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Enseignement supérieur de type long de niveau universitaire

**To what extent can sustainable
materials and practices reduce the
fashion industry's environmental
impact?**

Mémoire présenté par :

Alexandra DE LANNOY

Pour l'obtention du diplôme de :

Master's degree in Management Science

Année académique 2023-2024

Promoteur :

Jacques SPELKENS

Summary

This thesis explores how sustainable materials and business practices can help reduce the environmental impact of the fashion industry, which is currently one of the world's most polluting sectors. With fast fashion accelerating overproduction, waste and emissions, sustainability has become an urgent priority. The research evaluates the potential and limitations of sustainable alternatives across materials, production and consumer engagement.

The study first outlines the industry's structural challenges, including its reliance on virgin resources, exploitative labor conditions and a linear "take-make-dispose" model. It then examines a range of sustainable materials, from organic cotton and recycled synthetics to regenerative fibers, and their benefits as well as contextual limitations. While some materials show promise in reducing emissions, water use and toxicity, their actual performance depends on sourcing, processing and scalability.

Sustainable business practices such as circular economy models, take-back and repair schemes, demand-driven production and supply chain transparency are also analyzed. These initiatives help extend product life, reduce waste and engage consumers in sustainability efforts. However, their impact remains constrained by technical, financial and infrastructural barriers, including the dominance of fast fashion, lack of standardized data and consumer price sensitivity.

Through two company case studies (MUD Jeans and Rifò) and a consumer survey, the thesis provides real-world insights into how sustainable strategies are applied and perceived. The findings show that while companies are innovating, most current efforts achieve only incremental progress. It also shows that consumer willingness to engage in sustainable brands is rising, although some resistance remains notably due to concerns about affordability.

In conclusion, sustainable materials and practices can meaningfully reduce fashion's environmental footprint, but only if paired with systemic change. In order to reach full effectiveness, these measures must be supported by regulation, infrastructure investment and a shift in both industry priorities and consumer behavior.

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General introduction

The fashion industry is widely recognized as one of the most polluting sectors globally, with its environmental and social impact worsening as production and consumption continue to rise. The rise of fast fashion has led to a cycle of overproduction where brands rapidly release new collections to keep up with fleeting seasonal trends. In response, consumers are encouraged to engage in impulsive purchasing behaviors, further increasing demand and resource consumption. This unsustainable model not only depletes natural resources but also generates massive textile waste, pollution and ethical concerns related to labor practices.

Addressing the industry's environmental and social impact requires systemic change at multiple levels, from consumer behavior to corporate practices. Shifting consumer habits is a complex and gradual process that takes time, commitment and a sustained effort to raise awareness through education. Financial constraints can also limit access to sustainable choices which further complicates the path to change. Given these obstacles, corporate action becomes essential. Brands have the power to promote sustainability not only through innovations in materials and production methods but also by implementing responsible business models. The adoption of sustainable materials and ethical production practices represents an opportunity to reduce fashion's overall footprint. However, questions remain about how effective and realistic these measures truly are in practice.

This thesis builds on existing research and data concerning the environmental and social impacts of the fashion industry, as well as the development of sustainable materials, circular business models and responsible production practices. By drawing information from industry reports, it places the analysis within the wider context of what is already known and studied about the topic and highlights the relevance of these issues in both academic and practical contexts.

With this reminder of existing contributions in mind, this research explores the extent to which sustainable materials and practices can mitigate the negative effects of the fashion industry. By examining their potential to reduce environmental harm and improve industry standards, this study aims to provide insights into how corporations can transition towards more responsible and sustainable business models.

This thesis will therefore explore the following question: To what extent do sustainable materials and practices reduce the fashion industry's overall impact?

To guide this research, the following **hypotheses** are proposed as a provisional answer to the research question:

H1: The adoption of sustainable materials and practices by fashion companies can significantly reduce the industry's environmental and social impact, and may contribute to achieving long-term goals such as carbon neutrality by 2050.

H2: However, structural barriers such as limited infrastructure, economic constraints and consumer price sensitivity reduce the overall effectiveness of these measures. Even if widely implemented, such practices alone are unlikely to help the fashion industry achieve carbon neutrality by 2050.

To help make sense of the different aspects explored, the thesis is structured as outlined below.

Before diving into the broader context of the fashion industry, it is important to first clarify several key concepts that form the foundation of this thesis. Chapter 1 will define and explore the scope of the apparel, textile and fashion industries, while also examining critical factors such as scalability and feasibility. Additional sections also address the role of innovation, the limitations of current solutions and the importance of systemic change. This section aims to provide helpful background context to support the more in-depth discussions that follow.

In order to answer the research question, the literature review begins with a broad overview of the fashion industry. It starts with a brief historical background to understand how the industry has evolved into its current form. The focus then shifts to the emergence and dominance of fast fashion which has played a significant role in shaping the sector. This section also explores the environmental and social consequences of current practices before delving into the structural constraints and challenges the industry faces today. These elements will help provide a clear understanding of the industry's complexities and the various factors that interact and influence its ongoing development.

After this key overview, the next part of the thesis focuses on one of the most visible and often discussed areas of sustainable fashion: the materials used to make garments. Section 2.2 explores the environmental performance of commonly used fibers and investigates the potential of sustainable alternatives. This includes a detailed examination of natural, recycled, bio-based and regenerative materials, as well as a discussion of the challenges surrounding recyclability, impact assessment and circularity. By comparing conventional materials with innovative options, this section aims to assess how much switching to more sustainable inputs can actually reduce the industry's overall impact.

After exploring the impact of materials, Section 2.3 moves on to the broader production process and its role in shaping the industry's environmental footprint. This section examines key stages in the fashion lifecycle and highlights sustainable practices that can reduce resource use, emissions and pollution. This section aims to understand how changes in the way clothes are made can contribute to a more sustainable fashion system.

Following the literature review, chapter 3 presents the data collected to support the analysis of sustainable materials and practices in the fashion industry. It outlines the research methods used, including secondary research and interviews with selected companies, and explains how relevant information was gathered and organized. This chapter aims to provide transparency on

the sources and types of data used in the study, offering the foundation for the analysis and discussion in the following sections.

Following the literature review, chapter 3 presents the primary data collected to support the analysis of sustainable practices in the fashion industry. It is divided into two main parts. The first focuses on company-level initiatives, with case studies of MUD Jeans and Rifò used to explore how sustainability is applied in real business contexts. The second part examines consumer behavior through survey data and offers insight into attitudes and practices related to sustainable fashion. This chapter outlines the research methods used for both parts and provides the foundation for the discussion and interpretation that follow in the general conclusion.

Chapter 1 - Concepts

1.1. Scope and Definitions

1.1.1. Apparel, Textile and Fashion Industry

I will focus specifically on the **apparel industry** throughout this thesis rather than on the broader **textile industry**. The apparel industry refers to clothing and accessories, such as underwear, shoes, bags, jewelry, and items like hats, scarves, and belts. While the textile industry covers a variety of fabrics and materials, including products like carpets and towels, the apparel sector focuses on the finished consumer products. This thesis focuses on the apparel sector which is frequently tied to trends, design and aesthetics (Obviously Apparel, 2024). Understanding the apparel industry also involves taking a look into the entire production process, from raw materials to yarn production, dyeing, and fabric finishing (GlobalEDGE, 2024).

In this context, the terms "**fashion industry**" and "apparel industry" are used interchangeably, as the distinction between the two has increasingly blurred over time. As noted on the website of the *Encyclopedia Britannica*, « Some observers distinguish between the fashion industry (which makes “high fashion”) and the apparel industry (which makes ordinary clothes or “mass fashion”), but by the 1970s the boundaries between them had blurred » (Major & Steele, 2024).

The fashion industry is defined as: «...the fashion industry encompasses the design, manufacturing, distribution, marketing, retailing, advertising, and promotion of all types of apparel (men’s, women’s, and children’s) from the most rarefied and expensive haute couture (literally, “high sewing”) and designer fashions to ordinary everyday clothing...» (Major & Steele, 2024).

With a clear understanding of these terms, this thesis will focus on the specific dynamics within the apparel industry, which is where the primary trends towards sustainability and scalability are most apparent. Narrowing the scope from the broader textile industry will allow for a more focused analysis of these dynamics.

1.1.2. Scalability

Scalability is defined as follows: “The ability of a business or system to grow larger” (Cambridge dictionary, 2024). Achieving scalability in the fashion industry is not without its challenges. Businesses must effectively manage their supply chains, from manufacturing and inventory management to marketing and sales.

Scalability is crucial to achieve sustainability in the fashion industry. It’s not just about growth, but about maximizing the positive impact of sustainable practices. Without the ability to scale, the benefits of sustainable materials and methods remain limited. The widespread adoption of these materials and practices is essential to drive significant environmental and social change.

For example, if a sustainable fabric can only be produced in small quantities due to scaling issues, its potential to reduce the industry's carbon footprint is minimal. Therefore, scaling these practices up is key to achieving meaningful change. The path to scaling sustainable initiatives often comes with challenges as it will be demonstrated in the case study of MUD Jeans (Refer to section 3.1.2)

As companies grow, their operations become more complex. Managing this growth requires significant investments in restructuring to maintain transparency, traceability and ethical practices. As demand increases and the company grows, sourcing larger quantities of sustainable materials and maintaining ethical production practices becomes increasingly difficult. Eco-friendly processes, such as mechanical recycling or natural dyeing, may not be easily scalable or as efficient on a large scale. Additionally, ensuring that the entire supply chain remains ethical becomes challenging as it is harder to monitor and guarantee compliance.

Breaking down sustainability into three key challenges provides a clearer understanding of these complex dynamics: operational scaling, consumer related issues and broader logistical concerns.

One operational challenge is reducing waste at every stage of production which is particularly difficult in the fashion industry where overproduction and large inventories are common. Managing waste reduction while scaling up production requires innovation at multiple stages.

On the consumer side, making sustainable clothing affordable and accessible remains a challenge. Sustainable materials and practices are more expensive. Companies need to encourage consumers to choose sustainable fashion over fast fashion by showing that it can be affordable (or worth the higher cost) and stylish too (Fair Konnect, 2023).

Finally, broader logistical and transportation challenges must be addressed as companies scale. With the increase in shipment of materials and finished products globally, it becomes harder to maintain a low carbon footprint. Therefore, sustainable transportation solutions must also scale alongside the business.

In conclusion, addressing these sustainability challenges while scaling operations is essential for companies aiming to make a significant positive impact on the fashion industry.

1.1.3. Feasibility

Feasibility is defined as follows: “the possibility that something can be made, done, or achieved, or is reasonable” (Cambridge dictionary, 2024).

But is it feasible to make the fashion industry sustainable? Achieving sustainability in fashion presents several complex challenges.

One major challenge is greenwashing, a widespread marketing tactic where companies exaggerate their sustainability efforts. Initially, sustainability reports were intended to provide

transparency about companies' shortcomings and future goals. However, over time, they have become tools for companies to present a distorted image of their achievements. Greenwashing often involves bombarding social media with seemingly progressive content that lacks genuine environmental and social responsibility. The absence of strict regulations around these practices allows businesses to create an illusion of responsibility instead of making real progress (Ge Qu, 2024).

Greenwashing not only undermines genuine efforts to cut emissions and address the climate crisis but also compromises trust and diverts attention from necessary actions for meaningful global change (United Nations, n.d.).

According to a study by Kantar in the *Sustainability Sector Index 2023*, "...worries about greenwashing are universally high – over half of respondents believe brands across all industries are misleading when reporting their sustainability actions" (Kantar, 2023). This creates confusion for consumers, making it harder to distinguish truly sustainable initiatives from those that are misleading. As a result, trust is weakened and consumers become skeptical about sustainable products. Moreover, a study by Sun and Shi (2022) found that "consumers' greenwashing perception negatively influences consumers' green purchasing intentions, that perceived betrayal plays a partially mediating role in this influence relationship, and that environmental responsibility reinforces the negative influence of greenwashing perception on green purchasing intentions" (Sun & Shi, 2022). These findings demonstrate the considerable impact that greenwashing can have on consumer behavior.

To address this, it is crucial to implement transparent sustainability practices and tackle greenwashing through legal frameworks. Some legislations have already been introduced, including the new EU directive on greenwashing and misleading product information which was adopted by the European Parliament on January 17, 2024 and approved by the European council on February 20, 2024 (Garrigues, 2024). This directive bans vague environmental statements (such as 'environmentally friendly', 'climate neutral', etc.) without supported evidence as well as claims of carbon neutrality based solely on emissions offsetting and unapproved sustainability labels. It also aims to address early obsolescence and misleading durability claims (European Parliament, 2023).

This directive is intended to work alongside the 'Green claims directive' which provides more detailed guidelines on the use of environmental claims and labels (European Parliament, 2024). However, some concerns have been raised regarding the procedures proposed in the Green Claims Directive. Firstly, the introduction of a two-step verification process could add unnecessary complexity. An initial quick check might approve misleading claims, while a second review might reveal inconsistencies. Secondly, the presumption of conformity in Article 12 could potentially allow unchecked and misleading claims to remain. Thirdly, the fixed timeline for verification could be unreasonable given the complexities involved in the verification process (TIC Council, 2024). Lastly, another issue highlighted was that the directive could potentially make companies avoid talking about their sustainable initiatives altogether. The ambiguities in interpreting the articles and the fear of facing severe penalties,

even for unintentional rule violations, might discourage companies from discussing their efforts (Wangel, 2024).

Despite these efforts, there are still gaps and loopholes in the legislation that need to be addressed to enforce regulations effectively and achieve true sustainability.

While these concerns highlight important ongoing discussions in the regulatory landscape, they are outside the scope of this research which focuses more on the broader feasibility of sustainability efforts within the fashion industry.

Beyond the challenges of scaling and greenwashing, the fashion industry also faces another significant hurdle in its pursuit of sustainability; overconsumption. The rise of fast fashion has encouraged a culture of buying more and wearing less which leads to immense textile waste and serious environmental consequences. This problem is further intensified by the linear economic model that currently dominates the industry, which follows a traditional ‘take-make-use-dispose’ approach (Ge Qu, 2024).

A transition to a circular economy offers a promising solution to reduce the environmental impact of overconsumption. Extending the life cycle of materials and repurposing them into new products could play a key role in achieving long-term sustainability in fashion (Ge Qu, 2024). While crucial for the industry's future, this issue lies outside the direct scope of this research, which focuses on the feasibility of sustainability practices within the current framework.

As briefly mentioned in the previous section on scalability, the complexity of sustainable supply chains represents another hurdle in the pursuit of sustainability in the fashion industry. Numerous stakeholders must coordinate their efforts, often on a global scale, making it difficult to ensure transparency and accountability throughout the entire chain. This intricate network can make it challenging to maintain consistent sustainability practices across all stages of the supply chain.

Potential solutions could include the adoption of fair-trade certifications, robust supply chain monitoring or even advanced tracking technologies. These measures could help verify sustainability claims and ensure that ethical practices are maintained at every stage. Although these solutions would require significant investment and energy to implement, they offer promising options to address some of the systemic barriers to sustainability in fashion. This issue will be explored further in the section on Sustainable fashion production (Please refer to section 2.3).

But even with operational hurdles addressed, one major question persists: is sustainability economically feasible for an industry driven by speed and low costs?

While there is an increasing interest in sustainable alternatives within the fashion industry, questions remain about whether it can remain economically viable in the long term or not. The

slow fashion model has gained attention as a potential solution while standing in contrast with the fast-paced and high-turnover nature of “conventional” fashion. This model focuses on creating long-lasting, high-quality products while encouraging consumers to buy less and prioritize longevity over constant novelty. However, the profitability of slow fashion remains underexplored in both research and practice despite its promising prospects (Sarokin & Bocken, 2024).

One study examined the profitability associated with the use of sustainable raw materials and emphasized how compliance with regulatory frameworks can offer a competitive advantage particularly when compared to companies relying on traditional sourcing. It also noted that growing consumer demand, growing investor interest and the potential market differentiation present additional economic opportunities for brands that prioritize sustainable sourcing. In addition to that, such a transition can enhance operational efficiency and supply chain resilience by minimizing vulnerability to raw materials price fluctuations, reducing regulatory costs through early alignment with sustainability standards and improving long term resource stability and planning (Jensen, Stoneburner, & Et al., 2023).

So how do sustainability-focused fashion brands compare economically to fast fashion brands? Traditionally, fashion businesses have generated profits through high-volume production and rapid turnover models (Sarokin & Bocken, 2024). While growing consumer interest in sustainable alternatives suggests long-term potential, recent research comparing financial performance shows that conventional fast fashion companies still outperform sustainability-driven brands in terms of profitability and market resilience. This was evident during economic crises like the COVID-19 pandemic, when conventional brands reported sales revenues over 20 times higher and significantly stronger profit margins, while many sustainability-focused companies struggled to remain profitable. (Meskini, Mahmud, & Et al., 2024)

However, other research offers a more nuanced view showing that, in developed economies, sustainable firms outperformed traditional ones during the COVID-19 crisis as they benefited from stronger institutional support and greater financial resilience. In contrast, sustainable firms in emerging markets struggled to achieve comparable profitability due to limited resources and weaker public support (Lu & Khan, 2022).

These findings suggest that while sustainable fashion is increasingly adopted, it remains financially vulnerable and may require further support, incentives or scaling to reach similar financial performance. However, shifting consumer preferences suggest that profitability in the sustainable sector may improve in the coming years (Meskini, Mahmud, et al., 2024).

Beyond adapting existing models, some scholars suggest that sustainable fashion’s economic viability may lie in adopting more diverse and circular revenue streams. These new models promote reduced consumption while generating income in alternative ways. In practice, this could mean redesigning products for durability, reuse and longevity while offering complementary services such as repair, resale or rental. Together, these strategies aim to extend a product’s lifecycle and create added value without relying on overproduction. While a few

pioneering companies have started to explore these innovative models, widespread adoption of these models remains limited. Many businesses continue to resist shifting away from traditional sales-driven strategies often due to concerns over profitability and consumer demand. This resistance highlights the need for a broader shift not only in business practices, but also in consumer behavior. Such a shift should be supported by collaboration across stakeholders (Sarokin & Bocken, 2024).

In summary, although the fashion industry is gradually exploring sustainable business models, the path to meaningful change remains complex and uncertain. Challenges continue to undermine progress, from regulatory enforcement to economic uncertainty. However, growing awareness, evolving consumer expectations and emerging innovations point to a hopeful, though not yet assured, future for sustainable fashion's feasibility.

1.1.4. Defining Sustainable fashion

According to EarthDay.org, sustainable fashion can be defined as a clothing supply chain that prioritizes ecological and social responsibility, aiming to shift the industry and consumers away from the fast fashion model and toward more sustainable practices in sourcing, production, distribution, marketing, and consumption (EarthDay.org, n.d.). Similarly, Oxfam defines sustainable fashion as clothing produced with consideration for human and environmental impacts, supporting a more just supply chain. This definition also emphasizes the role of second-hand clothing, both in extending the life of garments and in raising funds for sustainability-focused causes (Oxfam, 2024)

While definitions of sustainable fashion often focus on its environmental and social aspects, its interpretation can vary across different stakeholders. For instance, an article in the *Journal of Fashion Marketing and Management* highlights how organizations, experts and consumers may each understand sustainable fashion in distinct ways. The paper further emphasizes that, beyond eco-friendly materials and reducing carbon footprints, sustainable fashion also includes social dimensions such as fair wages and ethical working conditions. Additionally, sustainable fashion is often associated with the "slow fashion" movement which contrasts strongly with the fast fashion model by promoting mindful consumption, higher quality and better working conditions across the supply chain (Henninger, Alevizou, & Oates, 2016). This movement, which emphasizes the importance of ethical and sustainable practices in fashion, will be discussed further in the next question.

