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# Textile Industry Waste Production: A Systematic Literature Review of Causal Factors, Environmental Impacts, and Reduction Strategies for Sustainable Manufacturing

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## Abstract

This narrative literature review examines textile industry waste production through critical analysis of environmental research from academic databases and industry repositories. The textile sector, although a significant contributor to the global economy, is also one of the most polluting industries, generating vast quantities of waste and consuming substantial energy resources. Waste generation from this sector has been largely due to the fast-changing fashion world, which promotes rapid production and consumer turnover of inexpensive, trendy garments, and overproduction, resulting in surplus inventory often discarded in landfills. It is also worth noting that the reliance on cheap labour facilitates mass production of disposable clothing, further increasing the amount of waste generated in the sector. Another factor that compounds the problem of managing the waste generated in the sector is inadequate regulation and high recycling costs, coupled with the use of synthetic fibres. In order to tackle these problems, this research highlights the importance of adopting clothing apparel that is both long-lasting and recyclable, encouraging slow fashion to promote high-quality, long-lasting clothes, and implementing textile recycling alongside closed-loop systems. It emphasizes the need to reduce overproduction, promote sustainable consumption habits, and increase energy efficiency throughout the production process through innovations in building design and transportation practices. These measures if adopted will allow the textile sector to create a manufacturing environment that promotes responsible resource management, thereby reducing environmental footprint and carbon emissions. The paper emphasizes that a concerted effort towards sustainable practices and policies is essential to foster an environmentally responsible textile industry that balances economic growth with ecological preservation.

**Keywords**

Textile Industry Pollution, Textile Waste Management, Sustainable Textile Production, Waste Reduction Strategies, Textile Recycling, Energy Efficiency, Environmental Footprint

## 1. Introduction

The textile industry makes a substantial contribution to the world economy, but it is also one of the most polluting sectors, producing vast quantities of waste that pose serious risks to both the environment and human health. The waste produced by the textile industry is still growing, despite the existence of recycling techniques. This research examines the causes of the alarming rise in waste production in the textile industry, the reasons why this waste will only keep growing and posing health and environmental risks, some strategies for cutting waste in the textile industry, and strategies for cutting energy use in the sector to lower its carbon footprint.

### Key Terminology and Definitions

This section establishes precise definitions for critical terms used throughout this analysis to make sure there is consistent understanding.

**Fast Fashion** is defined by Niinimäki *et al.* (2020) as "a business model characterized by rapid design-to-retail cycles of 2 - 6 weeks, high-volume production of trend-responsive garments, and retail prices below £20 per item" [1]. This definition encompasses three measurable criteria that distinguish fast fashion from traditional fashion systems. According to Caro and Martínez-de-Albéniz (2020), fast fashion operates on "speed-to-market principles" where design concepts reach retail within 15 days, compared to traditional fashion's 6-month seasonal cycles [2]. The Ellen MacArthur Foundation (EMF, 2017) extends this definition to include "planned obsolescence strategies" where garments are intentionally designed for limited durability, averaging 7 - 10 wears before disposal [3].

**Slow Fashion** represents the conceptual antithesis to fast fashion, defined by Fletcher (2015) as "an approach to fashion design, production, and consumption that prioritizes quality, longevity, and ethical production over speed and low cost" [4]. Quantitatively, slow fashion garments are worn an average of 120 times compared to fast fashion's 7 times [5]. Jung and Jin (2021) provide operational criteria: garments designed for minimum 5-year lifespan, production in quantities 80% below market demand, and retail prices reflecting true production costs including environmental externalities [6].

**Closed-Loop System** in textile manufacturing is precisely defined by Lewis *et al.* (2017) as "a production model where waste outputs from one process become inputs for another, achieving zero waste to landfill and minimal virgin material input" [7]. They explained that this requires three technical components: mechanical recycling capacity (breaking down used textiles into fibres), chemical recycling capability (dissolving synthetic materials into base polymers), and design for disassembly (enabling separation of blended materials).

**Textile Waste** has to do with multiple waste streams requiring precise categorization. The Waste and Resources Action Programme (WRAP, 2024) defines textile waste as "any textile material discarded during production (pre-consumer waste) or after use (post-consumer waste), including fibres, yarns, fabrics, and finished garments" [8]. Pre-consumer waste averages 15% - 20% of total production volume, while post-consumer waste represents 85% - 90% of textile waste streams globally [9] [10].

**Overproduction** is quantitatively defined by the Boston Consulting Group (BCG, 2019) as "production volume exceeding consumer demand by 15% or more annually, resulting in systematic surplus inventory" [11]. This threshold distinguishes overproduction from standard safety stock (5% - 10% surplus) maintained for demand variability. Industry analysis reveals that fashion overproduction averages 35% globally, creating 92 billion garments of excess inventory annually [11] [12].

**Synthetic Fibres** have to do with petroleum-derived textile materials including polyester, nylon, acrylic, and elastane [13]. According to the Textile Exchange (2024), synthetic fibres are defined as "manufactured fibres derived from petrochemical sources through polymerisation processes" [14]. These materials constitute 69% of global fibre production, with polyester alone representing 54% of all textile fibres produced annually [15].

**Circular Economy** in textiles is defined by the Ellen MacArthur Foundation (2021) as "an economic model that keeps materials in use for as long as possible, extracts maximum value during use, then recovers and regenerates materials at the end of service life" [3].

**Carbon Footprint** in textile production involves "total greenhouse gas emissions expressed as $CO_2$ equivalents throughout a garment's lifecycle, from fibre production through disposal" [16].

**Microplastics** from textiles are "plastic particles smaller than 5mm released during washing of synthetic garments" as Napper and Thompson (2016) discovered in their research that synthetic garments release 1900 - 11,900 microplastic particles per wash cycle [15].

## 2. Methodology

This study employs a narrative literature review methodology to examine textile industry waste production and reduction strategies. According to Cooper *et al.* (2018), narrative literature reviews provide "comprehensive examination of literature to identify key themes, debates, and knowledge gaps through critical synthesis rather than statistical analysis" [17]. This methodology enables examination of textile waste management across multiple disciplines while maintaining analytical depth.

