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Fashion, Innovation and Sustainability made in Portugal

Céline Abecassis-Moedas, coordination
Laure Leglise
Mariana Pereira Silva

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RESUMOS DA FUNDAÇÃO

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FRANCISCO MANUEL dos SANTOS

Largo Monterroio Mascarenhas, n.º 1, 7.º piso
1099-081 Lisboa
ffms@ffms.pt

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Research Team Coordinator: Carlos Jalali
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Authors: Céline Abecassis-Moedas, Laure Leglise and Mariana Pereira Silva
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Céline Abecassis-Moedas, Laure Leglise and Mariana Pereira Silva
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Fashion, Innovation and Sustainability made in Portugal

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Introduction

If there were one word to describe the textile and clothing industry since the start of this decade, that word would be 'uncertainty'. At least, that is the term chosen by a team of experts from The Business of Fashion and McKinsey & Company (2023) to characterize the state of the textile and clothing industry in their 2024 report. Although several factors may have contributed to this choice — in recent years, companies have faced the COVID-19 pandemic, geopolitical crises and economic volatility — one theme seems to stand out: sustainability.

The textile and clothing sector (also referred to in this study as the fashion industry) contributes significantly to climate change, accounting for between 2% and 8% of global greenhouse gas emissions (United Nations Environment Programme, 2023). This impact stems not only from the operations of its highly globalised production system, but also from the composition of the fibres, given that approximately 64% of global textile production relies on synthetic fibres derived from fossil fuels. According to recent estimates presented by the Ellen MacArthur Foundation (2017), more than 100 billion items of clothing are produced annually. However, as the average number of times each item of clothing is worn continues to decline, high levels of textile waste have become the norm.

Bearing these issues in mind, companies operating in this sector should consider how they can help mitigate the impact of climate change on their value chains, as well as do everything in their power to keep global warming below 2°C above pre-industrial levels (in line with the Paris Agreement, which came into force in 2016). Until recently, these measures were voluntary. However, with the sector's greenhouse gas emissions, resource consumption and waste production remaining at record levels, legislators are now seeking to regulate the behaviour of players in the textile and clothing sector and phase out fast fashion.

Whilst sustainability regulations may impose restrictions on the textile and clothing sector, they should not be viewed negatively. Challenges often drive innovation, and as the sector moves beyond a 'business as usual' approach, there is a significant opportunity to transform the industry into one that adds value to the economy, the environment and its stakeholders.

Collaboration will be a vital tool for driving this transition. Stakeholders across the entire value chain of the textile and clothing industry must work together to tackle the sector's most pressing challenges. Achieving milestones such as the decarbonisation of the fashion value chain — the cost of which is estimated at over one trillion dollars — will depend on long-term commitments between brands and suppliers. Consumers also have a key role to play, notably by aligning their purchasing behaviour with their sustainability intentions, opting for more environmentally friendly alternatives on the market. Ultimately, the success of the transition to

sustainability in fashion depends on the interconnected efforts of all stakeholders, placing the importance of collaboration centre stage.

Research purposes

This study aims to achieve several purposes: (1) to better define what constitutes sustainability-oriented innovation in the textile and clothing industry; (2) to understand the role of manufacturers and suppliers in sustainability-oriented innovations; (3) to explore collaboration between international brands, retailers and Portuguese manufacturers and suppliers; and (4) to develop sufficient knowledge to make recommendations to policymakers and industry stakeholders in Portugal.

Given the complexity of the textile and clothing value chain, which involves multiple stakeholders, most innovations in the industry result from collaborative efforts. Successful collaborations are therefore crucial to strengthening the global competitiveness of the Portuguese textile and clothing industry, which, in turn, has a positive impact on the national economy. In 2024, the sector accounted for 1.7% of the country's GDP (INE, 2026). As Portugal gains recognition as a hub for sustainable textile and clothing production, sustainability will become a significant business opportunity, with collaborations being essential to realising its full potential. It is important to note that sustainability is typically viewed through a three-dimensional lens, encompassing environmental, social and economic impacts. However, given that Portuguese textile producers are primarily investing in

innovations aimed at reducing their ecological footprint, this study will focus mainly on environmental aspects. Overall, the findings will be crucial for the strategic decisions of Portuguese manufacturers and suppliers, enabling them to identify how they can proactively respond to the sustainability needs of brands and retailers.

Structure

The rest of the book is structured as follows. Chapters 1 and 2 present a definition of sustainability in the context of the textile and clothing industry, detailing its three main pillars — environmental, social and economic — and outlining the actions required to achieve sustainability in each area. Subsequently, Chapter 3 explores the concept of sustainability-oriented innovation, emphasising the importance of collaborations for the successful development of such innovations amidst the complexities of the industry's value chains. Chapter 4 focuses on the Portuguese textile and clothing industry, presenting the data collected for this research, the case studies and the respective analysis. Finally, Chapter 5 concludes with strategic recommendations aimed at industry professionals and policymakers, with a view to strengthening the sector's competitiveness.

This summary aims to summarise the main findings of the study *Sustainability in Fashion: Innovation and Competitiveness in Portugal*, published by the Fundação Francisco Manuel dos Santos. The full study can be downloaded free of charge from ffms.pt.

1. Sustainability in fashion: society and the economy

The contemporary understanding of sustainability has its origins in the report entitled *Our Common Future*, published by the United Nations World Commission on Environment and Development in 1987. Often referred to as the Brundtland Report, it defines sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission on Environment and Development, 1987, p. 41).

Today, these ideas regarding sustainable development are enshrined in the 2030 Agenda for Sustainable Development, a framework proposed by the United Nations that sets out 17 goals (Figure 1) designed to guide humanity towards planetary well-being, social prosperity, peace and global collaboration. Several researchers have linked the UN's Sustainable Development Goals (SDGs) to the sustainable development of the textile and clothing industry, highlighting in particular the sector's role in promoting responsible consumption and production (SDG 12) (Gardetti & Muthu, 2020). However, textiles and clothing are directly or indirectly linked to all 17 Sustainable Development Goals, extending their impact to the environmental, social and economic pillars of sustainability.

Figure 1. The 17 Sustainable Development Goals (United Nations, 2015)



Tackling the underlying challenges of sustainability therefore involves examining the intersection of environmental, social and economic factors, transcending disciplinary boundaries and adopting a holistic approach geared towards systemic change.

An (un)sustainable industry

Due to its substantial impact on the environment, society and the economy, the textile and clothing industry has increasingly been examined from the perspective of sustainable development (Fletcher, 2008; Clark, 2008; Jung & Jin, 2014; Mukendi et al., 2020; Daukantiene, 2023). Despite its growing importance, it remains difficult to establish a clear and widely accepted definition of sustainable fashion, mainly due to its subjective nature and the broad scope of the research.

To explore how sustainability can be achieved in the clothing industry, we will focus on each of the three pillars

mentioned above. Whilst we separate these pillars for the sake of clarity, we recognise that they are closely interlinked. Firstly, we will focus on the influence of social practices on sustainable textile and clothing value chains, specifically through ethical labour initiatives. This includes the implementation of living wages, ensuring safe working conditions, and adopting tools to increase transparency and traceability. The social chapter will conclude by emphasising the importance of diversity, equity and inclusion practices. Secondly, by focusing on the economic dimension of sustainability, we will analyse the importance of business ethics and innovation. This section includes an overview of the development of new business models, technological advances and the latest legislative measures and initiatives aimed at improving consumer education. Finally, in the following chapter, we will present an in-depth analysis of environmental sustainability, as this topic is also the main focus of our research.

Social sustainability

Although most studies on sustainability in the textile and clothing sector focus primarily on investigating the industry's environmental impacts, scrutiny of brands regarding their social practices has been increasing. This scrutiny intensified following the Rana Plaza incident in 2013, in which more than 1,100 workers in the clothing sector died when a factory building collapsed in Dhaka, Bangladesh. Although this was not the first fatal accident linked to the textile and clothing sector, it significantly increased interest in the industry's social sustainability practices, particularly regarding ensuring safe working conditions and establishing fair wages.

In the following sections, we will explore the social impacts of the textile and garment industry, with a particular focus on wages, working conditions, transparency and traceability within the value chain, and practices relating to diversity, inclusion and equity.

Workplace ethics

Decent wages

Wages play a key role in ensuring the well-being of workers in the textile and clothing sector and can contribute to addressing broader issues, such as reducing the gender pay gap and achieving inclusive economic growth. However, many workers, particularly within the textile and clothing value chains in the Global South, receive pay in line with the national minimum wage, which, in many countries, is not enough to cover basic living costs.

There are various definitions of the concept of a 'living wage', but the predominant focus is on the idea that it provides the amount a worker needs to enjoy a decent standard of living. This includes the ability to cover 'food, water, housing, education, healthcare, transport, clothing and other essential needs, including provisions for unforeseen circumstances' (Global Living Wage Coalition, n.d.).

The social sustainability of the textile and clothing industry depends on brands and manufacturers paying their workers a living wage. Given that wages account for a small percentage of the retail price of clothing — approximately one to three per cent — wage increases could

be implemented without any negative consequences for consumers (Bhattacharjee & Roy, 2016).