While definitions vary, they all share a common goal: reducing harm to the environment and society through more conscious practices in fashion production and consumption.

Core Principles of Sustainable Fashion

Having established the different definitions of sustainable fashion, it is now important to explore the key principles that shape this movement. These principles play a crucial role in making the industry shift away from the fast fashion model by fostering more sustainable, ethical and responsible practices in both production and consumption. They also offer a clear

framework for implementing the necessary changes to make the fashion industry align with these values.

Environmental Dimension

As sustainable fashion involves reducing environmental impact, at the core of these principles lies *environmental sustainability*, which is a fundamental aspect of it. This principle emphasizes the use of renewable and eco-friendly materials along with the reduction of the carbon footprint associated with fashion production. By promoting durability and longevity of garments, it aims to minimize the environmental impact and encourage mindful consumption. Manufacturing with reduced environmental impact and the use of recycled materials are also vital practices that support these efforts (Pires, Morais, Delgado, & Duarte Santos, 2024).

Social Dimension

Another core principle closely tied to this is *social responsibility*, which prioritizes the well-being of workers throughout the supply chain. This involves adopting fair wages, safe working conditions and ethical operational practices to ensure that the people behind fashion production also benefit from its success.

Transparency and Traceability

Another important principle is *transparency and traceability* in the fashion supply chain. Sustainable fashion necessitates clear communication about the origins of raw materials, the conditions under which they were produced and the processes involved in manufacturing. This transparency builds trust with consumers and encourages businesses to hold themselves accountable. It also aligns with the need for clear communication regarding product origins and ethical production processes. Sourcing materials and production locally is also crucial as it supports local economies by manufacturing garments near their source. This reduces transportation emissions and fosters more meaningful connections between producers and communities.

Quality Over Quantity

A central principle of sustainable fashion is the emphasis on *quality over quantity*. This aligns with the principles of slow fashion, where the focus is on high-quality, durable clothing that lasts longer rather than disposable fashion. By promoting more thoughtful consumption, it encourages consumers to invest in fewer, but better-quality items. While some consumers value sustainability, price sensitivity often hinders their purchasing decisions, a complexity noted in recent research (Pires, Morais, Delgado, & Duarte Santos, 2024), which adds depth to the remarks regarding the importance of promoting durable clothing. Additionally, sustainable fashion encourages upcycling and recycling, promoting the reuse of materials and garments to create new products. This practice extends the lifecycle of textiles, reduces waste and contributes to a more circular fashion system.

As consumer behavior plays a crucial role in this shift, it is also essential to understand how consumers value sustainable fashion practices. Despite the increasing awareness of sustainability, many consumers remain unwilling to pay a premium for sustainable products, a challenge pointed out in the article. This creates a barrier to greater acceptance and mainstream adoption of sustainable practices, highlighting the importance of balancing sustainability with consumer price perceptions.

Together, these principles form the foundation of sustainable fashion. They create a pathway for better fashion production and consumption that prioritizes both people and the planet. As the fashion industry continues to evolve, these key principles will play a crucial role in shifting the industry toward more sustainable and ethical practices (Henninger, Alevizou, & Oates, 2016).

1.1.5. Corporate Social Responsibility (CSR)

Corporate Social Responsibility (CSR) is defined as follows: "...a self-regulating business model that helps a company be socially accountable to itself, its stakeholders, and the public." (Fernando, 2024).

Over the past few decades, business leaders have increasingly recognized that their responsibilities extend beyond maximizing profits for shareholders and executives to embrace a broader social responsibility towards the employees, communities and environment in which their firms operate (Harvard Business School, 2021).

In other words, Corporate Social Responsibility refers to a business model in which companies take the initiative to commit to ethical, social and environmental standards without being legally required to do so. This definition emphasizes the voluntary nature of CSR, which is particularly relevant in the fashion industry, where many sustainability efforts are not yet mandated by law. In such cases, companies have the freedom to define the scope and depth of their commitments. To illustrate how this self-regulating model works in practice, a brand may choose to audit its supply chain to prevent child labor, even if not legally required. Others may set voluntary carbon reduction targets, publish sustainability reports or choose to pay living wages as part of their ethical commitments. This type of initiative will be examined further in Chapter 3, which presents case studies of two companies that have adopted CSR driven sustainability practices.

To better understand how CSR works in a business context it is useful to explore its core pillars. According to Investopedia, CSR typically includes four main categories: environmental responsibility, ethical responsibility, philanthropic responsibility and financial responsibility. These categories reflect the various dimensions through which companies can contribute positively to society and the environment. These categories include:

- Environmental responsibility refers to a company's efforts to minimize its ecological impact, such as reducing emissions, recycling or using sustainable materials.

- Ethical responsibility involves fair and transparent practices, including equitable treatment of employees, customers and suppliers.
- Philanthropic responsibility focuses on contributing to social causes through charitable giving, partnerships and employee engagement in community initiatives.
- Financial responsibility, in this context, emphasizes the need for businesses to financially support their CSR goals, such as investing in sustainable product development or social equity programs. (Fernando, 2024).

Understanding these pillars is essential when evaluating how fashion companies structure their CSR initiatives and the extent to which they align with broader sustainability goals.

Corporate Social Responsibility provides an important framework for understanding how fashion companies can integrate sustainability into their core operations. By establishing clear CSR policies, brands can transform abstract ethical aspirations into practical actions to address the environmental and social harms of fashion. These actions can include sourcing eco-friendly materials, enforcing labor standards, or investing in community and environmental projects.

Consequently, this model provides guidance for implementing sustainable practices and establishes criteria for assessing their ecological and social impacts within the fashion industry. By highlighting key areas of responsibility and encouraging transparent reporting, CSR offers a practical perspective through which the effectiveness of sustainable materials and practices can be evaluated. It therefore provides a relevant foundation for assessing the extent to which such initiatives actually reduce the sector's overall environmental and social footprint, aligning with the focus of this thesis (Abdelmeguid et al., 2024).

1.1.6. Key Models of Sustainable Fashion

As concerns about the environmental and social challenges in the fashion industry continue to grow, several conceptual models have emerged to guide the industry towards more responsible alternatives. Some of the leading concepts include circular fashion, slow fashion, ethical fashion and regenerative fashion. Each of these proposes a different approach to addressing sustainability and offers a foundation for rethinking fashion. These concepts offer alternative approaches to challenge fast fashion models and guide the industry towards sustainability.

While definitions of these concepts are provided in the glossary, the following section focuses on how each model relates to the objectives of this research.

The influence of these models will be seen again in later sections, where we examine specific sustainability initiatives within the fashion production process.

◦ Circular Fashion

Circular fashion is increasingly presented as a promising framework for reducing fashion's environmental impact by extending product life, minimizing waste and encouraging system-wide collaboration. However, its actual effectiveness depends on factors like consumer participation, recycling infrastructure and product design. While it supports the reduction of raw material extraction and post-consumer waste, the scale of its implementation remains limited and current recycling technologies often require blending with virgin fibers. This suggests that while circular practices contribute meaningfully, they cannot eliminate fashion's environmental footprint on their own (Dragomir & Dumitru, 2022; Sarokin & Bocken, 2024).

◦ Slow Fashion

Slow fashion offers a framework to reduce environmental and social impacts in the fashion industry by challenging the speed, scale and disposability of current production models. While it does not focus on materials in isolation, it contributes to sustainability by promoting product longevity, discouraging overproduction and encouraging conscious consumption. However, its broad focus may limit its adoption compared to more targeted solutions like material substitution or recycling. However, slow fashion is essential to long-term systemic change, as it calls for a fundamental reevaluation in what we produce, how we value it and how often we consume (Fletcher, 2010; Sarokin & Bocken, 2024; Švajdová, 2023).

◦ Ethical fashion

Ethical fashion practices contribute to reducing the industry's social and environmental impact by addressing labor rights, transparency and responsible production. While it is not primarily focused on material innovation, ethical fashion plays a critical role in minimizing social harm through fair wages, safe working conditions and supply chain accountability. These practices also align with sustainability goals through efforts to reduce overproduction, waste and emissions. However, the movement faces challenges, particularly in expanding beyond niche markets and ensuring consistent enforcement without the existence of strong regulations. Still, ethical frameworks are a vital element in any strategy aimed at transforming the fashion system (Innovation in Textiles, 2024; Safdie, 2024; Stanton, 2024).

◦ Regenerative Fashion

Regenerative fashion represents a shift in the industry aiming not just to minimize harm but to create a net positive impact on the environment and society. For example, by using materials from regenerative agriculture, such as organic cotton and wool produced through practices that restore soil health and biodiversity, this approach addresses the environmental footprint of raw material sourcing. Moreover, regenerative fashion emphasizes circular design principles in ensuring products are durable, repairable and ultimately biodegradable or recyclable. This reduces waste and encourages a closed-loop system within the fashion lifecycle.

Businesses following this model often incorporate community engagement and fair labor practices into their operations, thus contributing to social sustainability. While regenerative

fashion shows strong potential to reduce the industry's overall impact, challenges remain in scaling these practices and ensuring accessibility. It still offers a comprehensive framework to help businesses align with both environmental restoration and social equity goals (Mummery, 2022; Smith, 2022).

Chapter 2 - Literature Review

○ 2.1. The Dynamics of the Fashion industry and its challenges

To understand the role sustainable materials and practices play in reducing the fashion industry's impact, it is essential to first explore the broader context in which they operate. This section provides an overview of the industry's evolution, the rise of fast fashion and the environmental and social challenges that have emerged as a result. It ends by identifying key constraints and ongoing challenges that the fashion industry must face in order to progress towards sustainability.

2.1.1. A Brief Historical Overview

Fashion has continuously evolved over centuries and has been influenced by social trends, historical events, values and societal concerns. The increase of commercial exchanges over time has shifted the fashion landscape dramatically, leading us into an era where fast fashion is the norm. Overproduction and overconsumption have become common practices.

It doesn't come as much of a surprise that this system has harmful effects on both society and the environment.

In response, many companies are beginning to incorporate sustainability into their operations. Such efforts range from reducing environmental impact and improving labor conditions to considering animal welfare. These changes are reflected in practices such as the use of eco-friendly materials, transparent sourcing and circular business models. While this approach is being adopted increasingly among small and medium-sized companies, major fast fashion brands like H&M and ZARA have also begun to market sustainability initiatives despite often criticized for greenwashing.

2.1.2. The Fast Fashion Phenomenon

Before assessing the impact of fast fashion on society and the planet, it is crucial to explore its fundamental characteristics

Fast fashion companies achieve success by encouraging consumers to purchase more clothing than they need and by making them prioritize rapidly changing trends over durability. To achieve this, they continuously introduce new collections and overstimulate consumers to create a demand.

To sustain this demand, fast fashion brands strategically manage their digital platforms and social media to ensure a constant presence. They keep consumers, particularly younger audiences, engaged and always eager to purchase through targeted advertising and influencer partnerships. This persistent cycle of promotion and consumption reinforces the desire for

newness in consumers and makes it increasingly difficult to resist the appeal of keeping up with the latest trends.

The key components of fast fashion business models can be summarized as follows:

- Rapid production of low cost and often low-quality items
- Fast turnover to shorten delays between design creation and sale
- Expeditive distribution to ensure products reach stores quickly
- Aggressive marketing strategies to maintain consumer engagement
- Mass production that often exceeds actual demand
- Broad product variety to cater to diverse trends and tastes
- Low prices to encourage frequent purchase

Unfortunately, this intense production cycle has drastic long term social and environmental consequences. The true cost is paid by workers and the environment, and the cycle continues: driving climate change, depleting natural resources, and perpetuating social inequality.

To better understand the full impact of fast fashion, it is crucial to recognize the scale and growth of the global fashion industry. According to McKinsey & Company (2023), the industry was worth an estimated \$1.7 trillion in 2023 and employs over 300 million people worldwide across the value chain. Furthermore, between 2000 and 2014, clothing production doubled while the number of garments purchased per capita rose by about 60 percent. These figures underscore the significant impact of the industry and help explain the scale of its environmental and social footprint (McKinsey & Company, 2025).

2.1.3. Environmental impact

Now, let's examine some of the major issues that contribute to environmental destruction and climate change.

Carbon emissions

The emission of greenhouse gases (GHG), particularly carbon dioxide (CO₂), from textile manufacturing contributes to climate change and is closely linked to the depletion of natural resources. According to the European Environment Agency (2025), the fashion industry is the 5th highest emitter of carbon dioxide in the world. It is responsible for about 10% of global carbon emissions annually, surpassing the combined emissions of international flights and maritime shipping. When the entire lifecycle of creating a garment is considered, from manufacturing to transportation and waste treatment, the fashion industry is estimated to generate 1.2 billion tons of carbon emissions annually. Estimations indicate that the emissions could rise by more than 60% and reach approximately 2.8 billion tons annually by 2030 (Biyada & Urbonavicius, 2025; Clarke, 2021).

A large portion of these emissions comes from energy-intensive processes during textile manufacturing such as spinning, dyeing and finishing. Identifying and implementing sustainable practices in these stages is therefore essential to reducing the industry's overall

carbon footprint. In addition to production methods, the choice of materials also plays a critical role: synthetic fibers like polyester and polyamide generally produce more CO₂ than natural alternatives. The environmental impact of textile production is also further intensified by the source of energy used in manufacturing. In regions that rely heavily on coal-based electricity, emissions are significantly higher. For example, the textile industry in China is estimated to emit around 40% more CO₂ than similar producers in Turkey or Europe (Biyada & Urbonavičius, 2025). Without important shifts in production practices, sourcing, and energy use, the fashion sector is expected to further accelerate climate change. Thus, making it one of the most environmentally destructive industries after oil and gas (Biyada & Urbonavičius, 2025).

Despite the need for change being evident, fashion brands face several challenges in reducing emissions. Financial constraints often lead to sustainability being put aside, especially since the benefits of such initiatives are difficult to assess and tend to become visible only in the long-term. Achieving reductions also requires operational transformation across sourcing, production and retail. Many companies are unprepared to carry out such complex tasks. Furthermore, a lack of supply chain transparency and a highly fragmented supplier base complicate both the implementation of change and the accurate tracking of emissions. These difficulties are reflected in recent analysis showing that nearly two-thirds of fashion brands are currently behind on their decarbonization targets and about 40% have actually had their emissions increase since making sustainability commitments (Janmark et al., 2024). These challenges must be acknowledged in order to design realistic, effective strategies for decarbonization.

Strategies to address the growing carbon footprint of the fashion industry have been suggested. Among these are the adoption of sustainable practices, including transitioning to renewable energy, implementing circular economy models and promoting garment longevity and reuse. These approaches will be discussed in greater detail in Section 2.2. In addition to that, increasing the use of sustainable materials such as organic cotton and recycled fibers offers another viable approach to reducing emissions. This will be discussed in greater detail as well in Section 2.3. Furthermore, broader systemic interventions such as shifts in consumer behavior, strengthened regulatory frameworks and increased access to renewable energy within supply chains may also support impact reduction (Biyada & Urbonavičius, 2025; Janmark et al., 2024).

[Water consumption and pollution](#)

High water consumption in the textile and fashion industry contributes to freshwater depletion and intensifies water scarcity in some regions. In 2023, the textile sector was estimated to consume around 93 billion cubic meters of water (Biyada & Urbonavičius, 2025; Lindner, 2024). This reflects a significant increase from the 79 billion cubic meters reported in 2020 which indicates a concerning upward trend in the industry's consumption of natural resources (Mogavero, 2020). This rising demand puts an additional pressure on global water resources. As a result, the industry now ranks among the highest water consuming sectors worldwide,

second only to the agricultural and industrial sectors (Manganello & Schelmetic, 2023; UN News, 2019).

To better understand the high level of water consumption, let’s put into perspective the amount of water required to manufacture everyday clothing items:

Table 1: Estimated Water Usage for Common Cotton Garments

Item	Approximate Water Usage in Liters to Make One Item
T-shirt	2,700 liters (*)
Jeans	3,800-10,000 liters (**)
Cotton socks	600 liters

(*) 2 700 liters represent enough water for one person to drink for over 2,5 years (Reichart & Drew, 2019).

(**) Estimates vary depending on calculations methods and the scope of supply chain analysis (Stallard, 2022; World Bank, 2019)

Water usage estimates vary but producing a single cotton t-shirt typically requires around 2,700 liters of water (EU Parliament, 2020). Similarly, producing one pair of jeans requires about 3781 liters of water on average, from raw material processing to delivery (World Bank, 2019). Depending on factors like production location, irrigation needs and the stages considered in the calculation, estimates range from 3,800 liters to as high as 10,000 liters (Stallard, 2022).

Alongside excessive water use, the fashion industry also contributes significantly to water pollution, particularly in marine ecosystems. This is primarily due to the release of microplastics and synthetic fibers, as well as toxic chemical dyes and waste from textile treatment processes.

Plastic microfibers are difficult to eliminate and can accumulate in marine ecosystems once they are released into waterways. Estimates suggest that about half a million tons of microplastic fibers are released into the oceans every year mostly as a result of washing synthetic textiles (UNEP, 2019). A single load of polyester laundry can shed up to 700,000 microplastic fibers (European Parliament, 2024). These tiny particles are often not effectively captured by wastewater treatment systems and ultimately end up in water bodies. They are particularly concerning because they cannot be effectively removed from the water and have been shown to spread throughout the food chain, thus representing long-term risks to marine life and human health (UNEP, 2019; World Bank, 2019). Filtering microplastics from wastewater remains a significant challenge, as conventional treatment systems are often energy-intensive and not fully effective (EPRS, 2020).

Beyond microplastics, chemical pollution from textile manufacturing also introduces another environmental burden. Various chemicals are used throughout the manufacturing process, particularly during fiber production and wet processing steps such as dyeing, bleaching and finishing. The issue is that the wastewater generated during these stages is often directly discharged into waterways without adequate treatment, which leads to severe contamination and environmental damage (EPRS, 2020). In fact, the textile sector is estimated to be responsible for approximately 20% of global water pollution (Biyada & Urbonavicius, 2025; European Parliament, 2020)

Given the scale and long-lasting nature of water related environmental impacts, addressing these issues has become increasingly urgent. In parallel, new technologies and practices are being developed to reduce water use across the textile supply chain, particularly in its most water-intensive stages. Emerging innovations and ongoing research are also exploring more sustainable and efficient methods to separate microscopic contaminants from water, thereby offering potential solutions to reduce future contamination (EPRS, 2020).

Waste

Fast fashion companies significantly contribute to the growing issue of textile waste. Their business models are built around unsustainable practices. They produce clothes that are meant to be temporary and are designed to be quickly replaced by new collections rather than be made to last. As a result, garments are often made from low-quality materials to keep competitively low prices and facilitate their rapid sale and consumption. This disposable culture leads to the alarming global production of an estimated 92 million tons of textile waste annually, which could rise to 134 million tons per year by 2030. An estimated 85% of clothing ends up discarded in landfills, with the equivalent of a truckload being dumped or incinerated every second (UNEP, 2019).

Addressing the issue of textile waste requires a fundamental shift away from the linear "take-make-dispose" model that currently dominates the fashion industry (Ellen Macarthur Foundation, 2023). Solutions such as reuse, recycling and other circular approaches offer promising alternatives to reduce the volume of discarded clothing and extend the lifecycle of garments. Additionally, the choice of sustainable materials, such as biodegradable or recyclable fibers, also plays a critical role in limiting waste. These strategies will be further explored in the following chapters on sustainable practices and materials.