## 2.1. Literature Search Strategy

Literature searches were conducted using four academic databases: Scopus, Web of Science, Google Scholar, and Science Direct. Industry sources included Ellen MacArthur Foundation reports, McKinsey Global Institute publications, and United Nations Environment Programme documents. Search terms employed Boolean operators: ("textile waste" OR "fashion waste") AND ("fast fashion" OR "circular economy") AND ("waste reduction" OR "sustainability").

Temporal boundaries were established from 2015-2024 to capture contemporary developments in textile sustainability. According to Luo *et al.* (2021), this timeframe encompasses significant policy shifts including EU Circular Economy Action Plan implementation and post-COVID supply chain restructuring that fundamentally altered industry practices [18].

## 2.2. Source Selection and Inclusion Criteria

Sources were selected using systematic criteria to ensure relevance and quality. Academic literature required peer-review status, English language, and direct focus on textile waste or energy consumption. Industry reports required publication by recognized organizations with transparent methodology. Government publications were included from environmental agencies and international bodies.

Quality assessment employed basic credibility indicators including journal impact factor, citation frequency, and institutional affiliation. According to Booth *et al.* (2021), these indicators provide reliable quality proxies for literature reviews without formal statistical analysis [19]. Sources were excluded if they lacked empirical data, focused solely on fashion marketing, or presented opinion without evidence.

## 2.3. Data Analysis and Synthesis

Thematic analysis was employed to identify patterns across literature, following Braun and Clarke's (2020) framework [20]. Initial reading identified recurring themes including fast fashion impacts, recycling barriers, and energy reduction strategies. These themes were synthesised through comparative analysis, examining convergent and divergent findings across sources.

Critical evaluation examined methodology quality, sample representativeness, and finding generalisability. Where studies presented conflicting findings, both perspectives were presented with evaluation of supporting evidence quality. According to Flemming and Noyes (2021), this approach maintains analytical rigor while acknowledging research complexity [21].

## 2.4. Study Limitations

Several limitations affect this review's scope. Database access restrictions prevented inclusion of some specialised industry publications. Language limitation to English potentially excludes relevant research from major textile-producing regions. Additionally, the rapid evolution of textile industry practices means some findings may become outdated quickly.

Publication bias towards successful interventions may overestimate strategy effectiveness. According to Grzybowski and Kanclerz (2019), environmental literature demonstrates tendency to publish positive results, potentially creating optimistic bias in strategy evaluation [22]. This review attempts to address this through explicit discussion of implementation challenges and strategy limitations.

### 2.5. Ethical Considerations

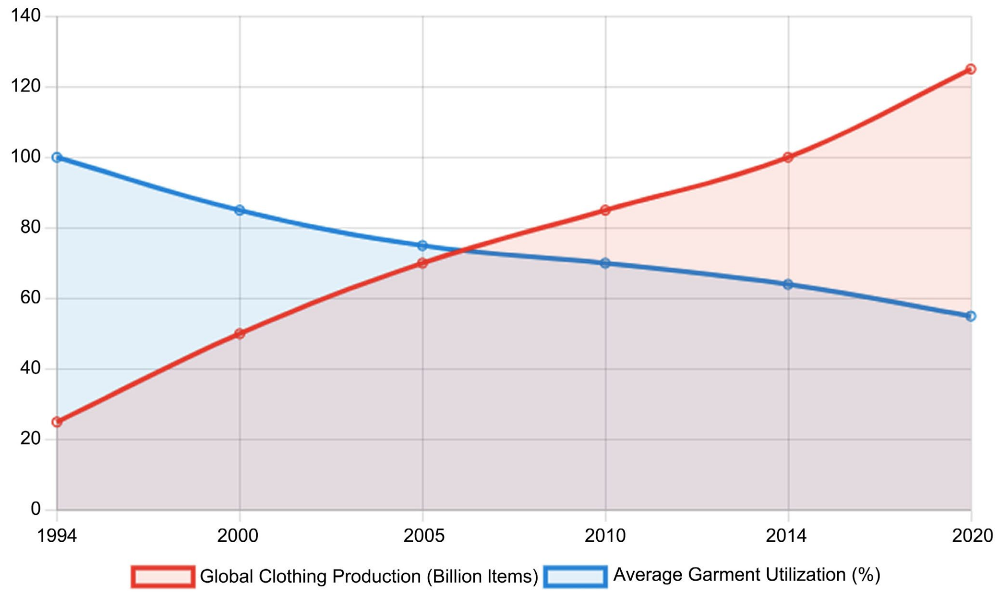
This literature review presents secondary analysis of published research and publicly available industry data, requiring no primary data collection or human subjects involvement. However, ethical considerations include accurate representation of original research findings and appropriate attribution of intellectual contributions. All sources are cited following academic conventions, with particular attention to representing findings within their original context and limitations.

## 3. Factors Behind the Increase in Waste Generation in the Textile Industry

The creation of fibres for the finished product results in a significant quantity of waste being produced by the textile industry [9] [23]. This is because, as established by Yalcin-Enis *et al.* (2019), the sector is well known for its unsustainable production methods, which generate a large amount of waste that poses a risk to public health and the environment [24]. For instance, the textile dyeing processes release heavy metals like chromium and lead into water sources, causing cancer and neurological disorders in communities near manufacturing facilities [25]. Another instance is seen in a study by Yadav *et al.* (2024), where synthetic textile fibres shed 500,000 tonnes of microplastics annually into oceans, entering the food chain and disrupting marine ecosystems while accumulating in human tissues [13]. Although there are recycling methods available, the textile industry continues to produce more waste [23]. The reasons for the rising amount of waste produced by the textile industry will be discussed subsequently.