Health and safety

Other issues contribute to undermining the well-being of workers in the textile and garment sector, particularly in countries of the Global South. These include long working hours, often exceeding the 48-hour working week recommended by the Asia Floor Wage Alliance, and work carried out in cramped spaces under conditions that put workers' health at risk. Previous studies have shown that workers in the garment industry are particularly susceptible to stress due to their vulnerabilities in the workplace, which leads to both physical and mental health problems (Yuan et al., 2022; Akram, 2014). Respiratory illnesses are particularly prevalent in this context, alongside safety risks associated with operating machinery without adequate protection and exposure to hazardous chemicals.

To ensure safe working conditions within their supply chains, textile and garment brands and retailers have established codes of conduct, addressing various issues ranging from working hours to wages, and prohibiting the use of child labour and forced labour at their subcontracted facilities. However, Yu (2008, p. 527) considers these tools to be inadequate, arguing that 'they should be recognised as complementary initiatives rather than alternatives to traditional regulatory approaches, [such as] national legislation and international law'.

Transparency and traceability

Transparency and traceability are frequently mentioned in analyses of sustainability within the textile and clothing sector's value chain. Although these two concepts are closely interlinked, it is important to distinguish between their meanings. Transparency involves making information accessible to the public, whilst traceability is the ability to retrieve that information. Transparency is sometimes seen as a catalyst for traceability. However, for the concept to be comprehensive, it is not enough for a company to possess internal knowledge — this information must also be communicated externally.

In sustainable value chains, ethical labour practices must be both transparent and traceable. This imperative stems from growing demand from consumers and stakeholders and plays a key role in promoting the industry's sustainable development. Transparency and traceability enable consumers to choose products that align with their values, making it easier to assess a brand's social and environmental practices and, consequently, leading them to regard it as more trustworthy. For brands, this commitment helps not only to ensure compliance with current legislation but also to improve their social and environmental performance, paving the way for more efficient and sustainable value chains.

However, the complex, fragmented and multi-tiered nature of the textile and clothing value chains poses a challenge to achieving transparency and traceability. Yet, given the growing importance of transparency to today's consumers,

brands are incorporating traceability tools, such as independent certifications, to bolster the credibility of their sustainable practices.

Diversity, equality and inclusion

Although they are often overlooked in debates on sustainability, Tsing (2009) argues that a comprehensive understanding of the dynamics of the value chain requires an analysis of cultural factors inherent to its workforce, such as gender, race and ethnicity. Vijeyarasa and Liu (2022) expand on this notion to explain that gender equality and sustainability in the textile and clothing sector are deeply intertwined.

Indeed, women make up most of the workforce in the textile, clothing and footwear industries, particularly at the manufacturing stage, which is often located in the Global South. Gender inequality is particularly evident in wages, with female workers in the clothing sector earning less than their male counterparts. It is well known that they under-report human rights violations in the workplace for fear of retaliation. These violations include gender-based violence, sexual harassment and difficulties in accessing reproductive health services and products.

As sustainable clothing brands implement diversity, equity and inclusion programmes to reduce gender and ethnic disparities, it is crucial that their impact is felt at all levels of the industry, ranging from marketing and design to supply chains.

Economic sustainability

The principles of sustainability are reshaping conventional business models. In the clothing sector, new business models centred on the resale, hire or repair of clothing are being developed, representing significant innovations for the industry. Niinimäki (2015) highlights two other relevant forms of innovation that drive sustainable business models: technological advances and legislative changes.

Business models of the future

The current 'extract-manufacture-dispose' system, on which the modern textile and clothing industry operates, is a relatively recent phenomenon. According to Wilson (2003), it was not until the 1950s that mass-produced clothing became predominant, because of the industrialisation of the textile and clothing sector, which led to the production of clothing in large quantities and a substantial fall in prices. This trend is expected to continue, with Textile Exchange (2022) estimating that around 150 million tonnes of fibres will be produced in 2030, should textile and clothing business models remain unchanged.

As described by Fletcher and Tham (2019), the current rate of growth in the textile and clothing industry renders any efforts to reduce its negative impacts — particularly on the environment — futile. This is because, historically, when resource use becomes more efficient, industries tend to increase their overall resource consumption, leading only to marginal improvements in overall material efficiency. Thus,

on a planet with finite resources, challenging the logic of growth is essential to achieving a more sustainable textile and clothing industry, as it enhances the effectiveness of other environmental practices, such as recycling or fibre selection.

This economic perspective is commonly referred to as the theory of degrowth. According to Schneider et al. (2010, p. 512), sustainable degrowth is defined as 'an equitable reduction in production and consumption that enhances human well-being and improves ecological conditions at local and global levels, in both the short and long term', ensuring that 'human progress without economic growth is possible'. Business models in the textile and clothing sector based on these principles are closely linked to the circular economy, as they keep garments and textiles in circulation for an extended period. This can be achieved through practices such as increasing product durability, repair, reuse, repurposing and recycling.

Drivers of sustainability in fashion

Innovation and technology

Technological innovation is regarded as a key factor in companies' competitive advantage, particularly in sectors undergoing profound transformation, such as the textile and clothing industry today.

In the previous section, we discussed the importance of systemic innovations geared towards sustainability. However, studies on sustainability in the textile and clothing sector also analyse technological improvements in depth, recognising their fundamental role in promoting positive

environmental and social practices within the industry. Blockchain technology enhances traceability and transparency within the textile and clothing value chain, helping to retrieve detailed information about products. By creating a digital twin, Textile Genesis enables suppliers, brands and, ultimately, consumers to track the journey of a fashion item in real time, all from their screens.

Legislation for sustainability

In the coming years, the textile and clothing industry is set to face a wave of regulation, spearheaded by the European Union. Within the European Union, various legislative measures have been adopted, proposed or drafted as part of the *EU Strategy for Sustainable and Circular Textiles*.

Examples such as:

- The Waste Framework Directive, which governs waste management in the EU, has proposed an amendment requiring Member States to establish textile waste collection schemes by 2025; it is also responsible for establishing extended producer responsibility (EPR) schemes, under which clothing producers will contribute financially to the collection, sorting, reuse and recycling of textile waste.

- The Corporate Sustainability Reporting Directive (CSRD) and the Corporate Sustainability Due Diligence Directive (CSDDD), which require companies to disclose information about their social and environmental practices.

- The Regulation on the Ecodesign of Sustainable Products sets out criteria to enhance circularity and environmental sustainability in the manufacturing process and recommends the development of digital product passports to facilitate communication on sustainability.

- The Ecoclaims Directive aims to eradicate greenwashing in communications on sustainability.

Despite the sector's efforts to minimise its environmental, social and economic impact, positive global changes have been largely overshadowed by rising levels of fast fashion consumption. This means that any moves towards sustainability cannot come exclusively from governments and businesses; consumers must also play their part.

Consumer education

As textile and clothing brands improve the social, environmental and economic sustainability of their value chains, consumers are expected to change their consumption habits to progressively include more eco-friendly products. When it comes to textiles and clothing, consumer education plays a crucial role in steering behavioural changes towards sustainable consumption, by promoting critical thinking about the industry.

Empowered consumers, with access to a wealth of information from various sources, feel more confident and capable of making informed choices. This can bring several benefits for consumers, businesses and society. Firstly, as businesses

invest more in educating their customers, the latter become more likely to trust the organisations' offerings and to become loyal customers. Secondly, as co-creation becomes more common in sustainable business models, educational initiatives can add value by facilitating the transfer of knowledge between consumers and businesses. The better customers understand the benefits of a particular product or service, the more likely organisations are to provide greater value to their audience.

This concept becomes even more crucial when communicating about sustainability, as companies are responsible for providing transparent, clear and evidence-based information to their consumers.

Whilst raising customers' awareness of their purchasing choices is extremely valuable for the development of a more sustainable textile and clothing industry, companies must also empower consumers to play their part as active citizens and demand further action from companies and policymakers. A change in individual behaviour is a crucial aspect of the path towards sustainability in the textile and clothing industry, but governments and companies are also responsible for providing policies, services and products that address the broader social, environmental and economic needs for a sustainable industry.

Key ideas

»» Sustainability refers to 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs', according to the United Nations (UN).

»» The concept is divided into three pillars: environmental, social and economic (the environmental pillar being discussed in Chapter 3, given its relevance to this study).

»» In the fashion sector, social sustainability is demonstrated through the payment of living wages, the guarantee of health and safety standards and non-discrimination in the workplace, as well as through the promotion of transparency and traceability throughout the production chain.

»» The economic sustainability of the textile and clothing industry requires the adoption of new business models based on circular and technological innovation.

»» Legislation and consumer education initiatives are essential for strengthening the sustainability initiatives implemented by fashion brands.

2. Sustainability in fashion: the environment

The environmental impacts of the textile and clothing industry are substantial and widespread. The rapid growth in textile production and clothing consumption over recent decades has played a significant role in the rise in global carbon emissions, water pollution, the consumption of natural resources and the generation of waste. For this reason, sustainability in the textile and clothing sector is often described as an effort to reduce these environmental impacts. Research indicates that, to mitigate these impacts, textile and clothing companies should focus on three key areas: materials (Niinimäki, 2010), resource consumption (Daukantiene, 2023) and the transition from a linear to a circular economy (Ellen MacArthur Foundation, 2020).

Fibres and materials

Materials are the first key area on which textile and clothing companies must focus in order to become more sustainable. Textile Exchange's annual report reveals that, in 2021, global fibre production reached a record 113 million tonnes; approximately 64% of fibre production consists of synthetic fibres, with polyester alone accounting for 54% of the global market. Natural fibres, such as cotton, wool and silk, account for almost 30%, whilst the remainder consists of semi-synthetic cellulosic fibres, specifically viscose. Compared with

previous years, there has been a marked increase in the use of synthetic fibres, at the expense of natural sources.