2.1.4. Social impact

Low-cost production encourages fashion companies to seek manufacturing locations offering the lowest production costs, often with little consideration for workers' welfare. The rapid production cycle is essential to boost sales and profits of the fast fashion industry. However, this approach indirectly contributes to the worsening conditions and poverty in some regions, having severe consequences for human welfare (McCosker, 2023; Assoune, 2021).

Globally, the number of workers employed in the fashion industry is estimated to reach 75 million (Ross, 2021). The constant demand for fast production places massive pressure on manufacturers who must adapt their operations to meet tight deadlines, often without the adequate planning or resources. Many countries where fast fashion companies source their labor have weak social regulations and human rights violations are too common (Aljazeera, 2023; Assoune, 2021).

The pressure for low-cost production results in unfair wages for workers that are often below the legally required minimum. The majority of these workers are young women who face harsh working conditions, exploitation and frequent harassment. In some areas, the level of poverty is so high that children are forced to work in factories, facing exploitation in dangerous and unsafe working environments. Forced child labour remains a serious issue often underreported in many countries such as Bangladesh, China, Indonesia, the Philippines, India and Vietnam (Assoune, 2021; Maiti, 2024).

Many workers often work up to 16 hours a day, 7 days a week and sometimes even sleep on factory floors (Ross, 2021). The lack of respect for workers' rights and the absence of adequate security measures put lives at serious risk. Injured workers often receive little to no assistance. In Bangladesh where conditions are harsh, particularly for women, a tragedy occurred taking the lives of 1134 workers and injuring more than 2500 people, including women and children (Maiti, 2024). Despite clear warning signs, such as large cracks appearing in the structure the day before, factory workers were forced to return to work the next morning. This negligence led to the catastrophic collapse of Rana Plaza and brought global attention to the complete disregard for worker safety in the fashion industry (Ethics Unwrapped, N.d.).

The strict requirements and tight deadlines imposed by fast fashion companies intensify the poor working conditions and compromise workers safety. Safety protocols are frequently neglected when handling chemicals and waste, leading to long-term health risks and contamination of local water sources which puts the surrounding communities in danger as well (Maiti, 2024; McCosker, 2023).

Despite the willingness of some fast fashion actors to investigate social and environmental conditions of their overseas producers, gaps in legislation continue to allow poor working conditions that endanger local populations. To avoid legal repercussions, many companies decided to reduce their controls on manufacturers. This disconnection between the industry's growth and its social impact is a cold and harsh reality (Aljazeera, 2023; Assoune, 2021).

Local legislations need to evolve to better protect workers. The initiatives implemented in Bangladesh following the Rana Plaza tragedy, such as the adoption of the Fire & Safety Accord, serve as a powerful example of what can be achieved when society demands better working conditions (Ross, 2021).

2.1.5. Constraints and Challenges

Sustainability in the fashion industry is gradually gaining recognition as a necessity to address the negative impacts on the environment and human welfare. However, the transition to sustainable practices may take longer than expected, as companies must address a range of constraints and challenges along the way.

The influence of fast fashion on the textile industry is significant. It is important to recognize that fast fashion has provided consumers with an affordable approach to fashion. However, this affordability often comes at the cost of environment and ethical labour practices. This creates a complex trade-off for both consumers and the industry.

Fast fashion continues to grow on the market. An analysis from coherent market insights estimated that the “Global Fast Fashion Market size was valued USD 39.90 Billion in 2023 and is expected to reach USD 99.84 Billion in 2030, growing at a compound annual growth of 14% from 2023 to 2030” (Suryawanshi, 2024). The already significant environmental and social consequences are likely to intensify if fast fashion continues to expand at this rate while maintaining its current practices. The industry urgently needs to shift towards sustainability, but can the industry giants also take up the challenge, or will they continue prioritizing profit over sustainability?

Current sustainability initiatives within fast fashion seem limited and lack the necessary commitment to achieve significant progress towards environmental goals. For example, H&M has launched clothing made from recycled materials and Zara has introduced an eco-denim collection. However, these efforts only represent a small part of their overall offering, which raises questions about their potential to bring significant change.

In contrast, smaller companies are emerging with innovative sustainable concepts that prioritize sustainability over cost. These brands often adopt a completely different business model that prioritizes ethical practices and eco-friendly materials over sheer profit. Although they may not match the scale of larger fast fashion brands, their commitment and approach to sustainability could be a good lead in addressing environmental concerns.

Consumers also appear to be increasingly aware of the need to shift towards more responsible fashion. However, are they truly willing to embrace a different model of consumption that may be more expensive, and require changes in their purchasing habits?

The path to sustainable fashion is full of challenges (Coherent Market Insights, 2025; McKinsey & Company, 2025).

Regulation

It is important to highlight that a more generalized model of sustainable fashion cannot be achieved without government action. Legislative change is essential to accelerate the reduction of the textile industry's environmental and social impact."

The current predominating fast fashion system is cost-effective for businesses and meets the needs of their customers in terms of variety and cost. The lack of strict regulations to protect human rights and the environment allows companies to make substantial gains. Increasing legal constraints could obviously be an obstacle to their profitability but becomes a necessity (Sehnem et al., 2024).

In Europe, the Commission has defined specific objectives to be reached by 2030. Let's briefly go through some major points of the proposed changes. Recent approaches suggest that, in practice, sustainable clothing requires well-informed consumers, greater responsibility from manufacturers throughout a product's life cycle, respect for human rights and the environment and increased efforts in recycling and reusing textiles.

As referred to in the proposal of the Sustainable Corporate Due Diligence Directive, companies will be obliged to assess their supply chains to avoid and mitigate risks on human rights and environment and ban all structures who have recourse to forced labor.

Clear information to the consumer on durability, reparability and programmed obsolescence of products will also be a key point of the new strategy to protect the consumer from greenwashing.

Another important dimension will be the revisions of the Waste Framework Directive and Waste Shipment Regulation with the objective of getting to a "circular" mode.

In parallel, economic incentives could help reach the objective of reducing impact on environment and social welfare. Reforming taxation could help in reversing the trend by supporting initiatives in favor of environment and social welfare (Petitalot, 2023).

Cost

Moving towards sustainability requires a complete rethink of the model based on cost efficiency. As previously mentioned, the global model relies on overproduction, overconsumption, poor quality, limited transparency to reduce costs, growth and profits boosts. Changing towards a model based on transparency, better materials, a circular economy, recycling, respect of the environment and social welfare would require high investment and might endanger the profitability of fast fashion companies.

This would also mean that higher costs should be passed on to consumers. In a way, this would imply moving from fast fashion to slow fashion, with major risks in terms of profitability and growth, given the investment required upstream (Cohen, 2022; Stauffenegger, 2023).

Consumers

Another key obstacle to sustainability is consumer behavior. Shoppers often prioritize low prices and a wide variety of choices over environmental and ethical considerations. Since sustainable products typically come at a higher cost, many consumers continue to support fast

fashion even when it involves unethical practices. Inflation further reinforces this behavior by making affordability an even stronger priority. This dominant mindset offers little incentive for fast fashion brands to change their business models.

As with many necessary transitions, education must play a central role. There is a pressing need to raise awareness among consumers about the environmental and social challenges linked to fashion. People need to understand the urgency of reducing and mitigating the industry's negative impact. Access to clear and reliable information is essential for building ecological awareness and encouraging more responsible consumption habits (Sehnm et al., 2024).

2.2. Exploring Materials and their Sustainable Alternatives

Now that the broader environmental and social impacts of the fashion industry have been outlined, this section focuses on the influence of materials on sustainability. While material choice is an important factor, its impact on sustainability is difficult to quantify universally, if not impossible, as it depends on context, processes and suppliers. The production and processing of fibers influence emissions, water use, waste and biodegradability depending on how and where they are produced.

This chapter explores the extent to which alternative lower-impact materials might reduce the fashion industry's environmental footprint when compared to conventional options. To explore this, it considers the characteristics of different material categories and how their environmental impacts can vary. Rather than offering definitive answers, the aim is to present a nuanced perspective on how different materials may perform.

2.2.1. Introduction to Sustainable Materials in the Fashion Industry

As outlined in Section 2.1, the fashion industry faces urgent environmental challenges that demand a fundamental shift in production, consumption and resource use. For decades, the industry has relied on the extraction of virgin resources and the continuous production of new goods to create value. As global fiber production continues to rise, so does the pressure on ecosystems, natural resources and the communities that support them. In this context, rethinking the value system behind material selection has become increasingly necessary (Biyada & Urbonovicus, 2025; Textile Exchange, 2023).

Choosing the right fiber for the right application is key to achieving the most sustainable performance across its life cycle, and can significantly influence the overall environmental footprint of fashion.

Material impacts are shaped by a wide range of factors including agricultural practices, energy sources, processing technologies and supply chain transparency, which is essential to identify hidden environmental and social risks. Choosing the right fiber for the right application is essential in order to get the most sustainable performance across its life cycle and can significantly influence the overall environmental outcome. Understanding when and where in the life cycle these impacts occur is also important. While CO₂ is emitted at every stage of a

garment's life, more than half of a garment's total environmental cost is generated before it even reaches the customer. This is mostly due to the raw material extraction and processing stages which are often energy and resource intensive (Mulhern, 2020). However, simply classifying materials as sustainable or unsustainable based solely on their category oversimplifies the complex factors that shape sustainability. For instance, while conventional cotton demands large volumes of water and chemical inputs, organic cotton's sustainability can depend on the location and farming practices. Similarly, fossil-fuel based synthetic fibers contribute to plastic pollution, but may have lower water impacts and offer more durability in some cases (Centobelli et al., 2022).

Despite the growing focus on sustainable materials, more than half of global fiber production still relies on fossil-fuel-based synthetics. In fact, their production has increased from 63 million tons in 2021 to 75 million in 2023 (Textile Exchange, 2024). This shows a worrying gap between environmental commitments and actual progress, as well as a delay in adopting available alternatives. Addressing this will require investment in infrastructure, innovation and systemic change along with more standardized frameworks to assess and compare fiber impacts in different contexts (Biyada & Urbonovicius, 2025).

Design strategies at the product level also influence sustainability performance. Decisions in design not only affect how long a product lasts, but how easily it can be reused, repaired, or recycled. Therefore, choosing the right materials is not just a technical or aesthetic concern, it is a strategic decision that influences the environmental impact of fashion (Mazzitelli, Papille & Del Curto, 2023).

The following sections will examine the different material categories and explore their potential and limitations in contributing to more sustainable fashion.

2.2.2. Conventional Materials: Characteristics and environmental impact

In this section, various conventional materials will be examined to assess their respective characteristics and environmental impacts. To structure this analysis, fibers will be grouped based on their origin.

Textiles are produced from a range of raw materials and can broadly be classified into four main categories: synthetic fibers, plant-based fibers, man-made cellulosic fibers and animal fibers (Textile Exchange, 2023).

Synthetic Fibers

Firstly, synthetic fibers are produced through chemical processes and are primarily derived from fossil-fuel compounds such as petroleum-based chemical and petrochemicals. However, they can also be produced from plant sources such as corn or sugar cane, as well as from recycled plastic waste like PET bottles (Okcabol, Rex & Roos, 2019). They are the most widely used type of fiber globally, accounting for around 67% of total fiber production in the textile sector in 2023 (Textile exchange, 2023).

Polyester is the most common synthetic fiber and represents around 57% of global fiber production. It is known for its strength, durability and quick-drying properties. Another widely used synthetic is Polyamide (commonly known as Nylon), which accounts for about 5% of global fiber production. Other synthetic fibers include elastane, acrylic and polyolefins, which together represent roughly 5% of global production.

Despite the benefits in terms of performance and low cost, synthetic fibers pose a significant threat to the environment. As fossil-based materials, they rely on non-renewable natural resources, making their production unsustainable in the long term. Additionally, most synthetic fibers are non-biodegradable which complicates their disposal (Mulhern, 2020). One major environmental concern is their contribution to plastic pollution through the release of microplastics. This poses serious risks to marine ecosystems, as discussed in Section 2.1.3. The production process also releases harmful chemicals and pollutants that pose risks to both human health and the environment. Additionally, the manufacturing process is highly energy intensive and requires significant amounts of electricity, heat and water, especially during stages such as polymerization, extrusion and fiber spinning. This results in significantly higher greenhouse gas (GHG) emissions during the manufacturing stage compared to many natural or cellulosic alternatives (Muthu, 2020). In fact, they are estimated to be responsible for up to two-thirds of total fashion industry emissions linked to processing and manufacturing (Biyada & Urbonavicius, 2025).

The following table provides an indicative overview of the environmental impact of common synthetic fibers, focusing on their greenhouse gas emissions, energy requirements and water consumption per kilogram of fiber produced.

Table 2: Environmental Impact of Common Synthetic Fibers (per kg of Fiber Produced)

Fiber Type	CO₂ Emissions (kg CO₂/kg fiber)¹	Energy Consumption (MJ/kg)	Water Consumption (L/kg)
Polyester	~2.31-2.8 kg CO ₂ /kg	~97-127 MJ/kg	~17-62 L/kg
Nylon 6	~5.5 kg CO ₂ /kg	~120.47-262 MJ/kg	~185 L/kg
Nylon 66	~6.5 kg CO ₂ /kg	~138.62-262 MJ/kg	~663 L/kg
Polyolefins ²	~1.6-1.7 kg CO ₂ /kg	~73-115 MJ/kg	~32-47 L/kg
Acrylic	~5 kg CO ₂ /kg	~157-194 MJ/kg	~210 L/kg

Compiled based on data from (Muthu, 2014), (Johansson, Roos & Sandin, 2019) and (Textile Exchange, 2025).

¹ Note: CO₂ values include CO₂-equivalent emissions unless otherwise specified.

² Values represent synthesized averages based on environmental impact data for the following polyolefins: Low-Density Polyethylene (LDPE), High-Density Polyethylene (HDPE) and polypropylene (PP)

The values are presented as indicative ranges compiled from multiple sources which reflect differences in production methods, energy sources and regional contexts. While this table provides an overview of key indicators, it represents only a portion of the available data and analysis on fiber sustainability. Numerous studies have attempted to unify existing data and address the complexity of such comparisons. Notably, *The Fiber Bible Part 2: Environmental Impact of Textile Fibers – What We Know and What We Don't Know* report published by Mistra Future Fashion compiles data from a wide range of sources. The report includes approximately 30 pages of detailed tables, each line citing data sources. This report underscores both the depth of available data and the continued challenges of standardization and comparability across studies on fiber impact assessment.

In summary, while synthetic fibers like polyester and nylon dominate global fiber production due to their durability, affordability and performance, their environmental impacts are significant and complex. Their widespread use represents an urgent sustainability challenge as they often rely on non-renewable resources and contribute heavily to greenhouse gas emissions. Addressing these issues requires not only innovation in materials and recycling technologies but also systemic shifts in consumption patterns and design strategies.

Plan-based Fibers

Plant-based fibers are natural fibers derived from parts of plants such as seeds, stems or leaves (Qi, 2016). In terms of global fiber production, plant-based fibers continue to play a major role in the textile sector, representing about 25% of global fiber production. Cotton, in particular, is the most widely used plant-based fiber in fashion. It accounts for approximately 20% of total production in 2023. Other materials include fibers made from flax, hemp, jute and ramie, which represent approximately 5% of global production (Textile exchange, 2023).

Plant-based fibers are primarily used to produce textiles that are breathable, biodegradable and renewable. Their natural feel, softness and comfort combined with consumer preferences for natural and breathable fabrics make them an appealing material option (Schirrer, 2024). This has enabled cotton, in particular, to maintain a considerable market share despite the rise of synthetic fibers in recent decades. Cotton is also versatile and blends well with other fibers which makes it suitable for the production of a wide variety of textures (Anderson, 2025). In addition to their functional advantages, these fibers are generally biodegradable (Cottonwork, 2025; *The Fabric of Our Lives*, 2025).

While all plant-based fibers come from renewable sources, their environmental impacts vary significantly depending on cultivation methods, processing and scale of use. The conventional production of cotton, in particular, has significant environmental and social impacts. Conventional cotton farming is highly resource-intensive and requires great amounts of water, pesticides and fertilizers. In regions where cotton is grown in irrigated conditions, the excessive use of water often contributes to water stress and can accelerate soil degradation. Moreover, the use of synthetic agrochemicals, such as fertilizers, pesticides and herbicides, contributes to biodiversity loss and pollution of surrounding ecosystems (World Wildlife, 2025). In addition

to environmental concerns, labor practices in some cotton-producing countries have raised concerns around fair wages and working conditions (Anderson, 2024).

The following table provides an indicative overview of the environmental impact of common plant-based fibers, focusing on their greenhouse gas emissions, energy requirements and water consumption per kilogram of fiber produced.

Table 3: Environmental Impact of Common Plant-based Fibers (per kg of Fiber Produced)

Fiber Type	CO ₂ Emissions (kg/kg fiber)	Energy Consumption (MJ/kg)	Water Consumption (L/kg)
Cotton	~ 0.1-6 kg CO ₂ /kg	~ 6-60 MJ/kg	~ 1,214-22,500 L/kg
Organic cotton	~ 0.3-2.5 kg CO ₂ /kg	~ 6-54 MJ/kg	~ 1,440-18,000 L/kg
Flax (Linen)	~ 0-18.6 kg CO ₂ /kg	~ 0.84-30 MJ/kg	~ 214 L/kg
Hemp	~ 0-6 kg CO ₂ /kg	~ 15-30 MJ/kg	-
Ramie	-	-	-

Compiled based on data from (Muthu, 2014), (Johansson, Roos & Sandin, 2019) and (Textile Exchange, 2025).

The data presented above illustrates the wide variation in environmental impact among common plant-based fibers, particularly in terms of water use and energy consumption. The agricultural phase plays a critical role in shaping a plant fiber’s environmental footprint and is particularly impactful in terms of water use and pollution, most notably for cotton due to its heavy reliance on irrigation and fertilizer use. The textile manufacturing and consumer use phases, on the other hand, account for the majority of energy-related impacts. These next stages are particularly intensive due to fiber processing, garment finishing and the frequent washing and drying of clothing during its use phase (Cotton Today, n.d.; Cotton Incorporated, 2017).

In summary, plant-based fibers offer significant advantages in terms of renewability and biodegradability. However, their environmental impact can highly depend on farming practices, geographic conditions and processing.

Man-made Cellulosic Fibers

Man-made cellulosic fibers (MMCFs) are semi-synthetic fibers derived from natural sources such as wood pulp, bamboo or other forms of cellulose. While they are made from plant-based sources, these fibers undergo a significant chemical transformation to be converted into textile material.

Viscose (also called rayon), modal and lyocell are the most common types of MMCFs used in the fashion and textile industry today. Man-made cellulosic fibers represent approximately 6% of total global fiber production in the textile sector, with viscose being the dominant type and

accounting for 5% of the global share. The remaining 1% includes other MMCFs such as modal and lyocell (Johansson, Roos & Sandin, 2019; Textile Exchange, 2023).

MMCFs are appealing since they combine the comfort and breathability of natural fibers with the performance benefits of synthetics. They are soft, absorbent and have a smooth texture, which makes them particularly suitable for garments that require fluidity and comfort. Compared to synthetic fibers like polyester, MMCFs are made from renewable raw materials and are generally more biodegradable. This can reduce their long-term environmental impact when disposed of properly.

In terms of production, MMCFs typically require less energy than fossil-based synthetics like polyester and nylon. Some variants such as lyocell are produced using more environmentally responsible processes through a closed-loop system that recycles the solvent used in fiber production. This significantly reduces harmful emissions and chemical waste (Muthu, 2021). In contrast, viscose manufacturing relies on the use of carbon disulphide which is a hazardous solvent known to be harmful to both human health and the environment. Improper management of it can lead to water pollution and air emissions, including the release of toxic gases like Sulphur compounds. Large quantities of water and energy are also required in its manufacturing process, making viscose environmentally taxing despite its renewable raw material origin (Johansson, Roos & Sandin, 2019; Muthu, 2014).