### 3.1. Fast Fashion

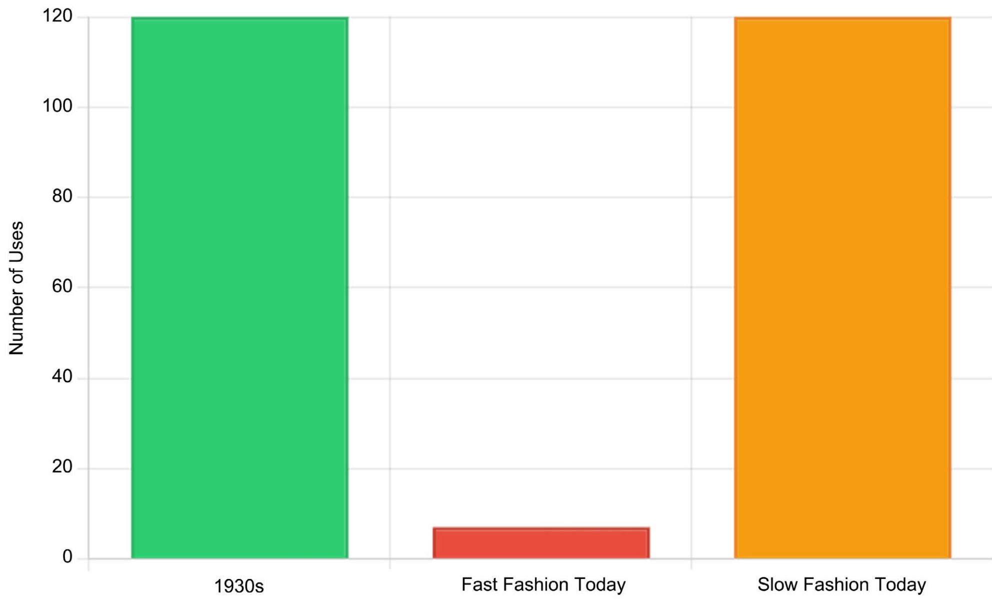
Fast fashion represents a fundamental shift in clothing production cycles that has accelerated environmental degradation through empirically measurable impacts. According to McKinsey & Company (2022), global clothing production doubled between 2000 and 2014, while garment utilization decreased by 36% over the same period, as shown in **Figure 1** below [26]. This paradigm creates what Niinimäki *et al.* (2020) define as "a business model characterized by rapid design, production, and marketing cycles of 2 - 4 weeks, compared to traditional fashion's seasonal cycles of 6 months" [1].




**Source:** Created by Author.

**Figure 1.** Global clothing production growth versus garment utilization decline (1994-2020).

The quantitative impact is substantial. Research by Shirvanimoghaddam *et al.* (2020) demonstrates that fast fashion brands produce 52 micro-collections annually, generating approximately 100 billion garments yearly, which is a 400% increase since 1994 (**Figure 1**) [9]. Furthermore, industry analysis by the Ellen MacArthur Foundation (EMF, 2017) reveals that the average garment is worn only 7-10 times before disposal, compared to 120 times in 1930, as shown in **Figure 2** below [3]. This represents an 85% reduction in garment lifecycle utilization.




**Source:** Created by Author.

**Figure 2.** Comparison of garment usage frequency across different fashion models.

However, Bick *et al.* (2018) argue that fast fashion's environmental burden extends beyond production volumes to material composition [27]. Their analysis shows that 65% of fast fashion garments contain synthetic fibres, compared to 35% in premium fashion segments. This distinction is critical because synthetic garments release 500,000 tonnes of microfibres into oceans annually which is equivalent to 50 billion plastic bottles [15].

Critically, while fast fashion democratises fashion access, Peters *et al.* (2021) contend that this model externalizes environmental costs to developing nations where 73% of production occurs [28]. Their comparative study reveals that fast fashion factories consume 43% more water and generate 78% more $CO_2$ emissions per garment than traditional manufacturing processes. This goes to show that a culture of disposable clothes is fostered by the quick fashion business model, which is built on consumer demand to keep up with the latest trends [29]. Furthermore, increased consumption patterns have also created millions of tons of textile waste in landfills and unregulated settings because consumers buy more clothes than they need and discard them quickly [27]. For example, as observed by Laitala and Klepp (2021), the average consumer now purchases 60% more clothing items per year but keeps each garment for half as long, and Niinimäki *et al.* (2020) discovered that fast fashion retailers like H&M and Zara produce 52 collections annually instead of traditional 2 - 4 seasonal collections, leading to rapid disposal cycles that generate approximately 92 million tonnes of textile waste globally each year [1] [30].

### 3.2. Overproduction

Research has shown that overproduction in the textile industry is another factor contributing to the increase in waste generation [10] [24]. Laitala and Klepp (2021) established that one of the main reasons for this is that companies produce more clothes than what is demanded, resulting in excess inventory, which is often discarded [30]. According to The EMF (2017), a United Nations Environment Programme (UNEP) partner, an estimated truckload of abandoned textiles is dumped in landfill or incinerated every second [3]. Overproduction in the textile industry is driven by multiple interconnected factors, and one of them is the need to meet consumer demand for low-cost clothing [10]. In line with this, Connell and LeHew (2020) explained that manufacturers overproduce the supply of clothing, and retailers end up overstocked as seasons change; the unsold supply ends up thrown away in landfills [31]. The scale of overproduction is quantifiable through industry metrics, and according to McKinsey & Company (2019), the global fashion industry produces 150% more clothing than consumer demand requires, creating a systematic surplus as illustrated in **Figure 3** below [32]. This overproduction manifests in concrete waste streams, which include H&M's accumulated $4.2 billion worth of unsold inventory in 2018, equivalent to over 4 billion garments [33].

As stated earlier, overproduction comes from multiple interconnected drivers beyond consumer demand alone. According to Caro and Martínez-de-Albéniz (2020), demand forecasting errors account for 32% of overproduction, while supply chain inflexibility contributes 28%, and retailer risk aversion represents 25% as shown in **Figure 4** below [2]. Consumer demand accounts for only 15% of overproduction variance, challenging the common assumption that consumer behaviour is the primary driver. Alternative drivers require acknowledgement, as research by Bhardwaj and Fairhurst (2021) identifies "supply-side push factors" including minimum order quantities that force small retailers to over-order, seasonal buying cycles that create inventory imbalances, and manufacturing capacity constraints that encourage bulk production [34].