Polyester is the most widely produced fibre globally, recognised, on the one hand, for its durability and low cost and, on the other, for its harmful environmental impact. Like other synthetic fibres, polyester is derived from fossil fuels; the world's most polluting industry, it is responsible for 75% of global greenhouse gas emissions (United Nations, 2024). Goyal and Nayak (2020) highlight that polyester production requires higher energy consumption compared with natural fibres. Furthermore, several studies identify synthetic fibres as one of the main sources of microplastic pollution (Browne et al., 2011; Cesa et al., 2017). Plastic particles are released at every stage of a garment's life cycle, from production to disposal, and even during domestic washing.

In contrast, natural fibres are considered a more sustainable alternative for several reasons. Firstly, they are derived from renewable resources, such as plants and animals. Secondly, they are biodegradable, thereby eliminating the problem of waste generation associated with synthetic fibres. However, natural fibres, particularly cotton, also have significant negative environmental impacts. Cotton is not only a water-intensive crop but is also associated with the use of hazardous chemicals that pose a risk to farmers' health and contribute to soil degradation and water pollution.

To address these challenges, there has been growing interest in adopting organic and regenerative practices for the cultivation of natural fibres. Organically grown cotton, for

example, is free from any synthetic chemicals, such as pesticides, which improves soil quality.

Regenerative agriculture, on the other hand, lacks a widely accepted definition, but is often characterised by practices aimed at improving soil quality, managing resources efficiently and mitigating the impacts of climate change through carbon sequestration.

In addition to these more conventional types of fibres, certain synthetic materials have been promoted by sustainable textile and clothing brands as a more environmentally friendly option. Altri, one of Portugal's leading producers of cellulosic fibre, is building a biofactory in Galicia, Spain, which is expected to supply 'around 200,000 tonnes of cellulose-based textile fibres per year, initially starting with the production of approximately 60,000 tonnes of lyocell' (Altri, 2022).

Furthermore, emerging innovative materials, often referred to as next-generation textiles, have been actively promoted through sustainable fashion innovation initiatives. According to a report by the Boston Consulting Group, in collaboration with the NGO Fashion for Good, these advanced materials could account for up to 8% of the global fibre market by 2030, equivalent to approximately 13 million tonnes. The adoption of these materials not only has the potential to significantly reduce the environmental footprint of the textile and clothing industry, but also to lower production costs for brands and suppliers.

Organic cotton — myths and realities

Although initially regarded as an environmentally friendly option, organic cotton is often the subject of misinformation and conflicting views. In this section, we address some of the most common myths and realities surrounding this fibre in terms of its sustainability performance.

Water consumption: In the '2017 Organic Cotton Market Report', Textile Exchange presented a life cycle assessment (LCA) of organic cotton cultivation, stating that this fibre consumes 91% less water than conventional cotton (2017, p. 54). Several experts have challenged this figure, culminating in the Transformers Foundation's 2021 report entitled 'Cotton: A Case Study in Misinformation', in which it is stated that the figures obtained by Textile Exchange were arrived at by 'comparing organic cotton fields, which happen to be largely rain-fed (green water), with conventional cotton fields, which actually use irrigation (blue water)' (2021, p. 43). In the same year, Textile Exchange removed this LCA from its website (Transformers Foundation, 2021). So, does organic cotton consume less water than its conventional counterpart? According to the Transformers Foundation, in 2021 there was 'no scientifically sound correlation between organic cotton cultivation and reduced water consumption in cotton farming' (2021, p. 42). And this remains true to this day.

Certifications: Organic cotton is often certified by independent bodies such as Better Cotton and the Global Organic Textile Standard (GOTS). Their mission is to develop, implement and evaluate certification schemes relating to organic farming methods, specifically for cotton production. Consumers tend to trust these labels; however, recent allegations of corruption have undermined their credibility. Products certified by

Better Cotton, for example, have been linked to deforestation and labour exploitation in Brazil. Furthermore, the European Centre for Constitutional and Human Rights revealed that GOTS-certified cotton had originated from Xinjiang, a Chinese province associated with forced labour. This led to a ban on cotton from this region, which has been in force for GOTS-certified products since August 2022. These and other cases have called into question the validity of certifications that classify organic cotton as sustainable.

The path to decarbonisation

Fibre production is not the only stage in the value chain responsible for the textile and clothing sector's negative impact on the environment. This industry is widely recognised as one of the most polluting in the world. Research carried out by McKinsey & Company (2020) revealed that the textile and clothing sector was responsible for over two billion metric tonnes of greenhouse gas (GHG) emissions in 2018, accounting for 4% of the global total. Other sources paint a more worrying picture, suggesting that this figure could reach 10% of global GHG emissions (European Parliament, 2020). In contrast, the Apparel Impact Institute (2023) estimates the clothing sector's contribution at 1.8%.

In line with the Paris Agreement's objective of limiting the temperature rise to 1.5 °C above pre-industrial levels, stakeholders in the fashion industry have joined forces to reduce emissions and transition to a net-zero industry, in which

nature is able to capture the residual levels of greenhouse gases produced. To achieve this goal, McKinsey & Company (2020) estimates that the textile and clothing industry needs to halve its GHG emissions by 2030. Also known as decarbonisation, the process of mitigating greenhouse gas emissions can be achieved by reducing overproduction, investing in energy efficiency improvements and adopting renewable energy sources, amongst other measures.

Natural resource management

The environmental impact of the textile and clothing industry extends beyond greenhouse gas emissions to include issues such as deforestation and biodiversity loss. One of the main drivers of deforestation linked to the textile sector is the production of semi-synthetic cellulosic fibres, such as viscose, lyocell and modal, which are derived from wood. Canopy (n.d.), a global leader in forest protection, estimates that over 300 million trees are felled annually for textile production, with 30% coming from old-growth and endangered forests.

Another way in which this industry contributes to biodiversity loss is through the intensive use of synthetic pesticides on crops such as cotton, which causes soil degradation and water contamination. However, the environmental footprint associated with water and chemicals extends far beyond the raw material production stage, with dyeing being one of the most concerning stages.

Transition to a circular economy

One of the plans for the circular fashion sector is set out in the Ellen MacArthur Foundation's *Vision of a circular economy for fashion* (2020, p. 2), which states that 'in a circular economy for fashion, products (clothing, footwear and accessories) are used for longer, designed to be reused and made from safe, recycled or renewable raw materials'. These principles stand in contrast to our existing linear economy, in which materials are extracted from the environment and transformed into products that are ultimately discarded at the end of their life cycle.

A circular economy must be based on three key actions: keeping products and materials within the value chain; minimising waste and pollution; and regenerating nature. In the textile and clothing sectors, as well as in various other industries, this can be achieved by extending the life cycle of products and adhering to guidelines such as reduction, reuse and recycling, as we shall examine below.

Designing for a circular purpose

Achieving circularity in textiles and clothing begins right at the start of the value chain — the design phase — where the European Commission (2020) estimates that 80% of a product's environmental impact is determined. To mitigate this impact, the Ellen MacArthur Foundation (2020, p. 7) recommends design for disassembly, a principle 'that enables the product to be taken apart so that its components and materials can be reused or recycled'. Other circular design

approaches for clothing involve designing to minimise waste, through waste-free pattern cutting or fully modelled construction, amongst other practices (Dan et al., 2023).

Once circularity has been incorporated into the design process, it is crucial to ensure that garments are manufactured to last for a considerable period. In the textile and clothing sector, product durability can manifest in two ways: physical durability, encompassing the qualities of materials that make a garment resistant to damage and wear and tear, and emotional durability, which relates to a garment's enduring relevance and appeal. Fletcher (2017) argues that physical durability can be achieved using strong, long-lasting materials. However, when it comes to emotional durability, design approaches alone are insufficient to counteract the perceived obsolescence of garments — this requires a change in consumer behaviour.

Reducing waste and pollution

Many of the measures that help minimise waste and pollution in the textile and clothing industry also help to keep materials and products in circulation, as they facilitate the transformation of old materials into new ones. As well as adopting design practices that reduce waste generation, as detailed in the previous paragraphs, it is also essential to tackle post-consumer waste through initiatives such as reuse and recycling.

The Ellen MacArthur Foundation (2020, p. 8) defines reuse as an 'operation whereby a product is created from existing products or components', exemplified by actions such as

dismantling, re-dyeing or remodelling. Recycling, on the other hand, breaks the garment down to its material level, which can be achieved through mechanical or chemical processes.

Despite its advantages in reducing waste, textile recycling faces significant challenges. It is estimated that less than 1% of the materials used in garment production, whether discarded in the pre- or post-consumption stages, are recycled into new garments. One of the main difficulties is the recycling of blended fibres, particularly when synthetic and natural fibres are combined. Furthermore, the inclusion of accessories made from various materials, such as buttons, fastenings and sewing threads, complicates the recycling process. These challenges highlight the importance of designing products with disassembly in mind, to achieve circularity in textiles and clothing.

Key ideas

»» The fashion industry is currently one of the most polluting sectors, contributing to high greenhouse gas emissions, pollution, and the consumption and subsequent waste of natural resources.

»» Over 60% of textile fibre production consists of synthetic materials, with polyester dominating the international market. More alternative fibres are appearing on the market, such as lyocell, with the aim of reducing the environmental footprint of fashion consumption.