Despite these challenges, MMCFs still have the potential to be a sustainable material option, particularly when the wood pulp is sourced from responsibly managed forests and when cleaner technologies are applied in manufacturing. In practice, their environmental impact can vary widely depending on the feedstock source, chemical inputs and processing methods. For this reason, not all MMCFs can be considered sustainable by default and a continuous monitoring of manufacturing standards remains necessary (Johansson, Roos & Sandin, 2019; Textile Exchange, 2025).

The following table provides an overview of the environmental impact of common Manmade cellulosic fibers, based on available data from reliable sources, focusing on their greenhouse gas emissions, energy requirements and water consumption per kilogram of fiber produced.

Table 4: Environmental Impact of Common MMCFs (per kg of Fiber Produced)

Fiber Type	CO₂ Emissions (kg/kg fiber)	Energy Consumption (MJ/kg)	Water Consumption (L/kg)
Viscose	~ 1.6-9 kg CO ₂ /kg	~ 51-100 MJ/kg	~ 263-740 L/kg
Modal	~ 1.6-6.4 kg CO ₂ /kg	~ 49-91 MJ/kg	~ 290-740 L/kg
Lyocell	~ 1.7-6.4 kg CO ₂ /kg	~ 49-91 MJ/kg	~ 290- 740 L/kg

Compiled based on data from (Muthu, 2014), (Johansson, Roos & Sandin, 2019) and (Textile Exchange, 2025).

As the data suggests, the environmental impact of MMCFs can vary considerably across fiber types and production contexts. Differences in energy consumption, emissions and water use are influenced less by the fiber itself and more by the specific technologies, energy sources and sourcing practices involved. This reinforces the need to evaluate case by case when assessing the sustainability of materials. Recent innovations, such as recycled MMCFs and closed-loop viscose production (e.g., EcoVero™), suggest that the environmental performance of these fibers may continue to improve as technology advances (Johansson, Roos & Sandin, 2019; Textile Exchange, 2023).

Animal-based Fibers

Animal-based fibers are natural fibers obtained from animals, including wool (sheep), silk (silkworms) and specialty hair such as angora, alpaca, mohair, cashmere and similar sources. These fibers are primarily composed of proteins such as keratin in wool and fibroin in silk. Animal-based fibers make up a relatively small share of the global fiber production, around 1%. Wool is by far the most widely used animal fiber, making up approximately 0.9% of total global fiber production (Textile Exchange, 2023).

In terms of characteristics, animal fibers are known for their insulating properties, softness, natural elasticity and moisture-wicking capabilities, which makes them particularly suitable for cold-weather clothing and performance wear. Wool, for instance, retains heat even when it gets wet and its crimped structure gives it natural stretch and resilience. Silk, on the other hand, is prized for its softness, strength, and sheen, often used in luxury fashion. These fibers are also renewable and biodegradable, which makes them more environmentally compatible at the end of their life cycle compared to synthetic fibers (Okcabol, Rex & Roos, 2019; Textile Exchange, 2023).

The raw materials are naturally produced by animals and often only need washing, carding and spinning before being woven into textiles. However, the environmental footprint of these fibers depends heavily on the farming and animal livestock management involved in its production. For example, conventional wool production leads to the generation of methane emissions from sheep and is a major driver of climate impact³. There can also be risks of land degradation depending on the grazing pressure and pasture management. Similarly, silk production raises concerns related to the energy-intensive boiling process used to harvest intact fibers. There are also ethical concerns regarding the treatment of the animals. Despite their renewability, animal fibers are therefore not impact-free and must be assessed based on the full life cycle and the specific practices used in their production. Certifications such as the Responsible Wool Standard (RWS) have emerged in response to these concerns and represent solutions for

³ Around 75% of wool's climate impact comes from methane emissions produced during sheep digestion. The way we currently calculate climate impact (GWP100) tends to make methane appear worse by comparison, even though carbon dioxide remains in the atmosphere much longer. However, CO₂'s full long-term impact is not fully captured by the 100-year window used in this method. As a result, GWP100 may overemphasize methane's impact and underrepresent the lasting effects of CO₂ (Johansson, Roos & Sandin, 2019).

improving the sustainability of animal-based fiber production (Derenne, 2023; Johansson, Roos & Sandin, 2019; Muthu, 2014).

The following table provides an indicative overview of the environmental impact of common animal-based fibers, focusing on their greenhouse gas emissions, energy requirements and water consumption per kilogram of fiber produced.

Table 5: Environmental Impact of Common Animal Fibers (per kg of Fiber Produced)

Fiber Type	CO₂ Emissions (kg/kg fiber)	Energy Consumption (MJ/kg)	Water Consumption (L/kg)
Wool ⁴	~ 1.7-36.2kg CO ₂ /kg	~ 24.5-1175 MJ/kg	~ 37-1,210 L/kg
Silk	~ 52.5-80.9 kg CO ₂ /kg	~ 244-1610 MJ/kg	~27,000-54,000 L/kg
Cashmere/ Other	-	-	-

Compiled based on data from (Muthu, 2014), (Johansson, Roos & Sandin, 2019) and (Textile Exchange, 2025).

In summary, while animal-based fibers represent a smaller share of the global fiber market, they continue to be valued for their performance, comfort and association with luxury. Their natural origin and biodegradability offer certain environmental advantages, particularly at their end-of-life. However, their production is closely tied to livestock farming and energy-intensive processes which can result in significant environmental and ethical impacts. These factors therefore highlight the need to evaluate based on the context across the entire life cycle.

Comparative Overview of Fiber Categories

While the previous sub-sections explored each fiber category in detail, sustainability performance is rarely determined by fiber type alone. The following comparative overview aims to offer a more holistic view of environmental patterns across fiber categories and summarizes sustainability tendencies for climate change potential, water use, human toxicity and energy demand.

The table is adapted from a study from Mazzitelli et al. (2024). It is important to note that this resource does not provide a fixed or universal ranking for materials, but instead highlights typical trade-offs and context specific factors such as production practices, geography and end-of-life options. Therefore, it should only be viewed as a reference tool to support more informed material choices in fashion design.

⁴ The wide range in wool’s CO₂ emissions (37-1,210 CO₂/kg) reflects differences in allocation methods. In some assessments, a portion of the environmental impact was attributed to meat production and therefore significantly lowered the impact assigned to wool.

Table 6: Comparative Impact of Major Fiber Types

Fiber Category	Climate Change Potential	Water Use & Consumption	Human Toxicity	Primary Energy Demand	Notes / Important Elements
Synthetic (e.g. Polyester)	Generally moderate to high (kg CO ₂ eq.)	Low water use in production	May be significant due to chemical processing	Often high (MJ/kg, fossil fuel-based)	Made from fossil fuels; releases microplastics during use and washing; recycling options exist but not frequently used
Plant-based (e.g. Cotton)	Highly variable (low to high)	Often very high	Can be significant (depends on pesticides, fertilizers)	Moderate; varies by cultivation & processing	Water use (especially in conventional cotton) is a major environmental issue; can be improved via organic production and regional practices; biodegradability is a benefit
Manmade Cellulosic (e.g. Viscose, Lyocell)	Moderate	Moderate to high	Depends on solvent closed-loop systems (e.g., lyocell better than viscose)	Moderate to high	Sourcing wood pulp can raise deforestation issues; new production methods (closed-loop) can reduce toxicity and water use
Animal (e.g. Wool, Silk)	Often high (methane emissions, energy intensive)	Moderate; depends on animal husbandry	Generally lower, but some concern over land use and animal byproducts	High (esp. for wool)	Durability can be high; dry-cleaning more common (increases chemical exposure & energy use); biodegradability is positive; ethical/societal factors also relevant
Recycled Fibers	Lower than virgin equivalents	Lower; depends on recycling process	Lower if recycling is clean	Lower	Impact highly dependent on recycling technology and supply chain setup; promotes circular economy; actual performance depends on infrastructure

Source: Adapted from Mazzitelli, M., Papile, F., & Del Curto, B. (2024). Materials Selection and Fashion Design: Strengthening Reflections on Fiber's Nature in Fibers and Textiles Selection. *Discover Sustainability*, 5, 180. <https://doi.org/10.1007/s43621-024-00294-3>

2.2.3. Alternative and Lower-Impact Materials in Fashion

While conventional materials continue to dominate the industry, a growing number of lower-impact alternatives have emerged, aiming to reduce resource use, emissions and waste. These fibers are often marketed as more sustainable options. However, it is important to note that sustainability is a complex concept and that such classifications are frequently based on perceived or intended benefits rather than on a universally agreed-upon criteria. Additionally, as discussed throughout this chapter, a material's environmental performance can vary significantly depending on how and where it is produced. With that in mind, this section introduces key categories of alternative materials and highlights examples across different fiber types.

Types of Lower-Impact Materials

- Recycled Fibers

Recycled fibers are derived from pre-consumer or post-consumer textile waste, or from waste sources such as plastic bottles. These fibers are increasingly promoted as lower-impact alternatives to virgin materials that have the potential to reduce reliance on finite resources, divert waste from landfills and lower overall environmental impact during production. The most common examples include mechanically recycled cotton, chemically recycled man-made cellulosic and synthetic fibers such as recycled polyester (rPET) which is typically made from post-consumer PET bottles (Textile Exchange, 2024).

While recycled fibers are often mentioned for their sustainability benefits, their actual environmental performance depends heavily on the recycling method, the quality of the input and their potential for future recycling. In particular, the distinction between downcycling and closed-loop fiber to fiber recycling is essential when evaluating true circularity and the material's ability to remain within the recycling loop over time. Additionally, many recycled textiles still require virgin input to maintain performance or durability, which can complicate impact assessments (Johansson, Roos & Sandin, 2019; Muthu, 2014).

Mechanically recycled cotton, for example, involves cutting and shredding used textiles which ultimately shortens the fiber length and affects quality. Blending in virgin fibers thus becomes necessary to restore performance. Emerging chemical recycling methods offer an alternative by dissolving cotton waste into a pulp to produce regenerated fibers such as viscose, lyocell or other cellulosic. However, chemically recycling cotton remains complex and resource-intensive because waste textiles are frequently blended, dyed or chemically treated. Technologies like Evrnu NuCycl™, Circulose® by Renewcell, and Infinna™ by Infinited Fiber Company represent innovations in this space but require significant infrastructure investment to scale for mainstream commercial use (Okcabol, Rex & Roos, 2019; Textile Exchange, 2024).

The recycling processes, environmental benefits, limitations of recycling at scale and systemic challenges will be explored in depth in Section 2.3.

In summary, recycled fibers hold significant potential for reducing the fashion industry's environmental footprint but their success depends on improvements in technology, transparency and product design.

- Certified or Improved Natural Fibers

Certified or improved natural fibers refer to plant or animal-based materials produced under standards that aim to reduce environmental and social impacts. These certifications typically address issues such as chemical use, water management, biodiversity protection and labor conditions. Common examples include organic cotton, Cotton made in Africa (CmiA), Better Cotton Initiative (BCI) cotton, and Responsible Wool Standard (RWS) wool (Okcabol, Rex & Roos, 2019).

While these fibers are often considered more sustainable than their conventional counterparts, their actual benefits depend on regional growing conditions, proper verification and farming practices. For example, organic cotton typically avoids the use of synthetic pesticides and fertilizers, which can in turn reduce soil and water pollution although the water use could still be high in some regions. Similarly, RWS certified wool requires animal welfare and land management practices that help mitigate the impact of livestock farming (Muthu, 2014; Textile Exchange 2024)

These materials also lack publicly available impact data, which may lead to them being undervalued and deprioritized compared to fibers with more documented environmental assessments. In some cases, there is a big difference between what certifications promise and what actually happens in practice. Nonetheless, some studies suggest that organic cotton, for example, can emit significantly less CO₂ than conventionally grown cotton by up to 3.5 times less in certain contexts. Research comparing Indian conventional cotton and U.S. organic cotton showed that Indian conventional cotton produced twice as much CO₂ as U.S. organic cotton (Roos et al., 2019; Sandin & Peters, 2018).

Such findings support the idea that increasing the use of organic fibers, which tend to have lower carbon footprints, could contribute to general emission reductions (Biyada & Urbonavičius, 2025). However, the extent of these potential benefits remains highly dependent on context. Factors such as region, farming practices and supply chain energy sources can impact the environmental outcomes of fiber production. These materials still represent important steps towards supporting more responsible sourcing practices, especially when they are combined with greater transparency (Johansson, Roos & Sandin, 2019).

- Next-Generation Cellulosics

Next-generation cellulosics refer to an evolving group of fibers derived from natural cellulose sources such as wood, agricultural residues or recycled textiles. They are processed using more advanced, closed-loop or low-impact technologies. These materials represent improvements made on older man-made cellulosic fibers (like viscose), but they aim to reduce environmental

harm through cleaner chemical use, responsible feedstock sourcing as well as improved water and energy efficiency.

Key examples of such fibers include TENCEL™ lyocell which is produced in a closed-loop system where solvents are recycled with minimal emissions; EcoVero™ which is a lower-impact viscose variant with verified sustainable wood sourcing; and also innovative materials like Infinna™, Spinnova® and Orange Fiber which use innovative raw material inputs or processes to minimize chemical waste and the reliance on wood from virgin forests (Köfner, 2024; LTP group, n.d.).

While these fibers show strong potential to lower the environmental footprint of cellulosic textiles, their sustainability depends on factors like solvent recovery rates, land use for feedstock cultivation as well as transparency in sourcing and processing. Additionally, several next-generation fibers are still in their early stages of commercialization and have limited life cycle data available on them making it complicated to undeniably validate industry claims (Johansson, Roos & Sandin, 2019).

- Biobased Synthetics

Biobased synthetics represent an emerging class of materials designed to reduce dependence on fossil fuels. Unlike conventional synthetics derived from petroleum, biobased alternatives are made using renewable inputs such as corn, sugarcane or algae. Examples include PLA fibers (polylactic acid), biobased polyester and other experimental materials derived from agricultural waste (Textile Exchange, 2024; Transitions project, 2025).

However, biobased does not always mean low-impact. The environmental performance of these fibers also varies depending on land use, agricultural inputs and the energy source used in manufacturing. If they are produced using intensive farming methods or fossil powered sites, their carbon footprint can rival the one of conventional synthetics. Additionally, many biobased fibers are still not biodegradable and behave like plastics at end-of-life (Okcabol, Rex & Roos, 2019).

Furthermore, biobased and biodegradable materials are often marketed as sustainable without sufficient transparency or lifecycle data to support such claims. The biobased share of global polymer production remains small, representing around 1%. Particular assumptions made about their sustainability can thus be misleading (Okcabol, Rex & Roos, 2019).

Despite these challenges, biobased materials may represent a promising approach to reducing dependence on fossil resources, especially if they are produced with clean energy, responsible land use and models that prioritize long-term. However, it is important to mention that the overuse of any material, even renewable ones, can lead to resource depletion, soil erosion and other environmental consequences. Therefore, it is worth to highlight again that sustainability should be approached holistically by considering full lifecycle impacts, sourcing practices and replenishment rates (Jensen et al., 2023).

2.2.4. Conclusion: The Potential of Sustainable Materials

As previously discussed, the common classification of fibers as “good” or “bad” oversimplifies the reality of their environmental performance. Sustainability performance cannot be generalized even within the same fiber type. Instead, it depends on how the fiber is produced, the environmental practices of the supplier and how appropriately the material is used within a garment’s life cycle. Therefore, a meaningful evaluation of materials should also focus on the distinction between responsible and irresponsible production methods, as well as on how well a fiber is suited for its intended application. These distinctions are essential and should clearly be communicated (Johansson, Roos & Sandin, 2019; Mazzitelli, Papille & Del Curto, 2024).

As mentioned earlier, “Selecting the right fiber for the right application is key for optimizing its environmental performance throughout its life cycle” (Okcabol, Rex & Roos, 2019). This principle also involves choosing materials that suit the intended function of the garment. Not all fibers are suitable for every purpose as each has a distinct combination of technical properties that influence how well it performs in a specific context. Some perform better in terms of durability, while others offer advantages in softness, stretch or breathability. For instance, using a fragile fiber in a garment meant to last for years may shorten the product’s life unnecessarily. On the other hand, applying a high-durability synthetic fiber to a fast-fashion item destined for only a few wears creates unnecessary damages. The goal is thus to select materials that meet performance needs while minimizing environmental impact as much as possible. In this context, material choice must be part of a broader strategy that supports longevity, repair and reuse in order to ensure that garments are not only made sustainably, but also used and discarded responsibly. This includes considering how often the product will be worn, how it will be maintained and whether it can be recycled or safely disposed of at the end of its life. In short, sustainability is not just about what a fiber is made from, it is also about how well it fits the job it is meant to do (Abdelmeguid et al., 2024; Okcabol, Rex & Roos, 2019).

However, even when a fiber meets strong sustainability criteria at the cultivation stage, its overall impact depends heavily on what happens after harvesting. Once it enters the processing and manufacturing phase, the impact becomes more complex to evaluate and depends on factors such as energy use, chemical treatments and regional production practices. For example, although organic cotton is often associated with lower blue water use, research shows that regional differences can be more significant than the average difference between conventional and organic cotton (Johansson, Roos & Sandin, 2019). Similarly, a bio-based fiber may come from renewable sources but still carry a high environmental cost if fossil fuels are used to power the manufacturing process. This highlights the importance of evaluating not only material inputs but also the entire production system when assessing sustainability, especially if the goal is to produce truly sustainable garments.

Yet, despite the importance of evaluating fibers across their full life cycle, it is worth noting that such evaluation is often restricted by the limited availability of comprehensive and comparable environmental data, particularly for newer or certified fibers (Johansson, Roos &

Sandin, 2019). The diversity of fibers and production methods makes it difficult to generalize environmental performance across fiber categories. For newer fibers, such as those derived from recycled or bio-based feedstocks, artificial protein fibers or niche plant sources, publicly available life cycle data is often missing or limited to only a few environmental indicators. Even widely used fibers with sustainability certifications, such as organic cotton, BCI cotton or Cotton made in Africa, are backed by little environmental data. Furthermore, many commonly cited sustainable innovations (e.g., Econyl, Sorona, Recyclon, Orange Fiber, Ioncell-F, Infinited Fiber, and so on.) make strong sustainability claims without having transparent and peer-reviewed data to support them. In many cases, data is not disclosed until products reach commercial scale. This lack of data does not only concern fiber types but also specific impact categories like toxicity and eutrophication, which are frequently not included or insufficiently studied. As a result, comparisons between fibers are often inconclusive and claims about which materials are more sustainable must be made cautiously (European Parliamentary Research Service, 2024; Johansson, Roos & Sandin, 2019).

In conclusion, sustainable material adoption is a valuable but insufficient approach on its own for achieving sustainability. As many studies suggest, true sustainability depends on the combination of material innovation with sustainable production strategies. An extensive evaluation of materials, including their extraction, processing and integration into production systems is essential to identify environmental hotspots and reduce overall impact across the value chain (Abdelmeguid et al., 2024).

2.3. Sustainability in the Fashion Production Lifecycle

Building on the discussion of materials, sustainability in fashion must also be examined across the production lifecycle. The journey of sustainable fashion is not just a trend, but it is a response to the growing need for change in this industry that has long been associated with overconsumption, waste and exploitation. This is why, in this section, practices that are transforming the fashion supply chain will be explored.