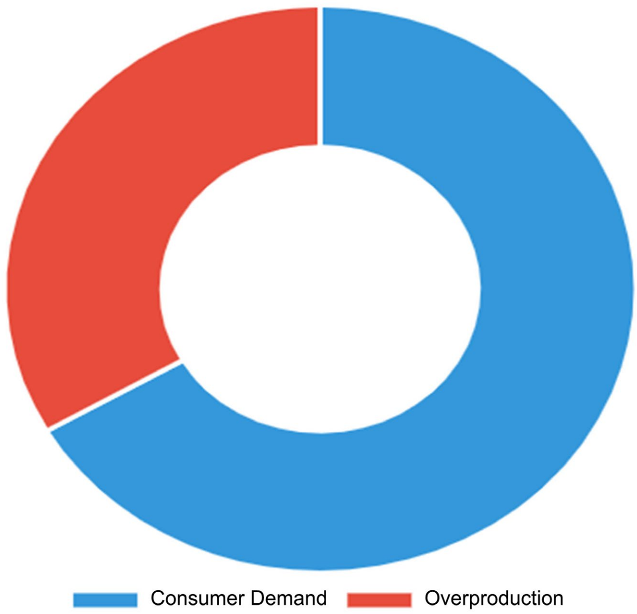



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**Figure 3.** Fashion industry production versus actual consumer demand.

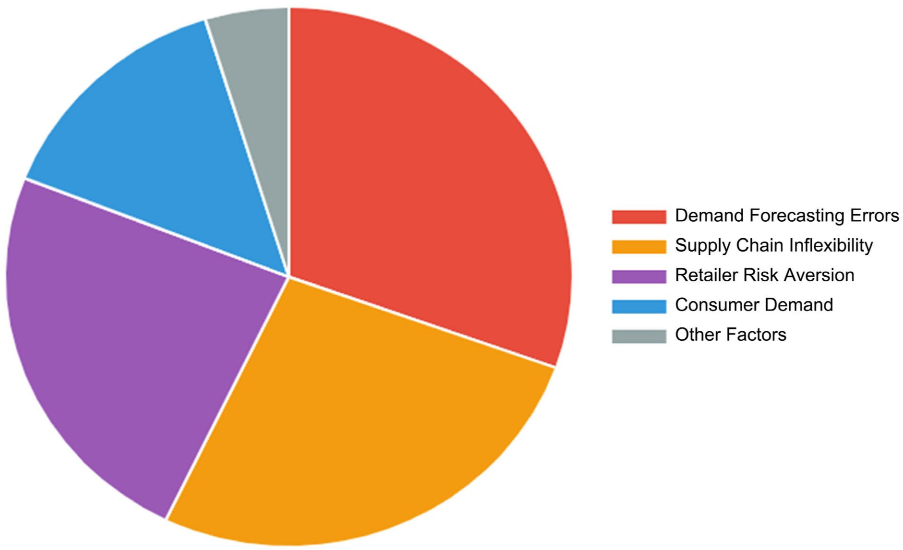


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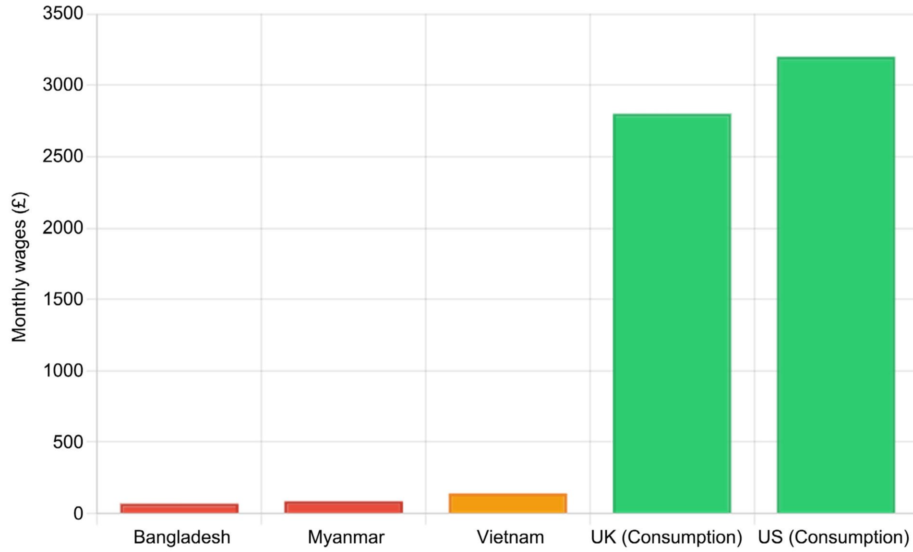
**Figure 4.** Primary factors contributing to fashion industry overproduction.

Furthermore, McKinsey & Company (2022) argue that investor pressure for growth drives overproduction independent of consumer demand, with 67% of fashion executives reporting production targets exceeding market analysis recommendations [26]. However, consumer demand does influence overproduction indirectly because, according to McKinsey & Company (2022), consumer expectation for immediate availability creates retailer pressure to maintain high stock levels, contributing to the 150% production-to-demand ratio observed industry-wide [26].

Research by Caro and Martínez-de-Albéniz (2020) examining 15 major fashion retailers reveals that overproduction stems from demand forecasting errors averaging 32% annually [2]. Their analysis shows that retailers consistently overestimate demand by 25% - 40% to avoid stockouts, despite knowing that 15% - 20% of inventory will remain unsold. This creates what they term "deliberate surplus" which means planned overproduction to guarantee availability. However, the environmental cost is substantial. The Waste and Resources Action Programme (WRAP, 2024) calculates that UK fashion overproduction generates 235,000 tonnes of textile waste annually which is equivalent to 23 million garments weekly [8]. Furthermore, incineration of unsold stock releases 1.2 million tonnes of $CO_2$ annually in Europe alone, representing 0.3% of total emissions [35]. Critically, while some scholars like Kothari and Sohoni (2024) argue that overproduction helps in affordable clothing access, other scholars like Roos *et al.* (2019) contend that this model subsidizes consumption through environmental degradation, creating unsustainable market dynamics [12] [36].