»» It is not enough to focus solely on the materials used. It is important to analyse the environmental impact of the production processes within the textile production chain, which also contribute significantly to the consumption of natural resources and greenhouse gas emissions.

»» One way to reduce the fashion industry's environmental impact is to transition from a linear economy to a circular model, where materials are reused. The circular economy in fashion must be considered from the outset, with design playing a key role in reducing waste and pollution.

3. Innovating for sustainability

What is an innovation for sustainability?

Recent studies call for a focus on innovation for sustainability (Brockhaus et al., 2019; Juntunen et al., 2019; Lee & Zhang, 2019; Van Wassenhove, 2019), given that innovations 'are necessary to incorporate environmental, social and economic considerations into the production and consumption patterns of businesses and society' (Juntunen et al., 2019, p. 332). In this research, we adopt the term sustainability-oriented innovation (SOI). The term SOI emerged in the 2000s and is defined as 'the implementation of intentional changes to an organisation's philosophy and values, as well as to its products, processes or practices, with the specific aim of creating and realising social and environmental value, in addition to economic returns' (Adams et al., 2016, p. 181).

The literature on production research identifies two main types of environmental innovation: eco-product innovation and eco-process innovation (Wong et al., 2020). Currently, eco-product innovation includes the incorporation of eco-friendly raw materials, the minimisation of material and resource use, and the adoption of circular or eco-design principles to improve recyclability. Eco-process innovation is defined as modifications made to manufacturing processes and systems with the aim of ensuring energy savings, pollution prevention and waste recycling. These changes do not involve redesigning the product. Instead, they focus on

reducing emissions, minimising the use of materials and resources, recycling and eco-friendly sourcing.

Previous studies have focused primarily on the outcomes of product innovation and its impact in terms of sustainability (Adams et al., 2016; Klein et al., 2021). They have also shown that environmental innovations depend on closer collaboration with external stakeholders, compared with other types of innovation.

Among the various external stakeholders, suppliers play a particularly crucial role. Sustainability-oriented innovation increases technical and organisational interdependencies with suppliers, as it relies on complex tasks and on skills and knowledge that the industry does not possess. Furthermore, the early involvement of suppliers in innovation exposes the core company to more potential ideas, concepts or technologies and gives it access to important products and complementary resources.

Tintex Textiles — A pioneer in sustainable innovations in dyeing

Dyeing is one of the most polluting stages of textile and clothing production (McKinsey & Company, 2020) and therefore presents a significant opportunity for sustainability-driven innovation. One company at the forefront of this movement is Tintex Textiles, based in Vila Nova de Cerveira. Founded in 1998, Tintex was one of the first Portuguese textile manufacturers to work with Lenzing's TENCEL™ Lyocell cellulose fibre

and has been certified to the Oeko-Tex® Standard 100 since 1999. Currently, the Portuguese company is focused on revolutionising dyeing processes through innovations ranging from the installation of water recycling infrastructure to the development of petroleum-free coatings, not only for clothing but also for automotive and military applications. Furthermore, Tintex Textiles is working to transform waste from other industries into valuable textile products. A notable example is its INVINOTEX® innovation, an alternative to animal leather made from by-products of grapes harvested at the local estate, Quinta de Soalheiro.

The power of collaboration

Vurro et al. (2024, p. 9) define sustainability-oriented collaboration as 'collaborative approaches in which companies establish partnerships with an explicit social and/or environmental intention, beyond conventional economic and competitive objectives'.

However, our understanding of the role of suppliers in collaborating with buyers and other partners to innovate towards sustainability remains limited. This gap can be attributed to the predominance of the buyer's perspective, both in value chain management and in the literature on innovation. Most studies on sustainability focus on how buyers drive change, overlooking the crucial contributions, challenges and perspectives of suppliers and other stakeholders. To generate more relevant and applicable knowledge on sustainability-oriented innovation, it is essential to adopt a more holistic approach that considers the perspectives of all actors involved. To

address this gap, some recent studies call on researchers and practitioners to consider them as actors (e.g. Watson et al., 2018). In this context, we propose to address the following research question:

How do suppliers and other actors in the value chain collaborate to create sustainability-oriented innovations in the textile and clothing industry?

Success factors in collaboration for sustainable innovation

The relational perspective initially developed by Dyer and Singh (1998, 2018) identifies the factors that can contribute to a successful collaborative relationship. Since innovation often requires access to diverse knowledge, resources and capabilities that no single firm possesses on its own, the authors identify four key factors for successful collaborations: (1) complementary resources. Unlocking this value requires strategic and organisational compatibility, particularly in areas such as decision-making. (2) Knowledge-sharing routines are fundamental to the transfer of both codified knowledge and tacit know-how. Such routines often emerge through repeated, trust-based interactions and are essential for the co-creation and recombination of innovative ideas (Grant & Baden-Fuller, 2004). Furthermore, (3) investment in relationship-specific assets is also crucial. These include the specificity of the location, as well as physical and human assets — ranging from shared premises to customised machinery. These assets are tailored to the partnership and can generate innovation-related advantages

that are difficult to replicate or transfer to another location (Williamson, 1985). Finally, (4) effective governance mechanisms, whether formal contracts or informal norms, also play a central role in facilitating collaboration, minimising opportunism and promoting transparency.

Play Up — Portuguese style with a circular twist

Although it was founded over twenty years ago, everything changed for Play Up in 2017, when Susana Correia took over the creative helm of the children's clothing brand, transforming it into a success story in terms of sustainability. Play Up was born out of a family-run textile manufacturing company, Etfor, with in-depth knowledge of the textile and clothing industry. In 2023, the Portuguese brand, based in Esposende, generated eight million euros in revenue, accounting for 35% of Etfor's total turnover. Susana Correia emphasised that the "Made in Portugal" label plays a significant role in this result; however, the brand's core strategy is driven by its circular practices. To begin with, Play Up recycles its own pre-consumer textile waste to create a circular yarn called "Replay". The brand also aims to develop a post-consumer textile waste programme, using items collected through its Take Back scheme, which allows customers to return previous purchases. However, most returned items are usually in good condition and are therefore repaired and sold on their online second-hand platform. "Since we started, we've had a very small and modest amount [of post-consumer waste for recycling], because the items of clothing really do arrive in very good condition, which also makes us happy, as it means our choices have been the best in terms of quality," explained Susana Correia. For Play Up,

circularity isn't just about finding solutions at the end of the value chain; it's primarily about designing with circularity in mind from the very start. "For example, a baby's bodysuit has two rows of poppers instead of just one," reveals the creative director, to demonstrate how Play Up's products are designed to keep pace with the wearer's growth and increase their durability. Other examples include trousers with multiple strap adjustments and garments from which a leg or a sleeve can easily be removed, transforming them into entirely new pieces. In the words of Susana Correia, 'I think Play Up ends up being much more than just a children's clothing brand. There's an intersection with art, a focus on sustainability and on constantly improving. In other words, Play Up has almost an activist voice — in a very discreet way — but one that conveys so much of who we are and what we value.'

The curious life of a football scarf

It's the final match of the season. Two teams are battling it out for the coveted title, and their fans are eager to wear their team's commemorative scarf. But there's a problem: only one team will come out on top. So, what happens to the unsold scarves from the teams that could have been champions? Most will probably end up in a landfill, unless they are returned to FORTeams Lab. This Portuguese manufacturer, based in Vizela, collects unused sports merchandise and gives it a new lease of life through its LOOP project. In collaboration with partners from the Portuguese textile industry, the items are recycled and transformed into new yarns, which can then be used by the very same teams that originally discarded the waste. This process is not only more environmentally sustainable but also makes

commercial sense. Brands (or teams, in this case) can turn their unsold products into new materials at a lower cost, creating value from waste. Although still in its early stages, FORTeams Lab's LOOP project is already being trialled by football clubs, and there are others eager to get on board.

Key ideas

»» Innovation for sustainability involves incorporating environmental, social and economic considerations into patterns of production and consumption.

»» This innovation can take place at the product level — through the substitution of materials, for example — or at the level of production processes themselves, through changes to manufacturing methods.

»» Given the complexity of the fashion supply chain, collaboration between brands and producers is essential for developing innovations capable of making the industry more sustainable.

»» There are four factors underpinning the success of a collaboration: the existence of complementary resources, the sharing of information and knowledge, investment in assets specific to the collaboration, and the establishment of governance mechanisms.

4. Innovation for sustainability in Portuguese fashion

Portuguese textiles

The Portuguese textile and clothing industry is also a key sector of the national economy, accounting for around 1.7% of the country's GDP in 2024 (INE, 2026). According to the Office for Strategy and Studies (GEE) (2024), the textile and clothing industry accounts for 7.8% of total Portuguese exports, 17.3% of employment in the manufacturing sector and 9.9% (2.7 billion euros) of the gross value added of the manufacturing sector. In 2023, imports of clothing and textiles into the Portuguese industry slightly exceeded 5 million euros, representing a 5.4% decrease compared with the previous year. More than 50% of these imports consisted of fashion and clothing products, followed by fibres, yarns and fabrics. Spain, Italy and China were the main import partners, accounting for 34.7%, 11.6% and 8.8%, respectively, of total imports in 2022.

Most textile and clothing manufacturers are located in northern Portugal (Porto, Braga, Guimarães and Famalicão), accounting for 87% of turnover and 85% of employment in 2019. In the Central Region, Aveiro stands out (3% of total turnover), as do the Beiras and Serra da Estrela regions (around 3% of activity in the textile and clothing industry) (ATP, 2019).