2.3.1. Key Stages of Garment Manufacturing and Their Environmental Impacts

Garment production involves a complex, multi-stage process with each phase contributing differently to the overall environmental footprint of fashion. The main stages can be summarized as follows:

- **Raw Material Preparation:** this core stage includes the cultivation of natural fibers (e.g., cotton, flax, wool) and the synthesis of synthetic fibers like polyester or nylon. It involves land use, water consumption and energy inputs, particularly in synthetic polymer production (Islam, Hossain, & Covington, 2025; Munasinghe, Druckman & Dissanayake, 2021) For example, producing 1 kg of polyester emits approximately 9.52 kg of CO₂, while conventional cotton farming requires intensive water use and large quantities of pesticides. These impacts are increasingly being assessed through Life

Cycle Assessment (LCA), thus encouraging the adoption of alternatives such as organic cotton or recycled polyester (Muthu, 2014).

- **Yarn and Fabric Production:** fibers are spun into yarn and then formed into fabrics through weaving, knitting or nonwoven processes. Fabric production is energy-intensive and often involves chemical treatments. Mechanical processes such as spinning and chemical scouring or bleaching remove impurities before dyeing (Muthu, 2014).
- **Textile Processing (Dyeing and Finishing):** this is one of the most polluting stages in the lifecycle. Dyeing, finishing and printing require large volumes of water, energy and chemicals and contribute significantly to greenhouse gas emissions and water pollution (Islam et al., 2025; Cotton Incorporated, 2017).
- **Garment Manufacturing:** cutting, sewing and assembling garments are labor-intensive but generally less impactful in terms of emissions and resource use compared to textile manufacturing. However, this stage is critical from a social and ethical standpoint due to working conditions in global supply chains (Muthu, 2014).
- **Consumer Use Phase:** this phase often surpasses production stages in terms of environmental impact, mainly due to energy and water use from washing, drying and ironing. It is estimated to be one of the largest contributors to a garment's overall footprint (Cotton Incorporated, 2017).
- **End-of-Life:** garments are often discarded in landfills, incinerated, or, in some cases, recycled. Disposal methods can significantly affect environmental outcomes. Circular options such as reuse and recycling help reduce waste and resource depletion (Islam et al., 2025).

In conclusion, while all stages of garment production contribute to environmental harm, textile manufacturing and consumer use are consistently highlighted as the most impactful. This aligns with data from MUD Jeans, which estimate that the use phase alone can account for between 19% and 80% of a garment's total environmental impact, depending on how the item is cared for. Efforts to improve sustainability should therefore prioritize these stages for maximum benefit.

2.3.2. Sustainable Business Practices in the Fashion Industry

This section explores practical strategies that fashion companies are adopting to reduce their environmental footprint. It focuses on circular economy initiatives, waste-reducing production methods and efforts to increase transparency and consumer engagement. These practices are often presented as key elements towards reaching a more sustainable fashion industry.

This section will explore how the principles of circular fashion are put into practice within the fashion industry. Some of the main circular practices examined here include *recycling programs, take-back schemes and repair schemes*. These initiatives aim to reduce the fashion industry's reliance on virgin resources and limit the volume of textile waste sent to landfills by extending the life cycle of garments. They also help brands respond to shifting consumer expectations and increasing regulatory requirements by aligning with industry standards, demonstrating accountability and preparing for future policy developments (Dragomir & Dumitru).

- Recycling programs

Recycling involves transforming textile waste (either post-consumer or pre-consumer) into new fibers, yarns or products. This can be achieved through various processes including mechanical, chemical, thermal or biological methods (Biyada & Urbonavičius, 2025; Clary & Leonas, 2023).

Impact and benefits

In theory, textile recycling can significantly contribute to reducing environmental impact by redirecting waste away from landfills and decreasing demand for virgin materials. In Europe, each person discards about 11 kg of clothing annually, most of which is incinerated, landfilled or exported. Only a little portion is recycled or resold locally (Changing Markets, 2023; Eppinger, 2022). In the United States, over 17 million tons of textile waste are generated each year, but only 15% of it is recycled or donated meaning over 11 million tons end up in landfills (Clary & Leonas, 2023). This 15% figure is frequently cited in the literature and appears to be based on widely referenced data from sources such as the U.S. Environmental Protection Agency. However, actual statistics may vary depending on how “recycling” is defined, whether it includes donations, mechanical recycling or downcycling (Seo & Jin, 2024; Biyada & Urbonavičius, 2025). Multiple studies reflect a general acknowledgment of the gap between the theoretical potential and the practical reality of textile recycling.

If implemented effectively at scale, textile recycling could offer multiple environmental benefits. Recycling practices can help reduce reliance on raw materials and harmful chemicals, although this depends on the quality and composition of the collected textiles (Clary & Leonas, 2023.; Seo & Jin, 2024). In theory, up to 95% of textile waste could be reused or recycled, with approximately 60% for direct reuse and 35% for conversion into secondary products such as cleaning cloths or recycled fibers, leaving only a small fraction truly non-recyclable (Biyada & Urbonavičius, 2025). According to Biyada & Urbonavičius, recycling processes can also conserve water and energy, reduce pollution and extend the lifecycle of materials. For example, using recycled textiles can eliminate the need for re-dyeing which requires significant amounts of water and energy, while biological methods such as composting or anaerobic digestion represent innovative solutions to convert textile waste into energy or fertilizers (Biyada & Urbonavičius, 2025).

Limitations and Challenges

Despite their promising aspects, current recycling practices face significant systemic and technical barriers that limit their effectiveness at large scale. While it is achievable in theory, only a small part of collected textiles are successfully reused or recycled into new garments. In fact, less than 1% of used clothing is recycled into clothing (Changing Markets, 2023).

Most collected textiles are downcycled into lower-value products, incinerated, stockpiled or exported to countries lacking proper waste management. A large portion of these ultimately becomes environmental waste (Changing Markets, 2023). The most common recycling method, mechanical recycling, can degrade the quality of fibers. In addition to that, low material quality, fiber blends and contamination make true fiber to fiber recycling difficult. As a result, virgin materials often need to be added, which means true circularity is not achieved (Biyada & Urbonavičius, 2025; Eppinger, 2022). The dominance of mixed-fiber garments in post-consumer waste, which are difficult to recycle mechanically, has driven growing interest in chemical recycling techniques. Although these technologies show promise, they are still relatively new and remain limited by high costs and technical barriers (Changing Markets, 2023).

Reliable, generalized data on the environmental benefits of textile recycling remains limited. Actual outcomes in impact reduction depend heavily on the specific recycling methods, input materials, energy sources and infrastructure involved.

Moreover, the environmental benefits of recycling can be limited by rebound effects: the increased availability of recycled or 'green' products may encourage greater consumption due to perceived responsibility, while practices such as blending small amounts of recycled fiber with virgin materials may inadvertently increase overall resource use (Sarokin & Bocken, 2024).

As a result, most take-back and recycling initiatives do not succeed in delivering large-scale environmental benefits. Unless product quality improves, recycling technologies and infrastructures are strengthened and transparency is enforced, the potential for change offered by these programs will remain out of reach.

In conclusion, while recycling is often highlighted as a key strategy for enabling circularity in fashion, they currently achieve only minimal progress in reducing production and waste. These initiatives offer incremental improvements rather than the transformative change the industry urgently needs (Biyada & Urbonavičius, 2025; Changing Markets, 2023; Clary & Leonas, 2023; Eppinger, 2022; Seo & Jin, 2024).

- Take back schemes

Take-back schemes are programs initiated by fashion brands and retailers to encourage consumers to return used garments, which are then either resold or recycled. In exchange, participants are typically offered incentives such as discounts, store credit or other rewards. These programs aim to reduce the volume of clothing discarded in landfills by promoting reuse

and recycling. They represent an effort to actively engage consumers directly in the brand's sustainability initiatives. Take-back programs also help brands strengthen their CSR image, promote greater customer loyalty and attract more customers into stores (Seo & Jin, 2024; Clary & Leonas, 2023).

When implemented carefully, take-back schemes can play a key role in reducing fashion's environmental footprint. According to Nizzoli, prolonging the lifespan of garments through resale, repair, or recycling can make a significant difference. They claimed that wearing an item at least 30 times or extending its use by just nine months can cut its carbon, water, and waste footprint by 20–30%. Moreover, these initiatives are most impactful when they are integrated into circular design strategies. Brands that design garments for durability and with the end life of the product in mind help ensure that take-back programs operate more effectively. These schemes can also support greater inclusivity in sustainable fashion by offering resold garments at lower prices, making ethical choices more accessible to a wider audience (Nizzoli, 2024; Seo & Jin, 2024).

While take-back schemes are often promoted as circular solutions, their effectiveness depends heavily on transparency and effective implementation. Only about 28% of companies reveal the fate of returned garments which in turn raises doubts about the sincerity of sustainability claims among consumers (Changing Markets, 2023; Clary & Leonas, 2023). Research from the Changing Markets Foundation revealed that over 75% of garments collected for recycling by major brands such as H&M, C&A and Primark were ultimately destroyed, lost or exported to countries like those in Africa thus potentially worsening environmental impacts rather than mitigating them. Such findings raise concerns about greenwashing. Genuine initiatives stand out by their ability to disclose clearly and verifiably what happens to returned clothing. In contrast, lack of transparency reduces the credibility and environmental value of these schemes. Several smaller brands are notorious for having effectively implemented take-back schemes, such as MUD Jeans, Swedish Stockings, Neem London, Fanfare and Leticia Credidio (Nizzoli, 2024).

However, it is important to note that take-back schemes can sometimes produce counterproductive outcomes. Contrary to their original purpose, incentives like discount vouchers can further encourage overconsumption rather than reducing waste (Eppinger, 2022; Clary & Leonas, 2023).

○ Repair Schemes

Repair schemes are sustainability initiatives led by fashion brands, retailers or third parties intended to restore worn garments and extend their lifespan. These can include in-store mending services, brand partnerships with aftercare specialists, repair cafés or DIY repair kits (Cernansky, 2022; Tonti, 2023). Examples of such initiatives include Patagonia's *Worn Wear* program, Veja's sneaker repair services and a brand operated "clinic" like Allude's for cashmere garments, among others (Schirrer, 2024).

In terms of environmental impact, repair schemes reduce the demand for new clothing and, by doing so, lower the need for virgin materials, energy and water. A study from The Renewal Workshop reports that only 46% of garments collected through takeback programs are ready for resale. However, with repair services that number rises to 82% (Cernansky, 2022).

As repair services prove to be more effective at making garments resalable, they have gained more interest from consumers, and brands are starting to invest in repair infrastructure. In the UK, 55% of adults reported repairing an item rather than replacing it in the past year, and 76% said they would consider using a repair service which can suggest a cultural shift toward more sustainable consumption habits. In response, brands have begun scaling their repair capabilities: Patagonia, for instance, repaired over 100,000 items in a single year through its 72 global repair centers, while Australia's national Seamless scheme identifies repair as a key strategy in addressing the 200,000 tons of clothing waste sent to landfill annually (Tonti, 2023). Because repair schemes are not yet widely implemented, comprehensive data on their environmental impact remains limited (Schirrer, 2024; Source Fashion, 2024).

Beyond direct environmental impact, repair initiatives can foster consumer responsibility and help normalize a culture of care. Visible mending and accessible services like Selfridges' collaboration with SOJO promote repair as a fashionable and everyday practice (Schirrer, 2024). They also create local employment opportunities, especially for tailors and artisans, and offer skill-building for consumers (Campbell, 2025).

However, repair schemes also face limitations. They can be time-consuming and costly, with brands often lacking incentives due to higher profits from new sales (Cernansky, 2022). Garment design is another barrier; many clothes are not made to be easily fixed, increasing repair difficulty and cost (Source Fashion, 2024). In addition, awareness is limited and many consumers remain unaware that repair is an option (Schirrer, 2024).

Legislation is slowly changing this. EU and UK "Right to Repair" frameworks, alongside France's repairability index and the CSRD, are pushing brands toward product longevity and lifecycle accountability (European Parliament, 2022; Schirrer, 2024). As regulation evolves, repair is becoming harder for brands to ignore.

Waste-Reducing and Demand-Driven Production Models

Building on circular fashion principles, waste-reducing and demand-driven models aim to minimize environmental impact from the very start of the design and production process. Eco-design strategies focus on using durable, recyclable materials in order to create garments that meet long-term consumer needs rather than following short-lived trends. Technologies like 3D design software and automated 3D weaving enable the creation and testing of prototype designs without making physical samples, thus avoiding material waste. On the manufacturing side, automation and lean production methods such as additive manufacturing enhance material and energy efficiency while lowering transport emissions. (Burzec, n.d.; Lectra, 2024).

Demand-driven production models aim to reduce overproduction by aligning supply more closely with actual consumer demand. Unlike traditional models that rely on forecasts, these

models use real-time data and analytics to produce only what is needed. Technologies such as AI, big data and digital platforms scan consumer behavior from brand websites, social media, and even second-hand markets to better anticipate demand and avoid excess inventory. Pre-order is presented as a business model where production occurs in response to customer demand, rather than anticipating demand and producing inventory in advance. This approach minimizes waste and overproduction by ensuring that items are only manufactured after consumers have committed to purchasing them. Pre-order and on-demand manufacturing are key strategies allowing brands to begin production only after receiving sufficient consumer interest or confirmed orders. This not only reduces waste but also shows that there is a way to make fashion based on real demand instead of relying on forecasts (European Parliament Research Service, 2024; Fashioninnovation, 2024; Lectra, 2024). A real-life implementation of these principles will be explored in the following chapter through the case study on Rifò.

Together, these approaches support a more sustainable and flexible fashion system by aligning production more closely with actual demand and minimizing excess at every stage.

Reducing Environmental Impact Across the Supply Chain

There are multiple improvements that fashion companies can implement across different stages of their supply chain to reduce environmental impact. These strategies address key environmental issues and can play a vital role in guiding the fashion sector towards more sustainable production practices. The following examples highlight some of the most widely documented and implementable strategies:

- **Water Use:** Closed-loop water recycling systems and low-water dyeing technologies. For example, some factories in Bangladesh have lowered water use from over 250 L/kg of fabric to as little as 57 L/kg using closed-loop systems. In denim dyeing, up to 94% of water can be recovered and reused. Additionally, low-liquor-ratio dyeing and microbial dyeing methods have achieved up to 90% water savings compared to conventional processes (Harsanto et al., 2023).
- **Water Pollution:** Effluent treatment plants (ETPs) and the use of certified safer chemicals (e.g., GOTS, Bluesign) significantly reduce textile related water pollution. Without treatment, 90–95% of process water becomes toxic wastewater with BOD⁵ levels reaching 550–650 mg/L and COD⁶ up to 1,200 mg/L. ETPs required by standards like GOTS and Bluesign lower these pollutant levels to meet legal and ecological discharge limits. These certifications also ban or restrict the use of thousands of hazardous substances and ensure compliance through strict inspection and chemical input control systems. This results in much cleaner wastewater and reduced ecological harm. These systems are effective at eliminating residual dyes and at processing

⁵ Biological Oxygen Demand (BOD): measures the amount of oxygen that microorganisms will consume while decomposing organic matter in water (Cotton Incorporated, 2017).

⁶ Chemical Oxygen Demand (COD): measure of the total quantity of oxygen required to chemically oxidize organic and inorganic matter in water (Cotton Incorporated, 2017).

chemicals from wastewater. It is worth noting that textile dyeing and finishing processes remain a major environmental concern, accounting for an estimated 17–20% of global industrial water pollution according to the World Bank (European Parliament, 2020; Muthu, 2014).

- **Energy Consumption:** Energy-efficient machinery, such as modern looms, high-efficiency motors and variable speed drives, can reduce energy use by up to 30% in textile production. Additionally, factories investing in on-site renewable energy sources like solar or biomass have reported 20–30% drops in GHG emissions. The impact is especially noticeable in coal-reliant regions like China and India. Overall, the adoption of these measures has contributed to a 22% reduction in greenhouse gas emissions between 2010 and 2022 in the textile value chain even as production increased (Biyada & Urbonavičius, 2025; European Environment Agency, 2025).
- **Local Production and Emission Tracking:** Having a local supply chain can significantly reduce transport-related emissions. Transport can disproportionately contribute to emissions depending on the method used. For example, shipping a cotton shirt from Asia to Europe by sea emits around 0.29 kg CO₂e, but by air it rises to 4 kg CO₂e. regional sourcing also enables faster adoption of cleaner energy since localized supply chains make it easier to monitor energy use, invest in local renewable infrastructure, and align with evolving environmental regulations (Muthu, 2014). In parallel, emissions tracking across Scopes 1, 2 and 3 is becoming standard. The use of digital tools and lifecycle assessments help brands identify emission “hot spots” and set reduction targets in line with climate goals (PlanA, 2025).
- **Chemical Use:** Many manufacturers are replacing toxic substances with biodegradable or enzymatic alternatives, such as amylases, pectinases and catalases. These alternatives can reduce water use by 30–50% and energy use by up to 18% during processing. These eco-friendly inputs are also safer for both workers and the environment. Industry-wide compliance with the Zero Discharge of Hazardous Chemicals (ZDHC) program has further accelerated the elimination of hazardous substances by requiring factories to adopt safer chemical management systems and meet strict effluent standards (Muthu, 2022).
- **Eco-friendly Packaging:** The fashion industry is increasingly adopting eco-friendly packaging solutions such as recycled paper, biodegradable bioplastics and reusable systems. These packaging choices are not only environmentally beneficial but also strategically important: they shape first consumer impressions, reinforce brand sustainability values and address the pressure from regulators to minimize waste. Sustainable packaging plays a growing role in aligning fashion with circular economy principles (Harsanto et al., 2023).
- **Natural dyes:** These dyes derived from plants, minerals and other natural sources offer a biodegradable and non-toxic alternative to synthetic dyes. They help reduce chemical

pollution and health risks in textile production. Common plant-based dyes include indigo (from *Indigofera tinctoria*), marigold, bougainvillea, pomegranate and Terminalia fruits. Although they are currently used in only about 1% of textile dyeing, natural dyes are considered one of the most sustainable options for fabrics. These face challenges such as cost, color consistency and scalability but their use continues to grow in sustainable fashion initiatives (Muthu, 2022).

- **Microfiber Pollution:** Microfiber pollution can be reduced through carefully designed products and effective filtration systems. Design strategies such as using tightly woven fabrics, long-staple fibers and anti-shedding finishes can reduce microfiber release during washing. In parallel, filtration systems in washing machines and industrial facilities have been shown to capture up to 90% of microfibers, thus helping prevent some of the estimated 500,000 tons of synthetic microfibers entering oceans annually (European Parliamentary Research Service, 2024; Muthu, 2022)⁷.

While this section does not cover every existing sustainable production strategy, it highlights key practices that illustrate practical ways in which the industry can reduce its environmental impact. The effectiveness of these strategies varies based on context but they provide a clear indication of where meaningful progress can be made.

Transparency and Accountability in Fashion

These practices contribute to sustainability in the fashion industry by increasing visibility across the supply chain, building consumer trust and ensuring that environmental and social standards are respected. Transparency allows brands and stakeholders to access data on sourcing and production, helping them take accountability and make more informed decisions.

Traceability is essential for verifying sustainability claims and detecting non-compliance. By tracking materials and processes from raw input to final product, companies can ensure ethical labor practices and environmental standards are maintained. Tools like blockchain technology and RFID/NFC systems further strengthen traceability by offering secure, real-time tracking of products and data throughout the supply chain.