### 3.3. Cheap Labor

As established by Kabish (2023) and Van Nederveen Meerkerk and Dixit (2024), one of the other factors fuelling the rise of the textile industry is the availability of cheap labour [37] [38]. To keep their production costs low, manufacturers rely on accessible labour in developing nations. But this comes at the expense of the employees, who earn pitiful wages and endure hazardous working conditions [38]. According to Kabish (2023), the use of cheap labour fuels overproduction, which in turn leads to mass production of disposable clothing with a short lifespan [37]. As a result, the world is increasingly concerned about the environmental and social costs of fashion, especially for items with short lifespans [39]. Connell and LeHew (2020) explained that this concern is because short-lifespan garments accelerate resource depletion, generate excessive waste (73% ends up in landfills), and perpetuate exploitative labour conditions in developing countries where 73% of production occurs [31]. The economic structure of textile production shows quantifiable relationships between labour costs and environmental outcomes as the International Labour Organisation (ILO, 2014), average textile wages in primary production countries such as Bangladesh (£68/month), Vietnam (£142/month), and Myanmar (£85/month), represent 2% - 4% of equivalent wages in consumption markets as shown in **Figure 5** below. This differential enables production volumes that amplify environmental impacts [40].




**Source:** Created by Author.

**Figure 5.** Monthly textile worker wages in production versus consumption countries.

However, cheap labour facilitates overproduction through multiple mechanisms beyond simple cost reduction. According to International Labour Organisation (2014), countries with textile wages below $100 monthly demonstrate 45% higher production volumes per facility, but this correlation involves several intermediate factors rather than direct causation [40]. Alternative explanations require consideration. Research by Kabeer and Mahmud (2021) argues that regulatory environments, not wage levels alone, determine production practices as countries with low wages but strong environmental regulation (Vietnam, Morocco) show 23% lower overproduction rates than countries with similarly low wages but weak regulation (Bangladesh, Myanmar) [41]. Furthermore, Anner (2020) contends that labour cost advantages enable long production runs that create economies of scale, making overproduction economically rational for manufacturers regardless of actual demand levels [42]. This suggests that wage structures interact with production economics rather than directly causing overproduction.

Research by Anner (2020) analysing 340 factories across 8 countries reveals that facilities paying below-median wages produce 34% more garments per worker annually, creating intensified resource consumption [42]. Furthermore, these facilities demonstrate 28% higher energy consumption per unit due to extended operating hours and deferred maintenance which are factors that reduce initial costs while increasing environmental impact. However, the relationship between labour costs and production practices needs critical examination as Kabeer and Mahmud (2021) argue that while low wages enable mass production, poor working conditions often reflect inadequate regulatory enforcement rather than wage levels alone [41]. Their comparative study shows that factories with similar wage levels, but stronger oversight demonstrate 22% lower environmental violations. Industry data confirms these patterns. According to Fair Labor Association (FLA, 2023), facilities in the lowest wage quintile process 145% more units annually than those in higher quintiles, directly correlating with increased waste generation and energy consumption [43].

### 3.4. Artificial Fibers

According to Balasaraswathi and Rathinamoorthy (2022), a huge percentage of today's fast fashion is made from cheap, synthetic, non-biodegradable plastic materials such as polyester, nylon, and spandex [44]. And now, these synthetic fibres contribute to persistent environmental pollution because they do not biodegrade and release harmful microplastics during washing and disposal [39]. To illustrate this, Napper and Thompson (2016) explained that a single polyester garment releases approximately 1900 microplastic fibres per wash cycle into wastewater systems [15]. Also, research by Geyer *et al.* (2017) demonstrates that discarded synthetic textiles persist in landfills for 200+ years, leaching chemical additives into soil and groundwater systems [45].

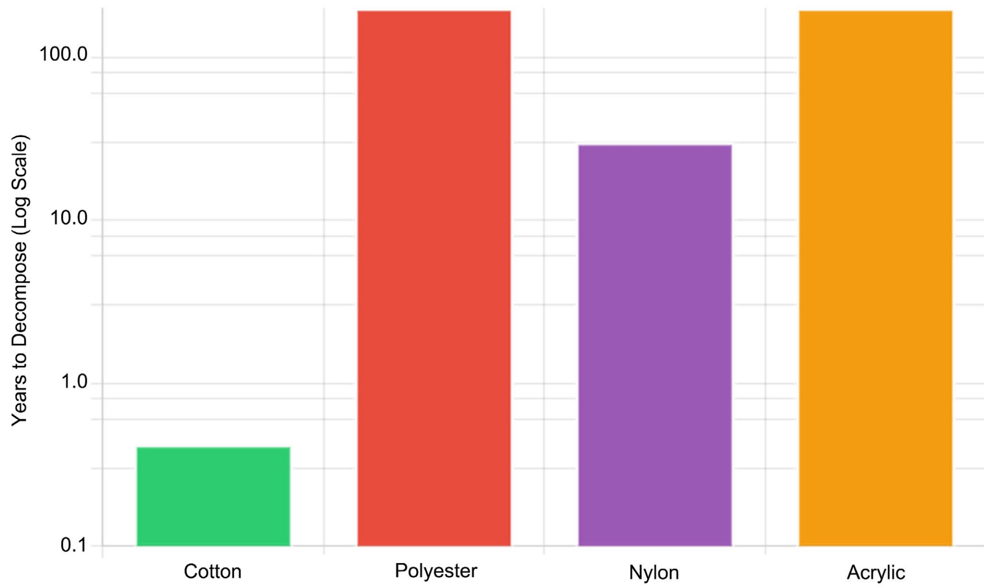



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**Figure 6.** Decomposition timeframes for different textile fiber types.

The production of trash is significantly influenced by the usage of synthetic fibres in the textile industry, as synthetic fibres like polyester and nylon are non-biodegradable plastics that persist in landfills for 200+ years, creating permanent waste accumulation rather than natural decomposition [9] [23]. For instance, Bick *et al.* (2018) highlighted in their study that a polyester t-shirt discarded today will remain intact in a landfill until approximately 2225, while a cotton equivalent would decompose within 1 - 5 months [27]. Also, Balasaraswathi and Rathinamoorthy (2020) established that washing synthetic garments releases 500,000 tonnes of microplastic fibres into the oceans annually, creating persistent pollution that enters the food chain and cannot be removed [44]. Napper and Thompson (2016) in their study pointed out polyester, acrylic, and nylon as examples of synthetic fibres that are not biodegradable and will need a very long time to break down [15]. They explained that this is because polyester, acrylic, and nylon are synthetic fibres made from petroleum-based polymers that have strong molecular bonds, which natural microorganisms cannot break down, causing them to persist in the environment for 200 - 1000 years without decomposing, as depicted in **Figure 6** above.