Overall, greenhouse gas emissions from the textile and clothing industry in Portugal have fallen by 36.4% since 2005. Almost all emissions from this industry in Portugal (97.5%) result from the burning of fossil fuels, with textile manufacturers accounting for 88.1% of the sector's GHG emissions. However, there are reasons to believe that Portuguese textile and clothing companies are on the path to decarbonisation, as the sector has seen a reduction of almost 30% in carbon intensity (GHG, 2024).

Despite the challenges posed by high labour costs and intense competition, the sector continues to make a substantial contribution to the Portuguese economy, generating employment and exports. As the global economy evolves, the national textile industries will face new challenges and opportunities. However, the sector is well positioned to grow in the future, capitalising on its skilled workforce, the availability of high-quality raw materials and favourable trade rules.

The organisation of the fashion industry

The textile and clothing industry is an important part of the global economy, creating jobs and supplying products that meet a variety of needs, including basic ones. Textiles take many forms, ranging from home textiles, such as towels and bed linen, to technical textiles, such as fire-resistant uniforms; however, for the purposes of this study, we will focus on textiles that contribute directly to the production of clothing, thereby establishing a link between the two industries.

The structure of the textile and clothing industry is characterised by the complexity of its value chain. Each stage is usually carried out by a different player. However, the brand is seen as the driving force behind the process, overseeing the entire value chain. The textile value chain begins with the production of fibres, which come from natural sources (e.g. cotton, hemp and wool), synthetic sources (polyester, polyamide) or semi-synthetic sources, derived from natural materials that are chemically processed (such as viscose). The fibres are then transformed into yarns through a process known as spinning. There are two main types of spinning: hand spinning, which involves techniques such as carding, twisting and sliver spinning; and machine spinning, which is predominantly used in current industrial practices. Once produced, the yarns are combined, which constitutes the fabric production stage. This can be done through weaving, which involves interlacing two yarns to create a fabric, or through knitting, which is achieved by interlacing sets of yarns, known as stitches, using one or more yarns. Non-woven fabrics, on the other hand, are manufactured not from yarns, but directly from fibres that are bonded together through mechanical, thermal or chemical processes, rather than being woven or knitted. Before dyeing and printing, fabrics are usually subjected to pre-treatment processes, such as washing or bleaching, in preparation for the final stages. Dyeing then involves the application of various colouring techniques, using natural or synthetic dyes. Finally, the fabric undergoes finishing processes, often of a chemical nature, to add functional properties such as water repellent or UV protection. The product development process concludes at the manufacturing stage, where garments are cut and sewn.

Case studies

We analysed seven case studies, each of which concerned the creation of a sustainability-oriented innovation involving different stakeholders in the textile and clothing value chain. The aim was to cover different stages of garment production, from fibre production to retail sale, identifying the collaborations that make up the sector's complex relational chains, as illustrated in Table 1. Some companies did not respond to our enquiries or chose not to participate in the study. Furthermore, as with all qualitative case studies, the data presented here are limited by the number of cases studied, the selective participation of companies and potential gaps in the available information. However, we have sought to mitigate these limitations by triangulating multiple data sources (e.g. sector reports, interviews with experts, presentations at professional conferences), conducting follow-up interviews and ensuring the representation of both suppliers and their partners in each case.

Table 1. Case studies according to their position in the value chain

Case	SOI	Fibre production	Wiring	Fibre production	Dyeing and printing	Finish	Manufacturing	Brand/Retailer
1	Regenerative cotton			RDD Textiles	RDD Textiles	RDD Textiles		ISTO.
2	Recycled polyester with a water-repellent finish	Company U	Riopele	Riopele	Riopele	Riopele		SNT
3	Lyocell textiles			Company A	Company A	Company A		Winqs
4	Regenerative cotton		Inovafil	Casa da Malha	Acatel	Acatel	Silsa	
5	PLA textiles	NOOSA	Inovafil	Casa da Malha	Acatel	Acatel	Silsa	Company N
6	Dyeing using microorganisms			RDD Textiles	RDD Textiles Colorifix	RDD Textiles		Company V
7	Pad-Dry/Ox finish			Somelos	Somelos Archroma	Somelos		

To analyse the data, we followed a two-stage coding process. In the first stage, we coded each case using the following codes: the buyer's location and size, the suppliers' location and size, who took the initiative in the production process, and the buyer's supplier selection criteria. We also examined the type of innovation, distinguishing between product innovations — where the SOI arose from new textile fibres, for example — and process innovations, which focused on production methods such as dyeing and finishing. We further specified whether the innovation included a service, such as recycling or traceability. Finally, we detailed the sustainability characteristics of each innovation; more specifically, how these enable brands and suppliers to reduce their environmental impact. This information is presented in Tables 2 and 3.

Table 2. Coding for the first phase on collaboration

	Location	Size (number of employees)	Partner who took the initiative	Selection criteria
Case 1	Portugal	RDD: 15 ISTO.: 10	Both	Supplier's location and capacity for innovation
Case 2	Spain, Portugal and Denmark	Company U: 2500 Riopele: 1014 SNT: 141	Both	The supplier's capacity for innovation
Case 3	Portugal and Germany	Company A: 336 Winqs: 6	Winqs	Portugal's position in the global value chain
Case 4	Portugal	Inovafil: 120 Casa da Malha: 63 Acatel: 172 Silsa: 206	Inovafil and Casa da Malha	A pre-existing relationship and trust between the partners
Case 5	Belgium, Portugal and France	NOOSA: 8 Inovafil: 120 Casa da Malha: 63 Acatel: 172 Silsa: 206 Company N: 10	Casa da Malha	The supplier's capacity for innovation and the existing relationship and trust between the partners
Case 6	Portugal and UK	RDD: 15 Colorifix: 100 Company V: 31	Both	Both were looking for partners, and the supplier held a specific licence
Case 7	Portugal and Spain	Somelos: 730 Archroma: 4500	Somelos	A pre-existing relationship and trust between the partners

Table 3. Types of sustainability-oriented innovation

	Innovation	Type of innovation	Sustainability characteristics of the innovation
Case 1	Regenerative cotton	Product	Positive impact on the soil and increased carbon sequestration
Case 2	Trousers made from recycled polyester with a water-repellent finish	Product and process	Water savings during production, a long-lasting product and the use of recycled materials
Case 3	Liocel sports T-shirt	Product	Production requires less energy, water and resources
Case 4	Regenerative cotton	Product and service	Positive impact on the soil, increased carbon sequestration and traceability
Case 5	Polylactic acid (PLA) fibres	Product, process and service	Production requires less water, reduces CO_2 emissions and is recycled after use by the consumer
Case 6	Colorifix: dyeing of tissues with bacterial DNA	Process	Production requires less water and does not use harmful chemicals
Case 7	Pad-Dry/Ox finish on denim	Process	Production requires less water and produces no waste water

The coding in the first phase helped us to contextualise the relationships between buyers and suppliers in each case. In our coding for the second phase, we used the relationship between the brand and the supplier as the unit of analysis. We used the concepts from Dyer and Singh's framework as codes to analyse each case separately.

Case 1: Regenerative cotton

In the first case study, we analysed the development of garments made from regenerative cotton, the result of a collaboration between a Portuguese fabric supplier, RDD Textiles — which is also involved in the dyeing and finishing stages — and a Portuguese fashion brand, ISTO. Although a manufacturer was involved, its contribution was minimal and was not included within the scope of this research. In this case, the fabric supplier played a central role in the brand's innovation activities, acting as a key partner in the identification and development of new products.

In terms of governance, the collaborative relationship was governed primarily by trust and transparency, underpinned by fluid and effective communication between the supplier and the brand. Apart from ISTO.'s needs to accept pre-defined minimum order quantities (MOQs), there were no formal contractual obligations, such as exclusivity agreements, particularly as the fabric in question was also being supplied to other brands. Notably, ISTO. chose not to exercise control over the process. However, although RDD proposed various fabric options, the final decisions were taken exclusively by the brand.

These governance mechanisms facilitated an intensive exchange of knowledge and information. This was particularly important for the buyer, who was in the process of acquiring knowledge about sustainable practices in the fashion industry. To ensure compliance with its existing quality standards, ISTO. provided samples from previous collections, whilst the supplier presented relevant innovations from its portfolio to meet these expectations. The geographical proximity between the two partners also facilitated this exchange of knowledge and information.

This SOI did not require the partners to invest in specific assets for the relationship, beyond the time and financial resources already committed to the collaboration.

Finally, the complementary resources were particularly important on the part of RDD, given the way in which its accumulated experience, knowledge, multidisciplinary team and investment in R&D were channelled into this sustainability-driven innovation. RDD also capitalised on its integration within a larger textile company to establish a network of partners capable of meeting both the specific requirements of ISTO. and those of the innovation. On the brand's side, these resources were mostly intangible (but no less important), such as its sustainability-oriented mindset and clear vision. Providing visibility to suppliers by promoting them through its marketing channels is also an important complementary resource on the part of the buyer. In summary, for a successful collaboration, the brand relied heavily on a substantial exchange of knowledge and information, whilst the supplier stood out due to its complementary resources.