To support transparency, digital solutions such as Digital Product Passports and supply chain mapping tools provide comprehensive overviews of product lifecycles. They help brands identify risks and improve efficiency. Similarly, AI and data analytics allow for deeper insights into resource use and sustainability performance. However, it is important to note that tools like Life Cycle Assessments (LCAs), while valuable for measuring environmental impact, depend heavily on the quality and specificity of input data. Inaccurate or generalized data can lead to misleading results, particularly in areas like textile recycling where outcomes vary widely based on method, material composition and regional infrastructure. This underscores the importance

⁷ European Parliamentary Research Service (2024) and Muthu (2022) served as key references for multiple sustainability strategies presented in this section.

of standardized data and full transparency to avoid misinterpretation or greenwashing (Ecochain, n.d.; Rai, 2025).

Accountability is also strengthened through certifications and auditing platforms. Systems like Fairtrade, GOTS, B Corp and the Higg Index help standardize environmental and social standards and give credibility to sustainability efforts. Transparency reporting platforms allow brands to publicly disclose their practices and thus foster trust through letting others verify their claims.

Together, these tools and practices form the foundation of responsible supply chain management by aligning corporate practices with broader sustainability goals (European Parliamentary Research Service, 2024; Lectra, 2024; UNECE, 2020).

Consumer Expectations and Engagement

Consumers play a crucial role in the success of sustainable fashion initiatives, particularly within circular business models. Encouraging behavior change such as prioritizing durable, high-quality garments and reducing overconsumption is essential in order to lower emissions and waste across the fashion lifecycle (Biyada & Urbonavičius, 2025). As the industry shifts toward circularity, customers are no longer seen as passive buyers but as active participants who contribute to sustainability by returning used garments, engaging in repair or resale programs and making informed purchasing decisions. Brands respond to these evolving expectations by developing strategies to educate and motivate consumers like offering environmental impact guides, care instructions and incentives like take-back schemes and discounts (as illustrated in the case studies of Rifò and MUD Jeans). These efforts not only foster long-term customer loyalty but also support broader environmental goals. However, challenges remain: price sensitivity and resistance to behavior change continue to limit the widespread adoption of sustainable habits. To better understand these dynamics, this thesis includes a consumer survey that explores public attitudes, awareness and willingness to engage in more sustainable fashion behaviors. Nonetheless, increasing public awareness and willingness to engage suggest that empowering consumers through clear communication and accessible programs is a key way to accelerate the industry's shift toward sustainability (Abdelmeguid et al., 2024).

2.3.3. Conclusion: Effectiveness of Sustainable Practices

Sustainable business practices, including circular economy strategies, repair initiatives, waste-reducing production models and supply chain transparency, offer measurable ways to reduce the fashion industry's environmental impact. The analysis has shown that practices like recycling, take-back schemes and localized, demand-driven production can lead to reductions in water use, energy consumption and emissions, while also extending garment lifespans and reducing textile waste. When they are combined with digital tools and certifications that enhance accountability and traceability, these efforts can contribute to achieving larger environmental goals.

However, while these practices could be effective, their impact is limited due to technical, financial and infrastructural barriers. Most current initiatives have only achieved minor progress rather than the systemic transformation needed. Key obstacles include high implementation costs, limited circular infrastructure, a lack of standardized data and ongoing consumer resistance to behavior change. These challenges are reinforced by the continued dominance of fast fashion's linear model which hinders the scaling of sustainable solutions (Ge Qu, 2024; Harsanto et al., 2023; McKinsey & Company, 2024).

Despite these limitations, examples such as Stella McCartney's material innovation and measurable emissions reductions, as well as MUD Jeans' and Rifò's implementation of circular business models, show that sustainable practices can drive meaningful environmental benefits when applied holistically and transparently. To fully unlock their potential, sustainability efforts must be supported by regulatory frameworks, investment in infrastructure and greater consumer engagement (Stella McCartney, 2023).

To summarize, sustainable business practices can significantly reduce fashion's impact but their full effectiveness depends on deeper systemic shifts. Without broader change, these initiatives will remain limited in their ability to reshape the industry at scale, however innovative they are (Changing Markets, 2023; Eppinger, 2022; Schirrer, 2024).

Chapter 3 - Data Collection and Presentation

o 3.1. Investigating Sustainable Companies

In this section, I will first outline the methodological approach used to gather data from companies and discuss the limitations of this approach. Following this, I will present a detailed profile of each company, MUD jeans and Rifò, based on a combination of online research and data obtained through interviews.

Each company's profile will be constructed using publicly available information, which I will then complete and critically assess with data gathered from the interviews. Additionally, I will evaluate the reliability of the data obtained as much as possible, highlighting any potential limitations.

3.1.1. Methodological Approach to Investigating Companies

I chose to conduct interviews because they provide valuable insights that may not be available publicly, allow me to explore the reasoning behind certain practices, and clarify any ambiguous points. This method facilitated the creation of more accurate company profiles.

I contacted 92 companies via email and through contact forms on their websites whenever available. My initial approach targeted organizations specializing in materials such as linen, bamboo, and hemp. These companies integrated sustainable practices into their operations, including ethical manufacturing processes, responsible collaborations, and partnerships with ethical suppliers. To ensure a diverse range of options, I reached out to companies from various regions.

Despite my efforts, I did not receive favorable responses to my interview requests. However, Patagonia and Reformation kindly provided links to past interviews. I then expanded my search to include companies that have launched sustainable initiatives, such as using recycled materials, upcycling methods and adopting circular economy practices, including product return services that offer loyalty discounts for future purchases

The companies I contacted include : Able, Afends, Allbirds, All the wild Roses, Amour Vert, Amaud, Artknit Studios, Aster & Oak, BAM, Boody, Bougainvillea London, Boyish, Blue of a kind, Cariuma, Casagin, Cérès, Christy Dawn, Cotopaxi, Dorsu, Eileen fisher, E.L.V. Denim, Etica, Everlane, Fair Indigo, Franc, Gaia Segattini Knotwear, Girlfriend collective, Glass Onion, Herth, Honest Basics, ID.EIGHT, Kampos, Kings of Indigo, LA Relaxed, Liege evasion, Little Green Radicals, Loud + Proud, Lucid, Mantis World, Mayamiko, Meeko, Metabamboo, Mila.vert, Mud Jeans, Naadam, Nisolo, No nasties, Norm, Nudie Jeans, Olmstend Outerwear, Opera campi, Organic Basics, Orbasics, Outerknown, Outland denim, Paka, Paapii Design, Pareto, Patagonia, Pact, People Tree, Poplinen, prAna, Purusha People, Raeburn, ReCreate, Reformation, Rifò, Rothy's, Rupahaus, Samara, Sassy spud, Saye, Seek Collective, Souldaze, Toads&co, Tentree, The Anjelm's Project, The classic t-shirt company,

The Good Tee, The R collective, The social Studio, The tiny Closet, Thought, Thought clothing, Tove & Libra, Vernisse, Veja, Womsh, Where does it come from?, Wholesome Culture, Wolven

I initially received a response from a young Belgian company called Lucid, which agreed to answer my questions via WhatsApp. The interview was planned to be conducted through text messages, with the participant responding via voice messages. I prepared a set of questions based on a review of relevant literature and refined my questions by removing any redundant ones for which I had already found answers online. The interview guide consisted of 17 questions covering various aspects such as company history, sustainability and social responsibility, challenges and obstacles, business operations and partnerships. Unfortunately, despite initial communication, Lucid did not respond to further exchanges.

I made a third attempt to contact the companies that had either not responded or had not explicitly rejected my initial request. This time, I was fortunate to receive favorable responses from 2 companies: MUD jeans and Rifò. I created the interview guides in a similar approach to the one I had used with Lucid.

MUD jeans were unavailable for a one-on-one interview but invited me to attend their monthly webinar on August 5, 2024, which I accepted. Due to time constraints and since three other students were also present to ask questions for their thesis, I was only able to ask three questions during the session. The webinar, initially conducted on Zoom, was moved to Microsoft Teams due to time limits on the Zoom call. They started a screen recording under the suggestion of another student. The webinar lasted approximately one hour. (See Appendix 1 for the interview guide and Appendix 2 for the transcription of the interview)

I was able to schedule an interview with the founder of Rifò following their suggestion to review the company's 2023 sustainability report. The interview took place on Google Meet on August 6, 2024. To ensure the interview remained focused and not overwhelming, I limited my interview guide to ten questions. However, the founder's responses were relatively brief and I found myself wishing I had written down additional questions. I intended to seek clarification on other specific points from the sustainability report but was unable to do so as I became flustered during the interview. (See Appendix 3 for the interview guide and Appendix 4 for the transcription of the interview)

3.1.2. MUD Jeans ⁸

MUD Jeans is a Dutch brand founded in 2012 by Bert Van Son that presents itself as a pioneer in circular denim production. It is committed to producing denim garments and accessories through a fully circular model in design, reuse and recycling. The company has been certified as a B-Corporation since January 2015 (B-Corporation, 2024). Their B-corp score increased

⁸ Unless referenced otherwise, all information in this section is sourced from the official MUD Jeans website.

from 91.2 in 2015 to 124.7 in 2020 which reflects their constant commitment to improving both their environmental and social performance.

Sustainable practices implemented by MUD Jeans

- Circular Business Model

Their vision stated on their website as: “*We stand for zero waste in fashion production without compromising design, comfort and fit*” (MUD Jeans, 2025) is reflected in their overall approach. As discussed in a webinar (see Appendix 2), the small founding team was united from the beginning around a shared commitment to circularity, which allowed them to adopt bold ideas without internal resistance. This shared vision created a cultural foundation that continues to influence their strategic decisions today.

This commitment is seen in the strategies they implement throughout their operations. They apply circular strategies such as circular design, regional production and a take back-scheme that accepts used jeans, even including those from other brands as long as they contain at least 96% of cotton. Once returned, old denim is either upcycled into vintage styles or fully recycled: the jeans are disassembled, shredded, cleaned and re-spun into new yarn. They effectively close the loop by transforming discarded garments into entirely new products. Rather than following the fast fashion model of frequent seasonal releases, MUD Jeans focuses on creating timeless and long-lasting styles designed for durability. Additionally, they offer a unique “lease or buy” program allowing customers to rent a pair of jeans for a monthly fee with the option to return, exchange or keep the jeans at the end of a 12-month period. As part of their circular strategy, MUD Jeans also provides free repairs during the lease period. They have launched a broader repair program in order to gather insights and develop strategies to eventually be able to offer this service on a larger scale and not just to those who lease. Through a partnership with MENDED, which handles the repair services, they were able to establish a resell platform for repaired jeans. In doing so, they are keeping the products in use longer until they truly reach their end-of-life (MUD Jeans, 2024).

However, the brand faced administrative challenges when first implementing the leasing system, such as managing recurring payments and tracking returns. These difficulties were only overcome by adopting specialized software in 2021. Repairs also create cost-related difficulties, which MUD Jeans addresses through cost distribution and a logistics partnership with the repair service Mended. This information was obtained from a webinar attended on August 5, 2024 (Please refer to Appendix 2 for the transcription).

- Demand-driven Production and Sustainable Manufacturing

In line with its circular philosophy, MUD Jeans also aims to reduce overconsumption and overproduction by aligning its production model with real demand. The brand relies on a “Never Out Of Stock” (NOOS) strategy by producing timeless and cross-seasonal denim styles in small batches based on monthly restocking needs. This demand-driven approach is reinforced by a B2B pre-order model, which allows retail partners to order according to actual store demand, therefore avoiding excess inventory. By maintaining a small transparent supply chain

and encouraging conscious purchasing through leasing and take-back schemes, MUD Jeans reduces unnecessary production while promoting sufficiency and long-term product use (MUD Jeans, 2024).

In addition to promoting circularity and demand driven production, MUD Jeans implements several sustainable practices in its production process, including the use of laser and ozone instead of PP spray, chlorine and stone washing as well as a foam dyeing technique that saves 100% water and reduces chemical use by 86%. These practices will be clearly indicated in the table about suppliers and show the specific production stages at which they are applied (Please refer to page 54).

- Transparency and External Engagement

In addition to its model, transparency is a core value for the brand. In practice, MUD Jeans demonstrates its commitment to transparency by publicly disclosing its suppliers and participating in third-party certifications such as Social and Labor Convergence Program (SLCP), B Corp and Cradle to Cradle. The brand also actively communicates its sustainability efforts through impact reports, webinars and social media. By doing so, the brand ensures its practices are accessible and verifiable. MUD Jeans also conducts and shares Life Cycle Assessments (LCA) to provide measurable data on water and carbon savings, which will be explored further in the section on their environmental and social impact. Overall, these efforts reflect a traceable and data driven commitment to sustainability.

Beyond their own operations, MUD Jeans also engages in broader environmental and social efforts through strategic partnerships. Such environmental and social initiatives include partnerships with organizations like Justdiggitt, Circle Economy and Sea Shepherd. For every old pair of jeans returned, they donate to Justdiggitt, which restores deforested land to boost local biodiversity. They also collaborate with Circle Economy on circular economy projects and have released a capsule collection with Sea Shepherd to support ocean conservation.

Sustainable Materials used by MUD Jeans

Since its early days, MUD Jeans has steadily increased its use of post-consumer recycled cotton from 20% to up to 40% now, which they claim is among the highest in the industry. In 2023, the brand launched the *Road to 100* mini-series in collaboration with Saxion University of Applied Sciences and TechForFuture, with the ambitious goal of creating denim made entirely from post-consumer recycled cotton. They successfully produced a prototype using a blend of 67% mechanically recycled fibers and 33% chemically recycled fibers, achieving a fabric that reportedly kept 90% of the typical denim feel. In order to eventually be able to scale up the process, they partnered with their Spanish supplier Recover Ferre Tejido who agreed to conduct industrial testing to determine the feasibility of bulk production.

The primary materials they use include post-consumer recycled cotton as well as GOTS and OCS certified organic cotton, which accounts for 60 to 75% of most of their denim items. Some products also incorporate hemp sourced from France, making up 30% of their composition. Additionally, for their stretch jeans collection and stitching yarn (uses a polyester core for

increased strength), they incorporate recycled elastane and T400 for their stretch properties, while limiting it to 3% of the composition at most. This low percentage ensures that the denim remains recyclable. One of their long-term goals is to eliminate the use of virgin raw materials entirely and produce jeans made exclusively from recycled sources, as highlighted in their Road to 100 project mini-series. In addition to these materials, MUD Jeans also integrates other low-impact fibers such as recycled linen and TENCEL™ Lyocell x REFIBRA™, sourced from European suppliers.

The brand's attention to sustainability extends beyond textiles. Instead of mixing materials like metal and plastics, their buttons are made from 100% stainless steel, making it easier to recycle. Labels are made from Jacron, a durable leather like paper made from cellulose which ensures that the product remains natural and vegan. Packaging is provided by their logistics partner and is made from mostly recycled cardboard and their paper tags are produced using OEKO-TEX certified materials.

Environmental and social impact of MUD Jeans

o Environmental impact

MUD Jeans reports having saved 48.7 million liters of water and avoided 251,000 kg of CO₂ emissions in 2022 through their water and energy saving techniques. In the first episode of their *Road to 100* series on YouTube, they stated that they achieve 93% water savings, 74% lower CO₂ emissions and reduce their impact on biodiversity by 51% (MUD Jeans, 2023). According to LCA results provided by Ecochain, MUD Jeans' products emit up to 66% less CO₂ and use 80% less water compared to industry averages, including comparisons with products from major brands such as Levi's (Ecochain, 2025). On average, each pair of MUD Jeans reportedly allows them to save up to 90% of water and reduce CO₂ emissions by 46.6%. In 2022, 18,363 jeans were reused and "saved" from landfills. In 2023, their take-back program received 2,317 pairs of jeans.

MUD Jeans conducts annual Life Cycle Assessments (LCA) in collaboration with Ecochain to measure the environmental impact of each product from cradle to gate.⁹ These assessments focus on key indicators such as carbon footprint, water consumption and biodiversity impact. They have shown steady improvements over the past four years. To better understand the benefits of their sustainable practices, MUD Jeans also compares their actual products with a hypothetical version made using conventional methods. Both are modeled identically except for four aspects: the use of recycled and organic cotton instead of conventional cotton, recycled water against conventional water, renewable compared to conventional energy sources and their primary supplier data compared to industry average data for manufacturing stages. This method allows them to quantify the environmental benefits resulting directly from their use of sustainable materials and practices (MUD Jeans, 2024). While their LCA data is conducted by

⁹ from the extraction of raw materials ("cradle") to the point where it leaves the factory ("gate"). The footprint caused by customer use is therefore not included in this LCA (Ecochain, 2023).

external experts, they acknowledged in a webinar that cost constraints have limited third-party audits and comparative benchmarking with other brands (see Appendix 2 for transcription).

The Life Cycle Assessments conducted by MUD Jeans provided detailed insights into the environmental impact of their material choices and production processes. Regarding materials, recycled cotton stood out as a key driver of sustainability and significantly lowered both CO₂ emissions and water usage. It is a central component of the brand's strategy to minimize its environmental footprint. In contrast, the organic cotton used by the company was shown to still have a considerable water impact despite being more sustainable than conventional cotton. According to the assessment, organic cotton accounted for approximately 50% of the average water footprint across all production stages which makes it the largest contributor to water use in the entire process. While the CO₂ and energy impacts of organic cotton were also significant, they were more evenly distributed across other production steps, such as spinning and weaving. MUD Jeans continues to address these challenges through efficiency improvements in cotton sourcing and production processes. In addition to material impact, the LCA findings also underscored the environmental impact of production processes such as drying, spinning, weaving and dyeing, which are energy-intensive. However, investments in energy-efficient technologies have resulted in consequent reductions in emissions. It is also worth noting that transportation was shown to contribute minimally to the company's overall environmental footprint (MUD Jeans, 2024).

The following table summarizes the findings of the 2023 Life Cycle Assessment of MUD Jeans:

Table 7: Summary of Environmental Impacts of MUD Jeans vs. Conventional Denim (2023 LCA)

Impact Category	MUD Jeans value (2023)	Conventional values (LCA benchmark)	Savings through sustainable methods	Notes
CO₂ Emissions (per jeans)	3.5kg CO ₂ -eq	5.9kg CO ₂ -eq	41% reduction	CO ₂ savings through recycled/organic cotton, renewable energy and efficient manufacturing
Water consumption (per jeans)	460 liters	1,400 liters	67% reduction	Water use reduced with recycled cotton, water recycling and water saving dyeing
Energy intensive stages	Most impact comes from spinning, weaving and washing	Idem but more energy intensive	Energy consumption improved through process changes	Major improvement in energy efficiency in Yousstex international supplier (sewing & ironing)
Source of main impacts	Organic cotton (biggest water use) and spinning + weaving (biggest CO ₂ emitter)	Conventional cotton: higher CO ₂ and water impacts	-	Organic cotton is preferable but still water intensive; recycled fibers reduce both water and CO ₂ impacts
Use Phase (customers)	Can account for 18-91% of a garment's lifetime CO ₂ emissions, depending on consumer habits (e.g., frequency of washing and tumble drying)	Idem, assuming they are treated the same	Frequent hot washes and tumble drying can increase impact up to 6× compared to production alone	Line drying and cold water washes minimize use phase related impacts <i>Data adapted from (MUD Jeans, 2024) LCA report</i>

o Social Impact

In terms of social impact, the brand states that it requires its partners to sign a Code of Conduct agreement to ensure fair wages and safe working conditions for workers. It also conducts regular factory visits which are documented and shared through their social media channels. The brand claims to maintain a short supply chain and shows transparency by publicly disclosing its suppliers. They provide a section on their website describing each supplier’s innovative sustainable production techniques which also features a production tour video along with a Q & A section addressing common questions.

MUD Jeans works with a wide range of suppliers across various stages of production, which are mentioned in the brand’s LCA report (MUD Jeans, 2024, p. 10). The table below focuses on the primary partners responsible for the majority of their production.