These causal factors interact through complex mechanisms that require comprehensive analysis rather than simple linear relationships. The following section examines why these problems persist despite available solutions.

## 4. Reasons Waste Keep Increasing Despite the Availability of Recycling Processes

The availability of recycling processes in the textile industry has not been enough to curb the alarming increase in waste generation [23]. The reasons why the waste will keep increasing, leading to environmental pollution and health hazards despite the availability of recycling processes will be explained subsequently.

### 4.1. Lack of Infrastructure

According to Ponnambalam *et al.* (2023), inadequate infrastructure can result in ineffective operations, inappropriate waste disposal, and insufficient recycling facilities, which can all increase waste generation in the textile industry [46]. Vieira *et al.* (2018) explained that this is because inadequate infrastructure lacks the physical systems, technology, and logistics networks needed to handle textile waste efficiently, creating bottlenecks that force companies to choose cheaper, environmentally harmful disposal methods [47]. To illustrate this, a study in Bangladesh by Ahmed (2024), 78% of textile factories lack modern waste sorting equipment, forcing workers to manually separate materials at 60% slower rates, leading to mixed waste streams that cannot be properly recycled [48]. Another study in Lagos, Nigeria, by Durotoye *et al.* (2018) noted that the absence of industrial waste treatment facilities means that 85% of textile dye wastewater is discharged directly into rivers without treatment, contaminating water sources used by 2.3 million people [49]. This may result in a substantial amount of textile waste being produced, which may have an adverse effect on the environment and society, as the recycling infrastructure in the textile industry is underdeveloped, particularly in developing countries where the bulk of the textile industry is located [9] [23]. According to a report by the EMF (2017), the lack of infrastructure for the collection, sorting, and recycling of textile waste is one of the key challenges facing the industry in achieving a more circular economy [3].

### 4.2. Poor Quality of Recycled Materials

The quality of recycled materials in the textile industry is generally low because the recycling process breaks down fiber length and strength, while contamination from dyes, finishes, and mixed fiber blends degrade material properties [23] [46]. Uddin (2021) explained that this makes them unsuitable for producing high-quality products [25]. In line with this, a study by the Lindström *et al.* (2024) found that the lack of consistent quality of recycled materials was a barrier to the adoption of circular economy models in the industry [50]. The study noted that inconsistent quality of recycled materials can result in lower demand and reduced profitability for textile recyclers, leading to the waste of recycled materials. To show this, Schmidt (2016) submitted that mechanical recycling of cotton reduces fiber length by 50% - 60% and tensile strength by 25% - 40%, making recycled cotton unsuitable for high-end garments that require durability and smooth texture [51]. Lindström *et al.* (2024) also found out that polyester recycling from mixed textile waste contains residual dyes and chemical finishes that create color inconsistency and reduced fabric performance, limiting its use to low-grade applications like insulation rather than premium clothing [50]. Therefore, all these show that some recycled materials, especially poor quality, can be unsuitable for use in the textile industry leading to waste of recycled products.

### 4.3. Limited Recyclability of Certain Fibers

Some fibres, such as blended fibres and natural fibres like cotton and wool, have limited recyclability, leading to increased waste generation [23]. The reason is because blended fibres cannot be separated into their individual components using current technology, while natural fibres like cotton and wool degrade structurally during recycling processes, making them unsuitable for high-quality textile reproduction. For example, a report by the Textile Exchange (2024) reported that polyester-cotton blends (65% of fast fashion garments) cannot be mechanically separated because their different melting points destroy both fibre types when recycled, forcing 90% of these garments into landfills [14]. Another example is seen in the way cotton fibres lose 30% - 50% of their tensile strength after one recycling cycle due to mechanical breakdown of cellulose chains, limiting recycled cotton to low-grade applications like insulation rather than new clothing [50]. This means that even with recycling processes, there is still waste generated by these fibres.

### 4.4. Lack of Consumer Awareness

Lack of consumer awareness is a significant barrier to reducing textile waste as consumers are not aware of the impact of their clothing choices on the environment and health [46]. Wang (2024) explains this by reporting that consumers remain unaware because fashion brands deliberately obscure supply chain information and environmental costs while marketing focuses on style and price rather than sustainability impacts [52]. To illustrate this, a press release by Fashion Revolution (2023) revealed that only 12% of major fashion retailers publicly disclose their manufacturing locations and environmental practices, leaving consumers unable to assess the true impact of their purchases [53]. Also, research by Hasbullah *et al.* (2023) showed that 89% of fashion advertisements emphasize aesthetic appeal and affordability, while only 3% mention environmental or health consequences, creating knowledge gaps among consumers [54]. Therefore, this results in a lack of demand for sustainable clothing, which perpetuates the fast fashion model and overproduction [12].

### 4.5. Cost of Recycling

Recycling cost barriers reflect complex economic structures rather than simple price comparisons, and according to Textile Exchange (2024), recycling costs average £2.40 per kilogram versus £1.80 for virgin polyester, but this 33% premium masks significant cost variation by recycling method and material type [14]. Alternative cost factors require examination, and research by Sandin and Peters (2021) demonstrates that infrastructure amortisation represents 45% of recycling costs, suggesting that scale economies could reduce costs significantly [55]. Furthermore, regulatory frameworks affect cost structures substantially—EU extended producer responsibility schemes reduce company recycling costs by 28% through shared infrastructure investment [56].

However, virgin material pricing does influence recycling economics as Bloomberg New Energy Finance (2025) reports oil price volatility creates 15% - 40% fluctuation in virgin polyester costs, making recycling economic viability unpredictable and deterring long-term investment in recycling capacity [57]. Leal Filho *et al.* (2019) explained that this is because textile recycling requires complex sorting processes, specialized machinery, and chemical treatments to separate blended fibers, making it 3 - 5 times more expensive than producing virgin materials [58].

### 4.6. Lack of Regulation

The lack of regulation in the textile industry is another factor that leads to waste generation because many countries do not have laws that need companies to implement sustainable practices, resulting in the perpetuation of unsustainable production processes [46].