Case 2: Recycled polyester with a water-repellent finish

In Case 2, two suppliers — a fibre manufacturer, Riopele, and a company specialising in the production, dyeing and finishing of fabrics, Company U — collaborated with the fashion brand SNT to create trousers made from recycled polyester with a water-repellent finish. Unlike the first case, there were some structural governance mechanisms in place to help regulate the collaboration, as Riopele and SNT signed a confidentiality agreement aimed at guaranteeing SNT's exclusivity over the developed formula and the fabric's composition. The partners also agreed on small minimum order quantities. However, Riopele was authorised to offer different versions of the formula to other clients. Governance was also achieved through informal mechanisms, namely a shared understanding and commitment to sustainability. This common vision served to align the partners' efforts and reduce reliance on formal controls.

In terms of knowledge and information sharing, Riopele guided the selection of materials, providing SNT with its expertise on the properties, performance and sustainability of different materials. This exchange of technical knowledge enabled the brand to make informed decisions based on Riopele's in-depth knowledge of materials. On the other hand, SNT played a central role in guiding the development of the product formula, specifying particular performance standards. It requested several rounds of sample testing, followed by iterative modifications to meet expectations. The prototypes were crucial in these iterations and, more

broadly, played a significant role in the overall process of knowledge and information exchange. There was also a significant exchange of knowledge and information between the two suppliers, albeit on a smaller scale and mainly prior to this specific collaboration. However, Company U emphasised that Riopele's testing processes and technical recommendations were fundamental to improving the quality of the recycled polyester fibre.

In terms of investment in assets specific to the partnership, SNT — despite being headquartered in Denmark — chose to second a Portuguese employee to Portugal to represent the company throughout the collaboration. This local presence significantly improved the exchange of knowledge and information, enabling frequent in-person visits to the factory, supported by regular online meetings. Furthermore, Company U demonstrated its commitment to the partnership by showcasing the brand as a success story on its website, contributing to a positive and trusting relationship between the partners.

Complementary resources played a significant role in the success of collaborative innovation. Company U contributed waste recycling facilities, the use of recycling technologies and the provision of a traceability platform. Riopele shared its knowledge and experience in the textile industry, backed by advanced equipment, an established reputation, a strategic location within the Portuguese textile cluster and its portfolio of innovations. SNT brought its ability to test samples with consumers, its knowledge of the fashion market, as well as its radically innovative mindset.

Case 3: Lyocell textiles

The third SOI analysed in this study is a product manufactured from TENCEL™ Liocel fibres, the result of a collaboration between a Portuguese fabric manufacturer, Company A — which is also responsible for dyeing and finishing — and a German brand, Winqs. As in the previous cases, the governance structure remained simple, with both parties choosing not to seek exclusivity. In fact, Winqs explicitly expressed its desire for the SOI to be widely adopted. The partners did, however, sign a non-disclosure agreement (NDA) to protect the confidentiality of the early stages of the innovation process. This agreement restricted the sharing of specific details with third parties, whilst allowing collaboration with other partners involved, such as the fibre manufacturer, who also contributed to the development efforts.

Regarding the exchange of knowledge, it is important to note that the partnership was at its peak during the COVID-19 pandemic, which resulted in minimal face-to-face interactions. Communication was primarily led by the brand, which, from the outset, put forward precise requests for materials and products, subsequently supplemented by ideas put forward by the supplier. This marked the start of a lengthy process of exchanging prototypes and feedback, with contributions from both the brand and its athlete consumers, who tested the innovation's performance.

Company A had to make new investments for this collaboration, having to rethink its development process from

scratch. The fact that Winqs requested a product that was entirely plastic-free, for example, led the Portuguese factory to seek out new suppliers and techniques for natural fibres, pigments and finishing formulas. As well as encouraging its partner to be more innovative, the brand also invested in communication tools to promote innovation.

Considering the role of complementary resources, Winqs brought its experience in the fashion industry and its commitment to sustainability to the partnership. The Portuguese supplier contributed more specific resources, in addition to its innovative infrastructure, such as renewable energy, water treatment facilities and 3D prototyping equipment. Its network of partners and its services, which enabled them to operate as a one-stop shop, also contributed directly and indirectly to the innovation process.

Case 4: Regenerative cotton

The fourth case study concerns the development of garments made from regenerative cotton by four Portuguese suppliers, covering almost all stages of the textile value chain, from spinning to manufacturing. The yarn supplier was the driving force behind the innovation process. In terms of governance, given that the various partners had a long history of collaboration, most information-sharing mechanisms remained informal. Furthermore, all the suppliers are located close to one another, which facilitates interaction and transparency, and they share similar values, particularly regarding sustainability.

Unlike in previous cases, this collaboration involved a limited exchange of knowledge and information between the partners, as the innovation was closely aligned with existing production processes. According to the Portuguese suppliers, the manufacture of garments using regenerative cotton did not require significant adjustments compared with conventional cotton.

However, the textile supplier, Casa da Malha, played a key role in facilitating communication between the partners, acting as an intermediary between the brands and the other suppliers. This exchange included the presentation of prototypes of garments made from regenerative cotton, developed by the four Portuguese suppliers, for the brands to test.

Investment in specific assets for this partnership included the purchase of a scanner to trace the cotton and a certification obtained by Acatel, the dyeing service provider. There were many other complementary resources that contributed to the success of this SOI, such as a large R&D department, machinery and equipment, certifications and traceability services.

Case 5: PLA textiles

The development of polylactic acid (PLA) textiles was driven by a value chain like that of the fourth case, with the addition of a Belgium-based fibre producer, NOOSA, and a French sportswear brand. This sustainability-driven innovation posed different collaborative challenges compared with the use of regenerative cotton, due to the more innovative

nature of the PLA fibre. Within the governance structure, NOOSA required all partners to sign a permanent non-disclosure agreement (NDA) to prevent them from sharing details about the material and its development process. Apart from the NDA, no additional contracts were signed, and governance was based primarily on informal mechanisms such as transparency and trust.

Due to the complexity of the innovation, all partners engaged in a substantial exchange of knowledge and information. NOOSA visited the Portuguese factories annually, met with partners at international textile trade fairs and provided written guidance on how to adapt production processes to the specific characteristics of the material. These guidelines were particularly important during the dyeing and finishing stages, and there was continuous contact between the PLA producer and the suppliers. Samples and prototypes played a key role in this exchange, enabling testing and the provision of feedback.

Investment in partnership-specific assets was limited to NOOSA's promotion of the other partners at international trade fairs, with the aim of attracting brands and thereby securing more customers. Once again, the contribution of additional resources was crucial. On the supplier side, the resources were like those identified previously. However, NOOSA brought a range of complementary resources, such as a patented recycling technology and a recycling programme covering both pre- and post-consumer waste. NOOSA also had a multidisciplinary team with expertise in areas such as dyeing, which enabled collaboration with the

other partners. Furthermore, NOOSA had in-house laboratory facilities to test new developments and played a key role in collecting waste from suppliers and brands for recycling.

Case 6: Dyeing using microorganisms

The sixth case study focuses on the development of an innovative dyeing process that utilises microorganisms. Three companies took part in the innovation process: two suppliers, RDD Textiles and Colorifix, and a fashion brand. The management of the relationship was based on a policy of non-exclusivity, allowing the partners to collaborate with other companies. However, the brand had a formal contract with RDD.

Substantial knowledge and information were exchanged through a wide range of experiments until the dyeing technology was ready to be scaled up. RDD helped the biotechnology company to better understand the different textiles and to adapt the process to their characteristics. Conversely, the brand helped RDD to refine the product. Feedback from the brand's customers played a crucial role in guiding these improvements. This close collaboration was supported by frequent in-person visits to RDD's premises, complemented by weekly online meetings.

The brand invested time. Colorifix invested in equipment and training, and even opened a branch in Portugal, going so far as to operate directly from RDD's premises. RDD invested in obtaining the regulatory licence to work with genetically modified organisms, acquired equipment

developed by the biotechnology company and trained its staff in the innovative dyeing process. Both suppliers promoted each other — RDD by highlighting the innovation in the dyeing process within its portfolio, and Colorifix by presenting the fabric supplier as its production partner.

Regarding additional resources, RDD, as part of a larger textile company, was able to bring together a multidisciplinary team, specialist knowledge of new materials and technologies, a network of partners, as well as a strong focus on innovation and sustainability. Colorifix contributed specialist knowledge of the dyeing process, alongside innovative equipment, infrastructure and research supported by public and private funding. Although to a lesser extent, the fashion brand brought a spirit of innovation and experimentation, as well as experience gained from other sustainability-driven innovations and an existing partnership with the fibre producer.

Case 7: Pad-Dry/Ox finish

The latest case study examines a textile finishing technique that uses significantly less water than conventional methods. It was developed by a Portuguese fabric supplier, Somelos, and a Swiss chemical company, Archroma. The collaboration was based on a non-disclosure agreement (NDA), supplemented by informal mechanisms and mutual trust, as the partners already had a pre-existing business relationship. Neither company sought exclusivity, and Archroma has since expanded its network to include other Portuguese suppliers. The partners engaged in a substantial

exchange of knowledge and information. On Archroma's side, the innovation was overseen by a Spanish employee who travelled frequently to Portugal during the initial development phases. Meanwhile, Somelos focused on experimentation and adjustments based on feedback from the brand. At the time of the interviews, the Portuguese supplier was also expanding its product range, working with a new range of dyes from Archroma.

As the chemical components required for the innovation had already been developed by Archroma, there was no significant investment in assets specific to the partnership. However, Archroma undertook significant promotional activities, showcasing SOI at international trade fairs and to its extensive customer base.