Table 8: Sustainability Practices Across MUD Jeans' Supply Chain

Supplier	Stage of production	Location	Sustainability
Cotton Farmers	Picking (raw cotton production)	Turkey and India	OCS certified
Recover & Ferre	Shedding, mixing and spinning (recycling and fiber preparation)	Spain	<ul style="list-style-type: none"> ● Collect fabric waste ● Solar power (50%) ● Higg Material sustainability index: high score (free from harmful substances) ● 1kg of their recycled fiber saves 2116 liters of water, 1.79 kg of CO2 emissions and 3.89m2 of land use.
Tejidos Royo	Dyeing and weaving (fabric production)	Spain	<ul style="list-style-type: none"> ● Wastewater treatment plants ● Energy self-sufficient with their co-generation station ● C2C indigo dye and Dry Indigo Process (zero harmful chemicals and saves 100% water and lowers chemical use by 86%)
Yousstex International	Stitching and washing (garment manufacturing and finishing)	Tunisia	<ul style="list-style-type: none"> ● water recycling through filtration with reverse osmosis ● Replacing bleach washes by ozone gaz (reconverted into oxygen before being released)

			<ul style="list-style-type: none"> ● e-Flow technology (use of mist and nano-bubbles for the abrasion and finishing process which saves 95% of water, reduces chemical use by 90% and electricity by 60%) ● laser (saves on water and chemicals) instead of stone washing and PP spray.
Active Ants	Logistics (Warehousing and distribution)	Netherlands	<ul style="list-style-type: none"> ● Solar panels ● Efficient and innovative methods of order picking, packing and storage (space and energy savings) ● FSC certified cardboard for package boxes (Active Ants, 2025).

They have completed three audits through the Social and Labor Convergence Program (SLCP), with the most recent conducted in 2022.

Conclusion for the MUD Jeans Case Study

MUD Jeans provides an interesting example of how sustainable material and practices can significantly reduce the environmental impact of fashion. Through the use of post-consumer recycled cotton, a take-back system and demand-driven production, the brand shows that circularity is not just a theoretical concept but a practical reality, even for a small-scale business.

At the same time, MUD Jeans openly acknowledges the challenges that come with pursuing strong sustainability principles while trying to remain commercially viable. These include higher costs for sustainable materials, a niche customer base and the logistical complexity of leasing and repair programs. Despite these challenges, the brand has remained committed to its values by limiting product lines, investing in long-term innovation and being transparent about both progress and limitations.

MUD Jeans is honest about what they have achieved and where barriers still exist, including issues with data, scalability and profitability. They do not claim to have reached full circularity, but their work makes it clear that it is a continuous process that requires creativity, flexibility and long-term commitment. Their journey illustrates that while sustainable practices can lead to notable environmental benefits, scaling them remains complex in the current fashion system. Despite these obstacles, the MUD Jeans case demonstrates that meaningful impact is achievable and sustainability goals can effectively be put into practice.

3.1.3. Rifò

The information in this section is taken from the brand's 2023 sustainability report, unless specified otherwise.

Rifò (S.r.l.) is an Italian clothing brand founded in 2018 by Niccolò Cipriani. Rifò follows circular economy principles, producing high quality clothes and accessories from recycled and recyclable fibers. Their goal is to transform old garments and give them new value. 'Rifò' is derived from the verb 'rifare' which means 'to remake'. This name honors the 'cenciaioli', the artisans who developed the traditional recycling method the brand uses. It reflects their commitment to preserving this historic Italian craft in a contemporary and sustainable way.

The company has been certified as a B-Corporation since November 2020. They stated on their website that this certification is not officially recognized by European or national regulations, highlighting their commitment to transparency. In 2022, they adopted the legal status of Benefit Corporation (Società Benefit) to further showcase their commitment to sustainability and social impact. This corporate form requires the company to not only generate financial benefits but also to pursue a broader social or environmental mission (Portolano cavallo, 2019). They are also working on their application to be officially recognized as a World Trade Fair Trade Organization (WTFO).

Sustainable practices implemented by Rifò

- Ecodesign

Rifò integrates sustainability into every aspect of their product design, aligning with the principles of the Ecodesign for Sustainability Products Regulation¹⁰ recently implemented by the European Commission. Ecodesign refers to the systematic integration of environmental considerations into product design with the goal of minimizing impact throughout the entire product lifecycle. In line with these standards, Rifò designs its products to be energy efficient, easily repairable, disassemblable and recyclable. They also contain a high proportion of recycled content, avoid the use of harmful substances and maintain a lower carbon footprint across their lifecycle. As part of its commitment to regulatory transparency and traceability, Rifò has also implemented the Digital Product Passport (DPP) to provide information on material composition, traceability and sustainability performance.

This attention to environmental impact is also reflected in Rifò's approach to address water use and pollution. The brand opted for natural dyes over synthetic alternatives, which often contain toxic chemicals. While natural dyes involve more manual steps and are better suited for small-scale production, they offer a significantly eco-friendlier solution. Rifò uses plant-based pigments for its recycled silk and mineral-based dyes for its recycled and organic cotton. Some

¹⁰ The *Ecodesign for Sustainability Products* regulation describes the characteristics that make a product sustainable, sets ecodesign standards and introduces other measures such as the Digital Product Passport (DPP) (European Commission, 2024).

fibers, such as their recycled cashmere and wool, require no dyeing at all since the fibers are manually sorted by colors.

Packaging choices are also designed keeping circularity in mind. Rifò's uses eco-conscious materials including kraft paper tape, natural glue, labels made from recycled and certified fibers, and cardboard boxes crafted from 100% recycled FSC-certified paper. This reflects the brand's intention to reduce environmental impact at every stage of the product lifecycle.

- Pre-order System and Inventory Management

Beyond product design, Rifò also rethinks production by using a pre-order model to align production with actual market demand. The brand only offers two collections per year and tests new creations at trade fairs to estimate customer interest and based on that, choose which pieces to launch. They then place orders to their suppliers based on the number of pre-orders received. The online pre-order period lasts from 3 to 6 weeks, with customers receiving discounts based on when they place their order: -20% for orders in the first two weeks, -15% in the third and fourth weeks, and -10% in the fifth and sixth weeks. This pre-order model remains rare in the fashion industry and contrasts with the conventional fast fashion approach, which prioritizes overproduction and rapid inventory turnover.

As part of its broader slow fashion approach, Rifò considers its products to be timeless and chooses not to rely on sales to clear stock. Instead, any leftover inventory is sold through their online store, resellers and e-commerce platforms like Sample Lover. By avoiding large inventories or overstock, they do not need to engage in sales and it allows them to keep their pricing consistent throughout the year. As they explain in their 2023 sustainability report: "*We believe in fair pricing 365 days a year, as the value of what we create does not change over time. For this reason, Black Friday is just like any other Friday for us.*" (Rifò, 2023, p. 51). This approach is reflected in their operational strategy: Rifò keeps successful creations in their collections as carryover products. In 2023, the company produced fewer items than in 2022 and instead focused on selling existing stock, which led to an 11% reduction in their overall inventory. In 2024, they limited their leftover inventory to under 5% by the end of the year.

Building on this slow fashion model, Rifò also focuses on promoting mindful consumption among customers. The brand encourages its customers to invest in high quality items that resonate with them and to make purchasing decisions based on necessity instead of impulse. To support this philosophy, Rifò provides a clothing care guide on its website to help consumers extend the lifespan of their garments. Additionally, the brand offers a 3 years "Love Lasts" Warranty which covers free repairs for any manufacturing defects. In 2024, 217 garments were repaired through this program. The brand plans to launch a resale platform by 2025 to allow customers to sell used Rifò garments directly through its website (Rifò, 2024).

- Take-back Service and Repair Service

Rifò offers a take-back service to motivate customers to return worn clothes in exchange for a discount code. This initiative was initially launched in 2019 and is central to the brand's circular strategy. The service expanded from 120 collection points in 2023 to 228 in 2024 which

significantly improved accessibility and participation. Only garments made of 100% cashmere or wool for sweaters, or at least 95% cotton for jeans were accepted, being more suitable for recycling. Once collected, the clothes are sorted by the social cooperative 'La fraternità' in Bologna. Items in good condition are resold through a second-hand shop called AND CIRCULAR managed by the cooperative, while damaged items are sent to Prato for recycling where they are pre-sorted by colors. Transport to Prato takes place once approximately 5 Tons of materials have accumulated which is the minimum required for initiating production (Rifò, 2023).

In 2023, the take-back program collected 3,088 garments for reuse or recycling with a total volume of 1,472 kg of wool, cashmere and denim cotton. Out of these, 50% were reused, 40% recycled and 10% did not meet the requirements due to their composition or condition. The unusable garments were repurposed to make their 'Fluffypack' which is a packaging made of mixed fiber composition therefore not requiring pure material input. That year, the collected garments represented 14% of post-consumer recycled fibers used in Rifò's production (Rifò, 2023). In 2024, the service contributed to the collection of 7,067 garments and a total volume of 3,546 kg of materials, more than twice the volume collected the previous year. That year, 23% of all textile fibers used by Rifò were sourced through the take-back program, representing an increase of nearly 10% from 2023 (Rifò, 2024).

o Local Production and Transport

One of Rifò's strengths is its location in Prato which is the largest textile center in Europe. This strategic position allows the company to maintain a short supply chain, with 90% of its suppliers being located within 30 kilometers from its headquarters. The proximity gives them more flexibility and enables close collaboration with suppliers to monitor the quality of their products and production quantities. As a result, Rifò can effectively implement its pre-order system and prevent overproduction through efficient inventory management.

Rifò is transparent about their suppliers, which can be consulted on an interactive map available on its website. They collaborated with 27 artisans in 2023 and 80% of them were family businesses. In 2024, this number increased to 40 small businesses. The following list is a selection of Rifò's key suppliers with the material they produce for the brand:

- Filpucci (Recycled cashmere, recycled wool, light cashmere)
- Pinori (Recycled denim)
- Marchi e Fildi (Recycle and virgin cotton)
- Torcitura di Domaso (Recycled silk)
- Mapel (Recycled wool fabric)
- Lanificio Becagli (Recycled & Organic denim sweatshirt)
- Belda Llorens (Recycled and organic cotton)

The benefits of being close to suppliers are numerous. By manufacturing locally, the company avoids intermediaries and saves on fuel consumption (Rifò, 2023). In 2024, they emitted 15.04 tons of CO₂ through transportation (Rifò, 2024).

Recognizing the environmental impact of transport related emissions, Rifò introduced a drop-off point delivery service to reduce the distance traveled by couriers. To further limit emissions linked to returns, the brand added a size finder tool on its website to help customers select the correct size and minimize unnecessary shipments. Additionally, Rifò announced it will start charging a fee for returns as a way to encourage more mindful and intentional purchasing decisions (Rifò, 2023).

Sustainable Materials used by Rifò

○ Rifò's Material Strategy

Rifò aims to incorporate at least 50% of recycled components into each material. When the recycled fibers are too short, they blend them with virgin or organic fibers in order to improve the fabric's durability. Most fabrics used by Rifò have a pure composition (meaning they contain only one material) to ensure that their clothes can be fully recycled. The only exception being their wool blend fabric.

○ Fabric Types and Composition

The following table provides details on the fabrics used by Rifò, including their percentage of the total production in 2023, their composition and their certifications:

Table 9: Summary of Fabrics Used by Rifò and Certifications

Rifò Fabrics	Composition	Water	Energy	CO ₂	Chemicals
Recycled cashmere	95% recycled cashmere and 5% recycled wool	-66%	-67%	-85%	-
Light cashmere	70% recycled cashmere, 25% virgin cashmere, 5% virgin wool	-40%	-39%	-55%	-
Recycled & conventional cotton	45-60% recycled cotton and 55-40% virgin cotton	-67%	-38%	-34%	-60%
Recycled & organic cotton	50% recycled cotton and 50% organic cotton	-43%	-42%	-44%	-99%
Recycled wool	100% recycled wool	-99%	-76%	-92%	-

Recycled wool fabric	62% recycled wool and 38% recycled polyamide	-	-	-	-
Twill denim	24% recycled cotton and 76% Regenagri cotton				
Recycled denim	75% recycled denim cotton, 20% virgin cotton and 5% other fibers	-	-	-	-
Recycled silk	100% recycled silk	-	-	-	-
Recycled linen	100% recycled linen	-	-	-	-
Recycled viscose	20% recycled viscose and 80% ECOVERO™	-	-	-	-

Source: Data adapted from *Sustainability Report 2024* by Rifò.

Note: All fabrics listed in the table are Global Recycled Standard (GRS) certified, except for the recycled denim, which is certified under the Recycled 100 Claim Standard. The following fabrics also hold an OEKO-TEX® certification: recycled & organic cotton, recycled & conventional cotton, twill denim, recycled linen and recycled viscose. In addition to that, light cashmere is RWS-certified, recycled & organic cotton is certified under the Organic 100 Content Standard and recycled viscose is FSC-certified.

The impact reduction percentages for water, energy, CO₂ and chemicals are from three separate Life Cycle Assessment (LCA) studies conducted by Rifò's fabric suppliers. Results for recycled cashmere, recycled wool and light cashmere were provided by Process Factory (4sustainability®) for Filpucci. The LCA for recycled & organic cotton was conducted by the Aitex Textile Research Institute for Belda Llorens. Finally, data for the recycled & conventional cotton fabric was produced by ICEA for Marchi e Fildi. Fabrics without listed impact reduction values did not have LCAs available at the time of reporting.

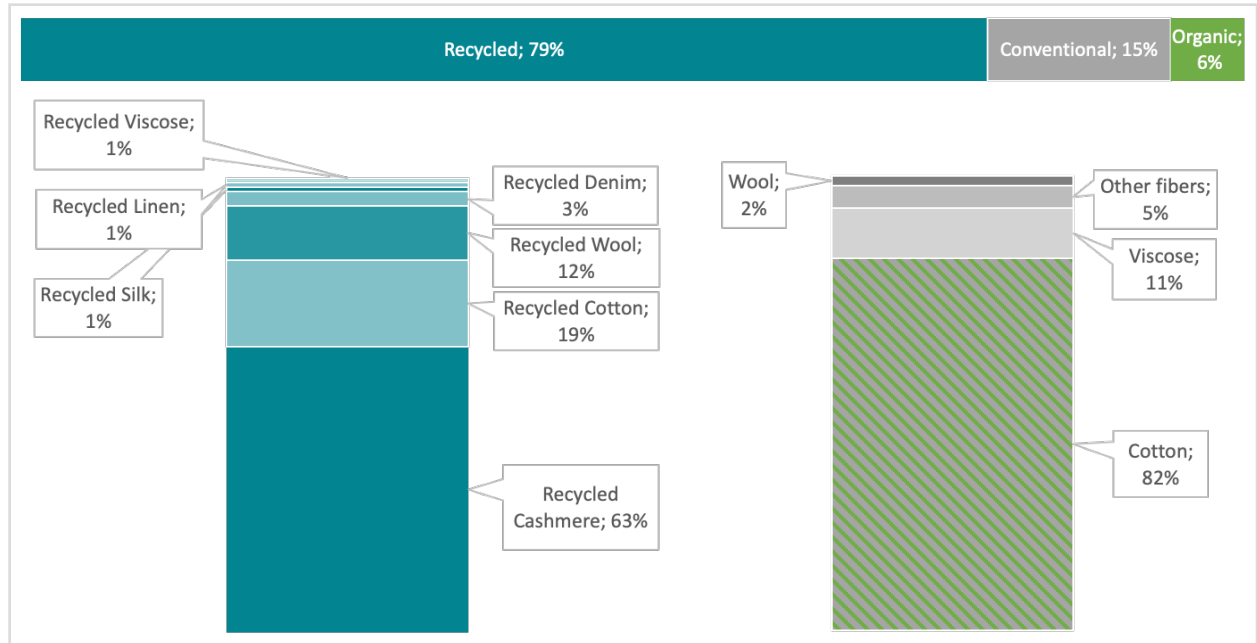
This data reflects Rifò's emphasis on high-recycled-content fabric which not only dominate the company's production, but also represent significant environmental benefits particularly in terms of CO₂, water and energy reductions. For instance, recycled wool shows reductions of up to 99% in water use and 92% in CO₂ emissions, while recycled & organic cotton significantly reduces chemical use by 99%. Although not all fabrics have LCA data, the majority of fabrics are certified and have mono-material compositions.

○ Distribution of Material Inputs in Production

In 2023, recycled fibers represented 85% (14.1 tons) of their total production of 16.7 tons, surpassing their goal of 80%. Their recycled fibers were made out of 22% pre-consumer fibers and 78% post-consumer fibers. The remaining 15% (2.6 tons) of their total production were virgin and organic fibers. In 2024, Rifò maintained its circular production approach.

The following figure illustrates the proportions of each material type used in Rifò's 2024 production, which amounted to a total of 16,727 kg of yarn.

Figure 1: Breakdown of Fiber Types Used in Rifò's Yarn Production (2024)



Source: Data adapted from *Sustainability Report 2024* by Rifò.

Note: Cotton is represented in grey with green stripes to indicate that it includes both conventional and more sustainable sources. These sustainable sources include organic cotton, Regenari certified cotton, which supports regenerative agriculture methods.

The figure highlights that recycled fibers made up the majority of Rifò's 2024 yarn input, accounting for 79% of total production. Recycled cashmere was the dominant recycled material (63%), followed by recycled cotton (19%) and recycled wool (12%). The remaining 21% of yarn inputs were virgin and organic fibers, with cotton representing the largest share (82%). This breakdown illustrates the brand's strong reliance on recycled materials while showing the diversity of fiber sources within its circular production model. Rifò maintained its commitment to circular production

Regarding the origin of recycled fibers, 53% came from post-consumer waste, more than half of which was collected through Rifò's take-back program. The remaining 47% came from pre-consumer waste (Rifò, 2024). Compared to the previous year, the share of post-consumer fibers dropped from 78% to 53% reflecting a change in the balance of recycled inputs.

Environmental and social impact of Rifò

o Environmental impact

Rifò presented Life Cycle Assessment (LCA) studies conducted by Process Factory (4sustainability) on their suppliers to show the environmental impact of their products. They also did an LCA study on their 100 best-selling products using the ‘BCome’ platform, which is regularly revised to meet EU regulatory standards.

The results show that Rifò’s products have a significantly lower environmental impact compared to industry standards:

- 79% less water
- 61% less CO₂
- 77% less phosphates
- 65% less abiotic depletion (use of non-renewable resources) (Rifò, 2023, p. 74)

In 2023, Rifò’s total carbon footprint amounted to 489 tons, the vast majority of which (479,5 tons) came from indirect emissions generated across their supply chain (Rifò, 2023, p. 79). In 2024, total carbon emissions decreased to 457 tons, with 98% (449.56 tons) still attributed to indirect (scope 3) generated throughout the value chain (Rifò, 2024, p. 33). They plan to transition to renewable energy along their supply chain in the future. To initiate this shift, they have begun sourcing green energy for their office through their local partner, ESTRA (Rifò, 2023)

To better understand where the environmental savings come from, the following figure also compares the impacts of key materials used by Rifò with their conventional counterparts. The values marked with “C:” refer to the estimated impact of a Conventional garment, while “R:” indicates the impact of a garment produced by Rifò. It is important to note that these figures are estimates.