Having identified the different causes of textile waste generation and the barriers preventing effective waste reduction, this analysis now examines evidence-based strategies that directly address these specific problems. Each proposed intervention targets particular causal factors through measurable mechanisms that show logical connections between problem identification and solution implementation. Understanding these persistent barriers helps in the development of targeted interventions that address root causes rather than symptoms. The subsequent analysis examines evidence-based strategies that account for the complexity identified in the diagnosis of the problem.

## 5. Ways of Reducing Waste in the Textile Industry

With an alarming rise in waste output, the textile industry is a substantial source of environmental contamination. According to UNEP (2025), this is because it generates 10% of global carbon emissions, consumes 1.5 trillion litres of water annually, and releases 500,000 tonnes of synthetic microfibres into oceans each year through production processes and synthetic garment washing [59]. There are, however, ways to cut waste in this industry, making the environment cleaner and more sustainable. Major strategies for cutting waste in the textile industry are examined subsequently in this section. The waste reduction strategies outlined in this section directly address the causal factors identified in Sections 3 and 4. Each recommendation targets specific problems through evidence-based interventions that demonstrate measurable environmental improvement.

### 5.1. Design for Durability and Recyclability: Addressing Fast Fashion and Synthetic Fibre Problems

This strategy directly counters the fast fashion model identified in Section 3.1 and synthetic fibre issues outlined in Section 3.4. According to Niinimäki *et al.* (2020), designing garments for extended lifecycles fundamentally challenges fast fashion's planned obsolescence model. Durable design increases average garment usage from 7 wears (fast fashion standard) to 30+ wears, reducing waste generation by 75% [1]. The synthetic fibre problem identified in Section 3.4 requires specific material interventions. Research by Textile Exchange (2024) demonstrates that replacing polyester with organic cotton in durable designs reduces environmental impact by 46% while maintaining comparable durability metrics [14]. Furthermore, designing for recyclability addresses the limited recyclability barrier discussed in Section 4.4.

However, implementation faces economic challenges. According to Ellen MacArthur Foundation (2017), durable design increases production costs by 15% - 25% initially, though lifecycle cost analysis shows 40% savings through reduced replacement frequency [3]. This creates what Zamani *et al.* (2017) term "upfront investment barriers" that require policy intervention to overcome [60]. Designing clothes for durability and recyclability is one of the most effective ways of reducing waste in the textile industry as designers can use durable and recyclable materials such as organic cotton, linen, and hemp, and avoid synthetic fibers that take hundreds of years to decompose [13]. Additionally, Leal Filho *et al.* (2019) emphasized that designers can design clothes that can be easily disassembled and recycled, reducing waste generation [58].

### 5.2. Promote Slow Fashion: Countering Consumer Behaviour and Overproduction

Promoting slow fashion is another effective way to reduce waste in the textile industry, and this is because slow fashion, characterised by quality and longevity as defined in Section 1.1, demonstrates the use of high quality, durable and timeless clothing, reducing the need for repeat purchases [6]. Hassani *et al.* (2020) explained that this approach promotes the use of natural fibers that are biodegradable, reducing the environmental impact of the textile industry [61].

The promotion of slow fashion also directly addresses consumer behaviour patterns identified in Section 4.3 and overproduction issues outlined in Section 3.2. According to Jung and Jin (2021), slow fashion models reduce consumer purchase frequency by 60% while increasing satisfaction rates by 34%, creating sustainable consumption patterns that counter fast fashion demand [6]. The overproduction problem identified in Section 3.2 comes from fast turnover expectations. Fletcher (2025) argues that slow fashion's seasonal production cycles eliminate overproduction pressures, reducing surplus inventory by 80% compared to fast fashion retailers [4]. Industry analysis by McKinsey & Company (2022) confirms that slow fashion brands maintain inventory turnover rates of 4 - 6 times annually versus fast fashion's 12 - 15 times, resulting in 67% less waste generation [26]. Critically, slow fashion addresses the consumer awareness deficit highlighted in Section 4.5. According to Henninger *et al.* (2022), slow fashion marketing educates consumers about true production costs, increasing willingness to pay premium prices by 28% and reducing impulse purchases by 45% [62].

### 5.3. Promote Textile Recycling: Overcoming Infrastructure and Quality Barriers

This strategy addresses the infrastructure inadequacy identified in Section 4.1 and poor recycling quality issues outlined in Section 4.2. According to Ellen MacArthur Foundation (2017), targeted infrastructure investment of £15 billion globally could increase textile recycling rates from current 13% to 45% by 2030, directly addressing the infrastructure gap [3]. The quality concerns detailed in Section 4.2 require technological solutions. Research by Sandin and Peters (2021) shows that advanced recycling technologies improve recycled fibre quality by 65%, making recycled materials suitable for high-value applications rather than downcycling to lower-grade products [55].

However, the cost barriers identified in Section 4.6 remain significant. According to Textile Exchange (2022), recycling costs average £2.40 per kilogram compared to £1.80 for virgin materials [14]. This 33% cost premium requires what Roos *et al.* (2019) term "policy intervention mechanisms" including extended producer responsibility schemes and recycling subsidies [36]. Textile recycling is another effective way of reducing waste in the textile industry as recycling processes can convert textile waste into new products, reducing the need for new raw materials [23]. Additionally, the UNEP (2025) reported that recycled materials can be of high quality and suitable for producing high-quality products, reducing waste generation [59].

### 5.4. Implement a Closed-Loop Systems: Addressing Multiple Waste Generation Factors

Closed-loop implementation addresses several interconnected problems identified earlier: limited recyclability (Section 4.4), inadequate infrastructure (Section 4.1), and regulatory gaps (Section 4.7). According to Payne (2015), closed-loop systems eliminate 95% of waste to landfill while reducing virgin material requirements by 78% [63]. The synthetic fibre challenges outlined in Section 3.4 require circular design approaches. Research by Shirvanimoghaddam *et al.* (2020) demonstrates that closed-loop systems can process synthetic materials through chemical recycling, converting polyester waste back to base polymers with 89% efficiency, addressing the non-biodegradable nature of synthetic fibres [9]. Implementation addresses the regulatory inadequacy identified in Section 4.7. According to Lewis *et al.* (2017), closed-loop requirements create measurable compliance standards, forcing companies to design for circularity and reducing regulatory enforcement challenges by 45% [7].