Finally, both partners contributed substantial complementary resources. As explained earlier, Archroma supplied the chemical components and its portfolio of formulations. Somelos contributed its water treatment infrastructure, its certifications and its technical expertise in textile production, as well as its network of partners within the Portuguese textile cluster.

Key ideas

»» Portuguese manufacturers, located mainly in the north of the country, stand out for their environmental innovation in the manufacture of textiles and clothing.

»» This study analysed seven cases of collaboration between national and international brands and national manufacturers for the development of product innovations and production processes.

»» Product innovations focus on the adoption of materials such as regenerative cotton, recycled polyester, lyocell and polylactic acid (PLA). In terms of processes, notable examples include dyeing methods using microorganisms, water-efficient denim finishes and processes to extend product durability.

»» The collaborations analysed demonstrate a high degree of knowledge and information sharing, as well as complementary resources, with producers offering innovative technologies and brands providing market strategies.

»» The governance mechanisms prioritised trust and close relationships between the professionals involved in the collaboration.

5. *Sustainably Made in Portugal*: next steps for the fashion industry

Recommendations for the Industry

To promote sustainability-oriented innovations, suppliers must adopt a strategic approach to investing in relationship-specific assets. Investing in certifications, training, and organizational processes supports long-term capacity building and reflects a deeper commitment to the transition to sustainability. Case 4 and Case 6 invested in new certifications and equipment, notably advanced machinery, highlighting an effort to comply with industry standards and regulatory requirements. Similarly, Case 5 and Case 6 focused on training and organizational programs, identifying capacity building as a key enabler of sustainable innovation. This involves dedicating time and financial resources. It also includes actively promoting their partners' sustainability initiatives to increase visibility and trust.

Suppliers should also view knowledge sharing as a central pillar of collaboration with brands, as well as with other suppliers. Cases 5, 6, and 7 demonstrated a greater reliance on robust knowledge-sharing practices among suppliers. These cases involved innovations with a higher degree of complexity, in which ongoing collaboration and the exchange of technical knowledge were essential to

overcoming challenges and achieving the desired results. In contrast, in Case 4, knowledge exchange was less critical to success, since the regenerative cotton production processes being implemented were not very different from established practices for conventional cotton.

Effective practices combine the exchange of physical items, such as samples and prototypes, with iterative feedback cycles and ongoing communication, both virtual and in person. Cases 1, 2, 3, 4, and 5 illustrate how product samples and prototypes were instrumental in sharing insights about the progress of the innovation. Flexibility is essential, as knowledge-sharing mechanisms must adapt to the specific needs and complexity of the innovation in question.

Governance structures must also be tailored to the nature of the collaboration. While formal tools, such as confidentiality agreements, are valuable in the early stages to protect proprietary knowledge, many cases (cases 1, 4, 5, and 7) demonstrated the effectiveness of agreements based on trust, particularly when partners shared a history of working together. The widespread adoption of a "non-exclusive" approach across all cases highlights the value of flexibility, allowing both brands and suppliers to engage in multiple sustainability initiatives without the restrictions imposed by exclusivity agreements.

The selection of partners should focus on the complementary resources that each stakeholder brings to the table. In most cases, brands have explicitly chosen production partners based on the unique resources they could contribute

to the innovation process—ranging from intangible assets, such as experience and knowledge, to tangible assets, such as specific equipment already in the partner's possession before the collaboration began. Therefore, suppliers should acquire and prioritize specialized machinery, sustainability certifications, and robust supplier networks. Meanwhile, brands with market knowledge, consumer insights, and a sustainability-oriented vision—essential for aligning innovation with broader market demands—are key partners for suppliers.

Finally, understanding the degree of servitization in their offerings is crucial for suppliers, as it determines how they are perceived and positioned in the market by current and potential customers. At the highest level, full servitization implies that suppliers collaborate to offer comprehensive solutions that promote sustainability throughout the entire product lifecycle, from the sourcing of raw materials and production to end-of-life processes, such as recycling. By integrating services into their offerings, suppliers have positioned themselves as strategic partners to brands in achieving their long-term sustainability goals. Partial servitization involves suppliers that include one or more services covering only certain aspects or phases of the life cycle, such as sustainability tracking. At the other end of the spectrum, product-only suppliers focus solely on supplying specific components directly to produce a product, without integrating services.

As sustainability becomes a strategic priority for fashion brands, suppliers that integrate sustainability-related services (such as recycling or material traceability) can

increase their relevance in competitive supply chains and develop long-term relationships with brands. In contrast, suppliers that remain purely product-oriented may find themselves less differentiated. By understanding where they stand on the servitization spectrum—whether they offer complete solutions, partial services, or just products—suppliers can make informed strategic decisions: whether by investing in service delivery capabilities to enhance their value proposition or by forming alliances that enable them to contribute to more comprehensive solutions throughout the product lifecycle.

How to boost the economic competitiveness of the Portuguese fashion industry

Although the textile and apparel sector in Portugal has faced significant challenges in recent decades, mainly due to growing competition from China and South Asian countries—which benefit from large-scale production capacity and low labor costs— the Portuguese cluster has been showing signs of recovery and renewed strength, particularly thanks to the strategic integration of sustainability into its value chains (GEE, 2024). The rise of these global competitors has exerted considerable pressure on the Portuguese textile sector, forcing suppliers to seek differentiation through the development of higher-value-added products, innovation, and sustainable practices. In this context, this section will explore some of the most significant opportunities and constraints influencing the global competitiveness of the Portuguese textile and apparel sector. Furthermore, we will present strategic recommendations to industry leaders and policymakers, with the aim of maximizing

the cluster's key competitive advantages and ensuring long-term resilience in the face of this changing landscape.

One of Portugal's key competitive advantages—consistently highlighted during interviews with brands and suppliers for this study—is the talent and experience embedded in the Portuguese textile and apparel value chains. The industry is widely praised for its high-quality standards and the presence of a diverse range of factories, which together cover the main stages of the production process, from yarn to the production of garments. In addition, brands frequently mentioned the advanced equipment used by Portuguese suppliers—which is essential for developing sustainability-oriented innovations—combined with the sector's strong commitment to transparency. These characteristics help explain why Portugal has positioned itself as a leading player in sustainable textile production at renowned international textile trade shows, such as Première Vision in Paris, where Portuguese suppliers have frequently been recognized for their sustainability-focused creations.

Another feature celebrated by both brands and suppliers is the geographic proximity of companies operating in the Portuguese textile and apparel sector. As one buyer noted during an interview, "Everything is within a 50-kilometer radius. You have the sea for shipping (…) all over the world. So, you have everything." This close geographic concentration is also highly valued by suppliers, who emphasize how it strengthens collaboration and facilitates more efficient communication and problem-solving throughout the entire production process. In an industry where value chains are

typically complex and spread across multiple continents, this cluster of Portuguese suppliers serves as a strategic safeguard against disruptions in global value chains, which are becoming increasingly common.

When analyzing the potential challenges to Portugal's competitiveness in the global textile market, one of the most frequently cited issues is the significant investment required to drive sustainability-oriented innovation. In fact, research and development in this area entail substantial costs, which poses a particular risk for Portuguese suppliers, especially when brands are reluctant to pass these innovations on to consumers due to their higher prices. This challenge is even more pronounced for small and medium-sized enterprises, which make up the bulk of Portugal's textile and apparel sector, as they may lack the financial resources needed to make these investments upfront. Another cost related to sustainability—one that is often overlooked—is the expense of obtaining sustainability certifications. These certifications are essential for verifying sustainable practices and bolstering credibility in international markets. To address these challenges, a strategic recommendation would be to support companies in the Portuguese textile cluster in securing funding for R&D and sustainability-related initiatives. This could be achieved through specific financial support programs, targeted particularly at SMEs, and by improving access to information and advice on available funding opportunities.

In addition to financial investment, other significant obstacles to innovation in Portugal's textile and apparel industry

include a shortage of human resources and infrastructure, especially during the expansion phase. As the CEO of a Portuguese textile supplier pointed out: "There are companies that do a lot, but there are [other] companies that don't even have the human resources to do so and lack the capacity [to innovate] because they are really small." This reflects a structural challenge in the sector, where SMEs often struggle to access the talent and operational capacity needed to drive innovation. To mitigate these limitations, some suppliers highlighted the potential for greater collaboration with sector organizations, such as CITEVE, which was frequently mentioned as a valuable partner in supporting research and development. Universities were also identified as key players in promoting innovation. Strengthening these collaborative networks among private companies, industry organizations, and academic institutions could help bridge resource gaps and accelerate the development and implementation of innovative solutions in the Portuguese textile sector.

During the data collection period, which took place between 2022 and 2024, Portuguese suppliers also expressed concern about the wave of new legislation for the textile industry coming from the European Union. This regulatory tsunami was perceived as a twofold challenge: first, because major competing regions in textile production, such as China and South Asia, are not subject to similar environmental and social regulations, which gives them an advantage in terms of production costs; second, because EU legislation was described as confusing and constantly changing, creating uncertainty and operational challenges. Overall, Portuguese

suppliers called for greater support and specific incentives to help them adapt to this evolving regulatory landscape—a gap that could be filled by industry organizations. Brands that manufacture in Portugal shared similar concerns, pointing to the bureaucratic hurdles involved in securing financing and other resources necessary for innovation. As one buyer put it: "Many companies lack the know-how; they need to hire consulting firms for support."