Table 10: Environmental Performance of Conventional Fabrics vs. Rifò’s Materials

Material	Water scarcity (m ³)	Eutrophication (g Phosphates eq)	Global warming (kg CO ₂ eq)	Abiotic depletion (MJ)
Cashmere	C: 6 m ³ R: 1.5 m ³ ≈ -75%	C:120 g P eq R: 3.5 g P eq ≈ -97%	C: 22 kg CO ₂ eq R: 3 kg CO ₂ eq ≈ -86%	C: 90 MJ R: 40 MJ ≈ -55.6%
Cotton	C: 83 m ³ R: 14 m ³ ≈ -83%	C: 54 g P eq R: 22 g P eq ≈ -59%	C: 7.1 kg CO ₂ eq R: 3.2 kg CO ₂ eq ≈ -55%	C: 95 MJ R: 40 MJ ≈ -58%
Denim	C: 130 m ³	C: 68 g P eq	C: 12 kg CO ₂ eq	C: 147 MJ

	R: 23 m ³ ≈ -83%	R: 18 g P eq ≈ -73.5%	R: 4.5 kg CO ₂ eq ≈ -62.5%	R: 57 MJ ≈ -61%
Silk	C: 72 m ³ R: 0 m ³ ≈ -100%	C: 90 g P eq R: 2.5 g P eq ≈ -97%	C: 16 kg CO ₂ eq R: 2.7 kg CO ₂ eq ≈ -83%	C: 152 MJ R: 26 MJ ≈ -83%
Wool	C: 5 m ³ R: 1 m ³ ≈ -80%	C: 85 g P eq R: 2,5 g P eq ≈ -97%	C: 17 kg CO ₂ eq R: 2.3 kg CO ₂ eq ≈ -86.5%	C: 7.3 MJ R: 3 MJ ≈ -59%

Source: The data presented in this table is adapted from graphs found on page 32 of Rifò's *Sustainability report 2024* and the values were confirmed through a series of emails with Rifò.

This LCA study aims to showcase the environmental benefits of recycling existing resources rather than extracting new ones and enables Rifò to assess their performance compared to industry standards. The results show consistently lower impacts across all categories, including water use, CO₂ emissions, eutrophication and resource depletion. The data indicate reductions above 80%, particularly in impact categories like eutrophication and carbon emissions. These figures support the idea that recycled and responsibly sourced materials can significantly reduce environmental burdens when compared to virgin alternatives. However, the results should be interpreted with caution since variations in methodology, assumptions, and scope can greatly impact such figures. Despite this, the data still provides a useful estimation of how circular design strategies, such as fiber reuse and natural dyes, can impact a brand's sustainability.

o Social impact

Rifò visits their suppliers based in Prato at least once a week and the one in Spain at least three times a year to check on them. To ensure that the production process is ethical, they also make their suppliers sign a code of conduct in which they include International Labour Organization (ILO) principles (Rifò, 2023):

Additionally, they conducted a social audit in 2022 through Bureau Veritas on 13 of their suppliers to ensure they adhered to their ethical principles. This audit also covered areas other than the ILO principles in their code of conduct, including regulatory compliance, working hours, remuneration and environment. The audit revealed 28% non-conformities for which suppliers were given a corrective action plan. Rifò emphasized that they would cease working with any suppliers who failed to address and resolve the identified issues (Rifò, 2023). As a continuation of these efforts, the most recent supplier audits were carried out in 2024, again in collaboration with Bureau Veritas. This time, four first and second tier suppliers were audited, with only 5 non-conformities found across 82 checks. According to Rifò's 2024 Sustainability Report, all issues identified were resolved through corrective action plans (Rifò, 2024).

Rifò also commits to honoring their own obligations, ensuring fair and respectful treatment throughout the partnership with their suppliers. They follow responsible purchasing practices,

adhering to the Common Framework for Responsible Purchasing Practices¹¹ in 2023 (Rifò, 2023, p 94)

As part of its commitment to positive social impact, Rifò also supports its local economy by involving small businesses in its production process. Among these small local businesses are:

- La Fraternità (a social cooperative) was involved in their take-back service and was responsible for sorting the collected garments. This cooperative provides employment opportunities to individuals with disabilities.
- CONVOI (a social cooperative) was involved in the creation of their home collection accessories made from recycled denim and cotton.
- Flo Concept (a social cooperative) collaborated with Rifò to produce accessories for an upcycling project with Levi's. They made upcycled bucket hats and shopper bags with old jeans collected in a Levi's store in Milan.
- Prod.84 (a social cooperative) was employed to clean their office space.

In addition to their work with suppliers and local cooperatives, Rifò also invests directly in social initiatives aimed at community development and inclusion. Since 2019, they have committed to contributing 2€ to social programs for each purchase. They first supported Non-Profit Organizations then decided to create their own project in 2022: '*Nei Nostri Panni*'. This project provides migrants with the opportunity to gain skills needed to work as a *cenciaiolo* (an artisan who sorts and selects rags) or as a spinner through specialized learning and training. There were 12 local companies that hosted these internships; 5 sorting companies and 7 spinning companies. The project lasts 7 months in total with the first month being dedicated to class learning (knowledge and certifications) followed by a 6 months long paid internship (900€/month), which leads to permanent employment at the end for most. They already completed 2 editions of the project and shared the results in their 2023 sustainability report. A third edition began in 2024 and is currently ongoing with internships scheduled to conclude in 2025. In the future, Rifò stated wanting to set up a social cooperative that will operate as a knitting factory for them and other local companies. Once again in an attempt to preserve their textile tradition

Within their own operations, Rifò employs 25 people at their Prato headquarters. As the team has grown, they implemented an organizational structure with six departments. In 2024, the company reported that the highest salary was 2.4 times the lowest salary among permanent employees, which is slightly higher than the 1.8 ratio reported in 2023, but Rifò continues to maintain transparency and fairness in its pay system. The company also stated that there is no gender pay gap. To support employee well-being, Rifò signed a Supplementary Agreement in 2022 outlining benefits such as flexible hours, healthcare assistance, annual bonuses, up to five days of remote work per week and train commuting reimbursements. In 2023, eight employees

¹¹ This approach minimizes negative impacts on workers in the production chain by focusing on five core principles: integration, transparent reporting, equal partnership, collaborative planning, fair payment terms and sustainable costing (Rifò, 2024).

benefited from this initiative, traveling a combined 37,500 km by train and avoiding an estimated 11.6 tons of CO₂ emissions.

Conclusion for the Rifò Case Study

The case of Rifò shows that a systematic approach to sustainable materials and practices can significantly reduce key environmental impacts, particularly water use, carbon emissions and resource extraction. The brand's use of high-recycled-content fabrics, local supply chains, low-impact dyes and take-back systems demonstrates that a circular approach is feasible for small to medium brands. By raising expectations for what sustainable fashion can look like in practice, Rifò contributes to shifting both industry standards and consumer demand towards more ethical and transparent models. Thus, its model can serve as a source of inspiration for change across the fashion industry. Socially, they show how sustainability can extend beyond environmental concerns and support more equitable industry practices through their commitment to ethical sourcing, local employment and community initiatives.

While challenges remain, such as maintaining high post-consumer fiber input and verifying long-term impacts, the brand provides a great example of how eco design and responsible business models can significantly mitigate fashion's footprint.

3.2. Investigating Consumer Behavior

3.2.1. Methodological Approach to Investigating Customer Behavior

I created a survey consisting of nine questions using Google Form in order to explore consumer attitudes and behaviors regarding traditional materials and more sustainable alternatives in the fashion industry. The survey included seven multiple-choice questions covering aspects such as respondent profile, preferences regarding materials and criteria considered important when selecting clothing. Two open-ended questions were also included to ask for respondents' opinions on the sustainability of the fashion industry and to gather potential contacts for the research. Respondents were given the option to provide their email addresses at the end of the survey for future qualitative studies or updates (For the full survey data and analysis, please refer to appendix 5).

My objective was to analyze how factors such as gender, age and profession might influence respondents' perceptions of sustainability and their preferences. By reviewing responses to the questionnaire, I aimed to assess engagement with sustainability, awareness of current sustainability initiatives in the fashion industry and the key decision criteria when buying clothing.

The survey was published multiple times on various online platforms, including LinkedIn, Facebook via a public post on my page and sharing it on multiple groups), Instagram and the website 'Survey Circle'. Additionally, I reached out to friends to broaden the audience's reach. Overall, the survey received 126 responses.

The study presents several limitations. Firstly, convenience sampling was used, meaning respondents were selected based on availability and willingness rather than specific criteria. This could introduce selection bias and impact the representation of the target population. Additionally, the absence of a clearly defined target population further affects the study's interpretability.

Secondly, although demographic data on respondents was collected, income information was not included. This limits the scope of the analysis.

Thirdly, the relatively small sample size (126 respondents) affects the statistical reliability of the study. Despite these limitations, the results of the survey have been compiled and analyzed, including the free text responses which provide deeper insights on the participants' perspectives.

3.2.2. Survey Data Analysis

Although an initial analysis of the survey results was conducted, it became clear during the writing process that this data did not directly contribute to answering the primary research question. As a result, the full analysis has been relocated to Appendix 5, where it remains available in full. A brief summary of key findings is included here, as it offers useful context on consumer attitudes toward sustainable fashion.

The main insights from the survey are summarized as follow:

The survey highlights a growing awareness of sustainability in fashion amongst consumers. However, financial barriers, accessibility and skepticism toward corporate sustainability claims hinder the widespread adoption of sustainable fashion. While younger consumers express an interest, affordability remains a challenge. Older consumers show greater willingness due to financial stability.

As reflected in the responses to the question on awareness of sustainable fashion brands, fast fashion brands still dominate sustainability discussions. This suggests that marketing and brand visibility plays a major role in shaping consumers perceptions, regardless of the credibility of sustainability claims.

Responses also indicated that affordability remains a major hurdle, with many consumers hesitant to pay more for sustainable clothing. This raises an important question: would they be willing to invest in garments that last longer? Greater transparency, clearer clothing labels and the integration of sustainability in education could help guide consumers towards making more sustainable choices.

The survey responses underscore the need for concrete solutions that turn awareness into action, making sustainability not just an ideal but a feasible choice. Meaningful progress depends on improving accessibility, affordability and trust in sustainable fashion to ensure it is both attainable and reliable for consumers.

General conclusion

○ Key Findings and Reflections

This thesis aimed to explore the extent to which sustainable materials and practices can reduce the environmental impact of the fashion industry, a sector known for its significant contributions to pollution, carbon emissions, water consumption and waste. The main objective was to assess whether adopting more sustainable approaches could realistically and effectively mitigate these impacts across various points in the fashion lifecycle.

To answer this question, the research combined an extensive literature review with real-world case studies and primary data collection. The literature review examined emerging sustainable strategies including alternative materials, circular business models and cleaner production technologies in contrast to the environmental effects of fast fashion production. It also addressed structural challenges such as scalability, feasibility and greenwashing.

Additionally, the case studies of MUD Jeans and Rifò provided concrete examples of how sustainability is implemented in practice. A consumer survey that helped evaluate the degree of public awareness and willingness to support sustainable fashion was also added. Together, both of these methods provided a comprehensive view of both industry initiatives and consumer behavior.

The findings show that while no single solution can completely mitigate fashion's environmental footprint, sustainable materials and practices have significant potential to reduce harm. For instance, circular production models, closed-loop water systems, renewable energy adoption and the use of recycled or regenerative materials have all shown measurable environmental benefits. However, the effectiveness of these measures often depends on their scale, transparency and integration into the full supply chain.

Despite the encouraging progress made by innovative companies, some systemic barriers remain. Economic viability, limited infrastructure, consumer price sensitivity and a lack of regulatory enforcement still make wider adoption of sustainable initiatives difficult. Therefore, while sustainable materials and methods can reduce the industry's overall impact, their ability to create real change is still limited by current market conditions.

Future research should focus on long-term performance data of sustainable business models, explore more detailed life cycle assessments (LCAs) and investigate the role of policy in enabling industry-wide change. Comparative studies across different regions and market segments could also help identify the most impactful levers for reducing fashion's environmental footprint. A summary of key recommendations for future research and action can be found in the table provided just before the reference list.

In conclusion, sustainable materials and practices are not a panacea, but they are an essential step toward a more responsible fashion industry. When implemented thoughtfully and at scale,

they can significantly reduce environmental impact and pave the way for a more sustainable future in fashion.

- Interpretation of Findings in relation to Hypotheses

The following section reviews the initial hypotheses proposed at the beginning of this thesis and evaluates them based on the research findings. Each hypothesis is examined based on the findings gathered through the literature review, case studies and data analysis.

- **H1:** The adoption of sustainable materials and practices by fashion companies can significantly reduce the industry's environmental and social impact, and may contribute to achieving long-term goals such as carbon neutrality by 2050.

This hypothesis is partially validated. The literature review and case studies demonstrate that sustainable materials, such as organic cotton, recycled fibers and bio-based alternatives, and practices like renewable energy, closed-loop water systems and ethical labor standards can reduce emissions, resource use and social harm. For example, between 2010 and 2022, the textile value chain achieved a 22% reduction in GHG emissions despite increased production, indicating progress is possible (European Environment Agency, 2025). However, while these improvements are meaningful, their long-term contribution to goals like carbon neutrality depends on wider systemic adoption and more rapid scaling across the global supply chain.

- **H2:** However, structural barriers such as limited infrastructure, economic constraints and consumer price sensitivity reduce the overall effectiveness of these measures. Even if widely implemented, such practices alone are unlikely to help the fashion industry achieve carbon neutrality by 2050.

This hypothesis is strongly supported. The findings highlight that even with best-case implementation scenarios, barriers such as high costs, limited infrastructure in key production countries, weak regulatory enforcement and consumer reluctance to pay premium prices continue to hinder broader transformation. Fast fashion's dominance and increasing consumption trends also offset gains from efficiency improvements. The data suggests that without a fundamental systemic shift, including policy support, circular economy models and reduced consumption, reaching carbon neutrality by 2050 remains unlikely (UNFCCC, 2023; Wicker, 2021).

- Limitations of the study

One key limitation of this research was the difficulty in obtaining consistent and comparable data on the environmental impact of materials and sustainable practices across the fashion industry. There is currently no standardized framework for life cycle assessment (LCA) that enables reliable comparisons of textile fibers, manufacturing technologies and production methods. As highlighted in the literature, inconsistency across studies due to variations in indicators, assumptions, functional units (e.g., per kilogram of fiber vs. per garment),

geographical context and scope (e.g., cradle-to-gate vs. cradle-to-grave) makes direct comparison difficult. This lack of uniformity was noticeable when analyzing sustainability data from MUD Jeans and Rifò. Although both companies are committed to transparency and conduct LCAs, their results differ in methodology, scope and depth. These differences reflect supply chain specifics but also reveal the broader issue of lacking a harmonized methodology. As a result, while individual brand data is informative, comparing findings across brands or materials remains challenging.

Another limitation lies in the absence of a defined regional or product-specific focus in the research question. Without narrowing the scope to a specific geographical area or product category, the research faced difficulties in targeting consistent datasets. Most existing databases are either Eurocentric or outdated which limits their relevance to current global supply chains, especially in regions like Asia. Regional variations in electricity sources, water access and regulation also complicate generalizations. Similarly, not focusing on a specific garment type (e.g., jeans or T-shirts) made it harder to compare data meaningfully, since many impact studies are product-specific. While this wide scope allowed for a more general overview, it limited the depth of analysis.

Additionally, while the study explored promising sustainable practices, it could not fully examine concrete strategies for overcoming the practical barriers companies face, such as financial constraints, supply chain limitations and lack of infrastructure or incentives. These real-world factors may significantly influence the scalability and effectiveness of sustainable initiatives regardless of their theoretical potential.

Finally, on the consumer side, the survey data provided useful insights but was limited in scope and representativeness. The sample size was small and may not fully reflect the diversity of consumer attitudes across regions or socioeconomic groups.

Recommendations	Opportunity	Feasibility	Achievability	Overall
Develop and enforce a unified framework for presenting LCA results, including standardized functional units across studies and sectors.	++ (growing pressure for transparency & comparability in ESG/sustainability reporting)	+ (technically possible, but hard to standardize across all industries)	+ (would need international cooperation, possible but slow)	+
Introduce a regulatory framework to accredit LCA auditors and enforce third-party verification of sustainability claims made by fashion brands.	++ (high demand for transparency; greenwashing is under fire)	++ (could build on existing ISO systems or EU frameworks)	+ (requires policy coordination and global cooperation)	++
Encourage sustainability-focused companies to report LCA results transparently, with a focus on identifying production-stage hotspots and including all key environmental indicators (e.g. water use, GHG emissions, eutrophication). Studies should isolate impacts up to yarn production to fill literature gaps.	++ (high demand for transparent reporting in ESG & supply chains)	++ (LCA tools and frameworks already exist; requires commitment from companies)	+ (depends on data availability and company willingness to go beyond greenwashing)	++
Governments should offer financial support (grants, subsidies, or tax incentives) to businesses conducting LCAs, third-party audits, and sustainability reporting, in order to encourage credible transparency and improve industry-wide data quality.	+++ (aligns with national sustainability targets, SDGs, and EU Green Deal-type initiatives)	++ (builds on existing public funding models)	++ (especially achievable at national or regional level, even without global coordination)	++

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Glossary

- **B-Corp:** (short for *Benefit Corporation*) is a certification granted by the non-profit organization B Lab to companies that meet high standards of social and environmental performance, accountability and transparency. Certified B Corps are legally required to consider the impact of their decisions on all stakeholders which include customers, workers, communities and the environment, rather than prioritizing profit alone. The certification process involves a thorough evaluation and requires companies to incorporate a legally binding social and environmental mission that goes beyond profit into their legal structure (MUD Jeans, 2025).
- **Circular Fashion:** A systemic approach to designing, producing and consuming garments with the aim of extending their life, minimizing waste and keeping materials in use. Circular fashion incorporates strategies like circular design, product life extension, take-back schemes and recycling to reduce dependence on virgin resources and environmental degradation (Dragomir & Dumitru, 2022).
- **Ethical Fashion:** An approach to fashion that prioritizes fairness, transparency, and accountability across the supply chain. Ethical fashion supports workers' rights, fair wages, safe labor conditions, and environmental responsibility, while encouraging informed consumer choices. Though the term varies in scope, it broadly seeks to minimize harm to people and the planet.
- **Forest Stewardship Council (FSC):** is an international, non-profit organization that promotes responsible management of the world's forests. FSC certification ensures that wood, paper, and other forest products come from responsibly managed forests that provide environmental, social, and economic benefits. It sets strict standards for forest management, including the protection of biodiversity, prevention of deforestation, and respect for the rights of indigenous peoples and workers (Forest Stewardship Council, n.d.).
- **Global Recycle Standard (GRS):** The Global Recycled Standard (GRS) is an international certification that verifies the recycled content of a product and ensures responsible social, environmental and chemical practices in its production. It applies to the full supply chain and includes requirements for traceability, environmental management, chemical restrictions and fair labor conditions. GRS aims to promote the use of recycled materials and reduce the harmful impact of production on people and the planet (SCSglobalservices, 2025).
- **Organic Content Standard (OCS):** is a certification that verifies the presence and amount of organically grown material in a final product, tracking it from source to final product to ensure transparency and integrity in the supply chain. It verifies that the materials are grown without the use of toxic chemicals, synthetic pesticides, or genetically modified organisms (GMOs) (Textile Exchange, 2025).
- **Regenerative Fashion:** An approach to fashion that goes beyond sustainability by actively restoring and enhancing ecosystems and communities. It involves sourcing materials from regenerative agriculture, designing products for longevity and biodegradability as well as implementing business models that contribute positively to the environment and society (Mummery, 2022)

- **Slow Fashion:** A movement that promotes a more thoughtful, ethical, and environmentally responsible approach to fashion. Unlike fast fashion, slow fashion values quality over quantity, supports local and small-scale production, and emphasizes longevity, craftsmanship, and fair labor. It represents a deeper shift in values, aiming to reshape how fashion is produced and consumed (Fletcher, 2010; Švajdová, 2023).