improves recycling efficiency (more than 95% accuracy)
- Reduces contamination
- Enables automation and scalability

**Societal impact:**

- Drives Industry 4.0 adoption
- Creates high-skill employment
- Improves waste management systems

## 4.2. Circular Fiber Regeneration

Innovative approaches such as bioengineered textile recycling and fiber-to-fiber regeneration are being explored to create fully circular textile systems, viz

(i) Cellulose dissolution and regeneration for high-purity cotton fiber recovery and

(ii) Polymer reformation techniques, enable direct re-spinning of recycled PET into new textile fibers.

These technologies represent the next step toward achieving a closed-loop textile economy but require further advancements in scalability and process optimization.

Emerging technologies focus on

- Fiber-to-fiber recycling
- Bioengineered material recovery
- Closed-loop production systems

These innovations are critical for achieving a zero-waste textile economy.

## 5. Comparative Analysis of Recycling Methods

Each textile recycling method offers unique advantages and limitations, making a hybrid approach the most viable strategy. While closed-loop recycling provided higher material recovery and more sustainable also but its industrial scalability remains limited compared to open loop systems, which are currently more widely used [25,26].

**Table 2.** Analysis of recycling methods

| Recycling Method | Advantages | Limitations |
|---|---|---|
| Mechanical Recycling | Energy consumption is low. Mostly used for natural fibers. | Fiber degradation; dust; limited synthetic fiber compatibility. |
| Chemical Recycling | High-quality fiber recovery. Suitable for synthetics and blends. | Processing costs is very high; solvent recovery challenges. |
| Enzymatic Hydrolysis | More Eco-friendly and selective breakdown of fiber is possible. | Enzyme costs are very high; requires advanced pretreatment. |
| Glycolysis | Most suitable for PET monomer recovery efficiently | Requires high energy input and catalyst optimization. |
| AI-Assisted Segregation | Increases recycling efficiency; Faster, reduces contamination. | Highly capital intensive. |

Life cycle assessment studies show that the climate impact of recycling technologies varies widely, ranging from 3.3 to 137.6 kg $CO_2$ equivalent per kg of material, highlighting that the environmental performance of recycling depends strongly on technology type, system boundaries, and operational conditions. The environmental benefits of textile recycling and reuse are highly dependent on their effect to reduce the production of new textiles [27].

## 6. Economic Feasibility and Industry Challenges in Textile Recycling

The large-scale implementation of textile recycling technologies depends significantly on economic viability, infrastructure development, and supportive policy frameworks. Among the most pressing concerns is cost-effectiveness, which remains a critical barrier across all recycling approaches.

Mechanical recycling is generally the most cost-efficient method, requiring lower capital and operational expenses. However, the quality degradation of fibres during the recycling process limits their potential for producing high-value textile products. In contrast, chemical recycling enables high-quality fiber recovery, particularly for synthetic and blended textiles, but involves substantial energy and solvent usage, leading to high processing costs. Enzymatic hydrolysis appears to be a promising solution with selective fibre breakdown, though its scalability is limited by enzyme costs and the need for complex pre-treatment.

AI-assisted sorting technologies represent a promising solution to increase recycling accuracy and efficiency. While these systems demand high initial investment, they have the potential to significantly improve material recovery rates and reduce contamination, thereby enhancing the overall economic value of recycled textiles.

**Table 3.** Cost and feasibility analysis of recycling methods

| Recycling Method | Capital Investment | Processing Cost | Revenue Potential |
|---|---|---|---|
| Mechanical Recycling | Low | Low | Moderate (due to fiber degradation) |
| Chemical Recycling | High | High | High (suitable for synthetic blends) |
| Enzymatic Hydrolysis | Medium | High | Moderate (potential for eco-friendly use) |
| AI-Assisted Sorting | High | Medium | High (improves sorting and efficiency) |

Despite recent advancements, several challenges continue to hinder the scalability and effectiveness of textile recycling. A major constraint is the lack of adequate infrastructure, particularly in developing regions, where textile waste is often managed through landfilling or incineration. In addition, consumer awareness and demand for recycled textiles remain relatively low, impacting the market viability of sustainable alternatives.

Technological limitations such as inefficient fiber separation, dye removal, and the complexity of recycling blended fabrics further complicate the process [28]. Moreover, the high operational costs involved in many advanced recycling methods discourage their adoption by manufacturers focused on cost minimization.

### 6.1. Key industry Challenges

Despite policy interventions, several challenges hinder large-scale textile recycling:

- Lack of Recycling Infrastructure – Many developing nations lack specialized recycling facilities, leading to reliance on landfills and incineration.
- Consumer Awareness & Market Demand – Limited consumer preference for recycled textiles affects profitability.
- Technological Limitations – Current technologies struggle with fiber separation, dye removal, and synthetic blend processing.
- High Processing Costs – Many brands prioritize cost savings over sustainability, delaying large-scale recycling adoption.