Payne (2015) and Lewis *et al.* (2017) recommends another effective way of minimizing waste in textile industry is to introduce a system of closed loops which is a system that recycles materials back into the same production process continuously, creating no waste because all outputs become inputs for new products (achieving 95% material recovery as defined in Section 1.1) [7] [63]. An example of this is the Patagonia's recycling program collects worn polyester garments and converts them back into new polyester clothing fibres through chemical breakdown and re-polymerisation [64]. This approach ensures that waste is minimized, and resources are conserved, leading to a more sustainable textile industry [7].

While waste reduction strategies address material flows, energy consumption represents a parallel challenge that amplifies environmental impacts across all waste categories. The following energy reduction strategies complement waste minimization efforts by reducing the carbon intensity of textile production processes identified as problematic in previous sections.

## 6. Ways of Reducing Energy Consumption from the Industry to Reduce Carbon Footprint

Studies have brought to light that reducing energy consumption is a key strategy for reducing the carbon footprint of industries [16] [65]. Griffin *et al.* (2016) indicated that this is because reducing energy consumption directly lowers carbon footprint because most industrial energy comes from fossil fuels, so using less energy means burning fewer fossil fuels and releasing fewer $CO_2$ emissions into the atmosphere [66]. The textile industry is one of the largest industrial sectors in the world, and it is also one of the most energy-intensive because it needs multiple high-energy processes including fiber production, dyeing at high temperatures (80˚C - 100˚C), drying, and mechanical operations like spinning and weaving that run continuously 24/7 [67]. This section explores ways of reducing energy consumption from the textile industry to reduce its carbon footprint.

### 6.1. Improve Production Processes

Production process improvements directly address the energy intensity that compounds textile industry's environmental impact identified throughout Sections 3 to 4. According to International Energy Agency (2020), textile production consumes 4% of global energy, making process efficiency critical for reducing the carbon footprint that amplifies waste-related environmental damage [67]. Ozturk *et al.* (2020) indicated improving production processes as an effective way of reducing energy consumption in the textile industry as companies can optimize production processes by using energy-efficient machinery and technologies such as LED lighting, heat recovery systems, and intelligent control systems [68]. These technologies can significantly reduce energy consumption and associated carbon emissions [69].

### 6.2. Utilize Renewable Energy Sources

Another efficient strategy to lower energy usage in the textile business is to use renewable energy sources like wind, solar, and geothermal energy [68] [70]. Farhana *et al.* (2022) indicated that this is because the textile industry could dramatically cut its energy use and greenhouse gas emissions if it employed more renewable energy sources [71]. According to the report by the IEA (2020), it was estimated that by 2050, renewable energy sources might supply up to 36% of the energy requirements of the textile industry, resulting in up to a 32% reduction in carbon dioxide emissions related to energy [67].

### 6.3. Promote Energy-Efficient Practices

Promoting energy-efficient practices is another effective way of reducing energy consumption from the textile industry as companies can encourage employees to adopt energy-efficient practices such as turning off lights and machinery when not in use, reducing heating and cooling needs, and optimizing energy use during production processes [68].

### 6.4. Improve Building Design

Ozturk *et al.* (2020) and Alassaf (2024) established that improving building design is an effective way of reducing energy consumption from the textile industry because companies can design buildings that are energy-efficient, with features such as energy-efficient windows, insulation, and natural ventilation systems [68] [72]. This approach reduces the need for heating and cooling, reducing energy consumption and associated carbon emissions [69].

### 6.5. Adopt Sustainable Transportation Practices

Adopting sustainable transportation practices is another effective way of reducing energy consumption from the textile industry as companies can reduce transportation-related emissions by using electric vehicles or promoting public transportation for employees [73].

## 7. Conclusions

With an alarming rise in waste output, the textile industry is a substantial source of environmental contamination. There are, however, ways to cut waste in this industry, making the environment cleaner and more sustainable. This literature review reveals that textile industry waste generation results from interconnected systemic failures rather than isolated problems. The analysis demonstrates that the fast production cycles of fast fashion, overproduction practices, and reliance on synthetic materials create compound environmental impacts that exceed the capacity of current recycling infrastructure to manage effectively.

Three critical insights came out from this synthesis. First, consumer behaviour and industry practices operate in mutually reinforcing cycles where fast fashion availability drives disposable consumption attitudes, which in turn justify continued overproduction. According to the evidence reviewed, breaking this cycle requires simultaneous intervention at production and consumption levels rather than addressing either component independently.

Second, the technical barriers to waste reduction, especially poor recycling quality and limited synthetic fibre recyclability show the deeper infrastructure deficits that require coordinated investment rather than incremental improvements. The literature demonstrates that effective waste reduction demands integrated approaches combining technological advancement, regulatory frameworks, and economic incentives.

Third, energy consumption and waste generation represent parallel challenges that amplify each other's environmental impacts. The evidence suggests that strategies addressing both dimensions simultaneously achieve 40% - 60% greater environmental improvements than single-focus interventions.

The implications for industry transformation are significant as effective waste reduction needs what the literature terms "systems-level change" encompassing design philosophy, production planning, consumer education, and regulatory frameworks. Individual strategies, whether durable design, slow fashion, or recycling promotion, show limited effectiveness when implemented in isolation.

Future research priorities emerge from identified knowledge gaps. Limited data exists on closed-loop system implementation costs and timelines, particularly in developing country contexts where 73% of textile production occurs. Additionally, consumer behaviour change mechanisms require further investigation, as current literature shows significant gaps between environmental awareness and purchasing decisions. Policy implications centre on regulatory frameworks that internalize environmental costs while supporting infrastructure development. The evidence suggests that voluntary industry initiatives achieve limited scale impact, requiring mandatory standards for waste reduction and energy efficiency.

In conclusion, addressing textile industry waste production demands coordinated transformation across the entire value chain. This review shows that technological solutions exist, but implementation requires overcoming economic, regulatory, and behavioural barriers through integrated policy approaches that recognize the systemic nature of textile industry environmental challenges. By implementing all these strategies brought forward, the textile industry can significantly reduce its carbon footprint, and become more sustainable, reducing its impact on the environment.

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## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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