Overcoming these challenges requires a multi-stakeholder approach that combines technological innovation with financial incentives, consumer education, and strong policy enforcement. Strategic investments and cross-sector collaboration can pave the way for a more economically sustainable and circular textile economy.

## 7. Global Policy Framework for Textile recycling

Effective policy frameworks play a pivotal role in driving the adoption of textile recycling technologies by creating incentives, mandating producer responsibility, and enabling infrastructure development. Across the globe, several countries have adopted different regulatory approaches to promote circular-economy principles in the textile industry. However, the effectiveness of these policies varies based on enforcement mechanisms, industry engagement, and consumer participation.

### 7.1. Extended Producer Responsibility (EPR)

EPR is among the most widely implemented policy tools in textile waste management. It mandates that producers are financially and/or physically responsible for post-consumer textile waste. In the European Union, the EPR framework has led to significant advancements, including mandatory textile take-back schemes and investment in recycling R&D.

France's textile EPR system, managed by Refashion, has collected over 250,000 tonnes of used clothing annually, supporting a well-established second-life and recycling market (as reported by ADEME, the French Environment and Energy Management, 2023). In contrast, the United States has no federal EPR mandate, and recycling policies are fragmented at the state level. While states like California and New York have introduced pilot programs, the lack of national coordination limits their scalability.

### 7.2. Japan and China’s Integrated Approaches

Japan’s Act on Promotion of Resource Circulation for Plastics has been extended to include textiles, incentivising businesses to invest in low-impact recycling and develop new biodegradable materials. The act provides tax benefits and R&D grants to companies adopting green textile technologies [29].

China's Waste-Free Cities Initiative incorporates AI-driven sorting and chemical recycling in its pilot programs. Cities like Shenzhen and Suzhou have begun integrating textile recycling into broader waste management systems, supported by data tracking and centralized logistics.

### 7.3. Policy and Market Trends

- EU’s Sustainable Textile Strategy (2025) is expected to ban non-recyclable textiles and enforce mandatory circular economy practices.
- Carbon credit incentives for textile recycling are emerging as a viable way to boost industrial investment.
- Consumer-driven sustainability movements are increasing demand for recycled fashion brands and ethical textile production**.**

## 8. Future Prospects in Textile Recycling

The future of textile recycling lies in integrating advanced technologies, optimizing economic models, and strengthening regulatory frameworks. Emerging trends such as AI-driven material sorting, enzyme-based fiber regeneration, and blockchain-enabled waste tracking offer promising solutions for achieving a sustainable textile economy.

For scalable and sustainable textile waste management, future research should focus on:

- Optimizing enzyme-based recycling to lower costs and enhance fiber breakdown efficiency.
- Developing energy-efficient chemical recycling methods with improved solvent recovery systems.
- Integrating technology like artificial Intelligence and automation for real-time textile waste classification, sorting and monitoring.
- Policy frameworks support for large-scale investment in recycling infrastructure.

By leveraging technological innovation, policy interventions, and circular economy principles, the textile industry can transition toward a more sustainable, resource-efficient future.

## 9. Sustainability and Society

Looking toward a futuristic approach, textile recycling will be shaped by the convergence of technology, policy, and societal behaviour.

Key Trends:

- AI-driven circular systems for real-time waste tracking
- Green chemistry innovations reducing environmental impact
- Decentralized recycling hubs promoting local economies
- Consumer-driven sustainability influencing market demand

Societal Transformation:

- Shift from ownership to responsible consumption
- Increased awareness and participation in recycling
- Integration of informal waste sectors into formal systems

Thus, the textile industry is expected to transition in the near future to a fully circular, low-carbon, and socially inclusive ecosystem.

## 10. Conclusion

Textile recycling is no longer a choice but a necessity for ensuring environmental sustainability and resource conservation. While mechanical, chemical, and biochemical recycling methods have increased the potential for textile waste recovery, their widespread adoption remains constrained by economic, technological, and policy barriers. However, advancements in artificial intelligence, enzymatic fiber recovery, and stronger regulatory frameworks are expected to catalyze major transformations in textile waste management.

Future research should prioritize the enhancement of fiber-to-fiber recycling techniques, the reduction of energy use in chemical processes through low-carbon innovations, and the development of globally harmonized recycling policies.

By embracing cutting-edge technologies, sustainable business models, and strong policy support, the textile industry can transition towards a zero-waste circular economy, ensuring a more sustainable future for global fashion and textile production. Aligning technological innovation with societal needs will be the key to realizing a resilient and sustainable textile ecosystem.

## Author’s Contributions

Mr Pramod Salunkhe (PhD researcher) gathered and compiled relevant information
Dr Rekha Ramakrishnan – edited and curated the data
Prof Ashok Athalye – supervised and guided the researcher

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## Data Availability

The authors reported all data and materials in the main text.

## Conflicts of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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