Another issue raised by brands and suppliers concerned communication. When brands seek to manufacture in the country without prior knowledge of the textile cluster, they have difficulty finding the information needed to select suitable suppliers. A common complaint from brands was the lack of promotion by suppliers, particularly on digital platforms. An international brand that manufactures in Portugal stated:

I've noticed that many factories don't promote themselves. If you look at their websites, they're terrible. It's very hard to figure out what they do, and they're very difficult to navigate. Many of them are really outdated, and considering how advanced Portuguese factories are, I would suggest taking this to the next level and promoting themselves as well.

Suppliers also recognized this issue, albeit to a lesser extent. Communication is particularly challenging for companies operating in the intermediate stages of the textile value chain, as they often lack direct contact with brands. Two possible recommendations emerge from this issue. On the one hand, Portuguese suppliers should invest in modernizing

their promotional platforms—particularly their websites—to convey the cluster's growing reputation for sustainability and innovation. On the other hand, industry organizations could act as intermediaries between brands seeking to manufacture in Portugal and suppliers, maintaining a centralized and up-to-date platform that provides detailed information about Portuguese textile companies.

Finally, communication is also crucial for consumers, who ultimately have the power to demand more sustainable products and services. However, both brands and suppliers recognize that greater consumer education is needed to raise awareness of the environmental and social impacts of the textile industry. Tools such as the European Union's digital product passport can play a valuable role in this effort by presenting relevant information in a clear and accessible format, helping consumers make more informed and sustainability-oriented choices.

In summary, the Portuguese textile and apparel value chain has faced significant challenges due to increased global competition, but has demonstrated resilience by focusing on high-quality, sustainability-oriented production—a strategy that has earned it international recognition. The industry benefits from a skilled workforce, advanced technology, and an interconnected value chain, which enhances efficiency and transparency. However, some challenges remain, such as the significant cost of research and development initiatives, limited resources for SMEs, and difficulties in adapting to evolving EU regulations. Increasing financial support for innovation, promoting collaboration with

industry organizations and universities, and improving the visibility of suppliers through digital promotion could help strengthen the sector's long-term competitiveness and resilience. With sustainability and innovation at its core, the Portuguese textile industry is well-positioned to write the next chapter of the "Made in Portugal" brand.

Key Ideas

»» In order to foster successful collaborations in the development of sustainable innovations, Portuguese producers should invest in resources that set them apart in the international market, such as certifications, talent, and cutting-edge technology.

»» Information sharing is particularly essential for the effectiveness of collaborative processes; frequent contact with brands and the exchange of prototypes at various stages of the innovation process should be prioritized.

»» Since brands choose their partners based on the unique resources they bring to the collaborative process, domestic manufacturers can also act as service providers by developing relationships with key partners at various stages of the production chain.

»» From an international perspective, Portugal's textile and apparel industry stands out for its quality and investment in innovation for sustainability. These strengths can be further enhanced through financial support for investment in talent and state-of-the-art machinery.

»» Domestic producers must also be supported so they can cope with the wave of legislation emanating from the European Union, which has proven to be complex, especially when it comes to implementation.

»» **Investment in communication—particularly digital communication—is also crucial to enable domestic producers to promote their work internationally, projecting the image of quality and sustainability for which they are recognized among experts.**

Conclusion

An industry increasingly subject to a negative environmental reputation (albeit one that reflects reality, given the continued rise in the consumption of natural resources, greenhouse gas emissions and waste), it is essential to highlight narratives of change. Innovation for sustainability in the textile and clothing sector is not merely a set of ideas on paper — it is an everyday practice in production chains around the world, including in Portugal. By adopting materials and production processes that prioritise efficiency and circularity, the way is paved for fashion that is more environmentally friendly and better integrated into the communities in which it operates. After all, this is an industry of great economic significance, generating billions of dollars and creating millions of job opportunities. However, we must ensure that this social impact does not come at the expense of the balance of ecosystems and intergenerational justice, and that it is indeed possible to meet the needs of the present without compromising the ability of future generations to meet their own needs — as the United Nations defined in 1987, in the report that established the current interpretation of sustainability.

The path to sustainability in the textile and clothing industry is, however, as complex as its current structure. Spanning dozens of countries, the fashion production chain relies on the actions of a diverse range of stakeholders, which

means that collaboration must be at the heart of any environmental, social or economic change undertaken. In the field of innovation, this is no different. Although brands are typically recognised as the orchestrators of garment production, this study has revealed that, in fact, it is the manufacturers who typically lead sustainable innovation efforts within the industry. It is within these manufacturers that the knowledge, technical capacity and willingness to tackle the challenges inherent in innovation lie, often assuming the risks of such initiatives themselves. Brands emerge here as essential agents in providing (creative, financial and strategic) support for these ventures and must recognise that the path to the success of an innovation is not always straightforward, but that the results tend to outweigh any growing pains. In this sense, effective collaboration for textile innovation must necessarily be built on a foundation of trust and a relationship between professionals who, together, overcome day-to-day challenges whilst keeping long-term objectives in mind.

Although this study focuses on Portugal, it echoes what is already recognised internationally: that the Portuguese textile and clothing industry stands out for its high quality, particularly in the field of innovation for sustainability. The seven case studies carried out have illustrated numerous examples of this trend, demonstrating how a country situated at the southern tip of Europe is leading the way in adopting materials and production processes that pave the way for a greener future for fashion. However, this does not come without its challenges. The economic competitiveness

of the Portuguese sector has not followed a path of steady growth, whether due to the international geopolitical landscape or to market trends themselves, with the proliferation of brands and consumers who choose to prioritise low cost over quality and sustainability. With the wave of European legislation on the horizon, we find ourselves in a period of transition that could impact the Portuguese industry's leadership in a wide variety of ways. To ensure that this wave is successfully navigated, domestic producers must be supported through information campaigns and public funding to implement the new directives, as well as through investment in the talent and resources needed to sustain their sustainable innovation initiatives.

Ultimately, sustainability could emerge as one of the country's key competitive advantages in the international fashion market. In many parts of the world, a 'Made in Portugal' label is already synonymous with sustainability. But there is still some way to go before this perception becomes firmly established. And collaboration between producers, brands, government and educational institutions, research centres and many others is emerging as one of the most important drivers of innovation that will shape the future of the 'Sustainably Made in Portugal' brand.

Abbreviations

CSDDD Directive on corporate due diligence in sustainability matters

CSRD Directive on corporate sustainability reporting

EPR Extended producer responsibility

EU European Union

GDP Gross domestic product

GHG Greenhouse gases

GOTS Global Organic Textile Standard

IOS Sustainability-oriented innovation

ITV Textile and clothing industry

LCA Life cycle assessment

MOQ Minimum order quantity

PLA Polylactic acid

R&D Research and development

SDGs Sustainable Development Goals

Glossary

Dyeing — The manufacturing process of colouring yarns, fabrics, knitted fabrics or garments.

Fast fashion — A business model associated with the production and consumption of clothing, characterised by high production volumes, speed and low prices.

Finishing — A production process involving the treatment of fabrics or knitted fabrics with the aim of imparting aesthetic or technical properties to the product.

Knitwear — The production process of transforming textile yarns into knitted fabrics.

Living wage — The remuneration required to maintain a decent standard of living, defined by the ability to cover the costs of food, water, housing, education, healthcare, transport, clothing and other essential needs.

Natural fibres — Materials derived from natural resources (plant or animal).

Semi-synthetic fibres — Materials derived from natural resources, chemically processed in a laboratory.

Spinning — The production process of transforming textile fibres into yarns.

Sustainability-oriented innovation — Intentional changes to an organisation's values and philosophy, as well as to its products,

processes and practices, with the aim of generating environmental and social value in addition to economic returns.

Sustainable development — Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Synthetic fibres — Materials derived from fossil fuels.

Textile and clothing industry — The set of actors and processes involved in the production of textiles and clothing, from the transformation of fibres into yarns, then into fabrics, and finally into finished clothing products. It does not include footwear and accessories. In this study, home textiles were also excluded.

Weaving — The manufacturing process of transforming textile yarns into fabrics.

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Authors

Céline Abecassis-Moedas is Pro-Rector for Innovation and Entrepreneurship at Universidade Católica Portuguesa and Associate Professor in Strategy and Innovation at Católica-Lisbon School of Business and Economics, where she served as Dean for Executive Education (2019–2024). She serves as a Non-Executive Director at Vista Alegre Atlantis and at Lectra, a technology provider for the fashion industry. Céline holds a PhD in Business Strategy from École Polytechnique (Paris), a Master's in Management from Université Paris Dauphine, and undergraduate degrees from École Normale Supérieure de Cachan and the Sorbonne in Economics and Management. Prior to joining Católica, she was Assistant Professor at the Centre for Business Management at Queen Mary, University of London, Product Manager at Lectra in New York, and Consultant at A.T. Kearney in London. She has also been a Visiting Professor at MIT Sloan School of Management. Her research focuses on the role of design and design thinking in innovation, as well as innovation in the fashion industry, and has been published in leading international academic journals.

Laure Leglise is a Lecturer (Assistant Professor) in Sustainability at the Department of Strategy, Enterprise and Sustainability at Manchester Metropolitan University, United Kingdom. She joined MMU in 2023, following her appointment as a Research Fellow at Católica Lisbon School of Business and Economics in Portugal. She holds a PhD from Paris Dauphine University, France. Her research examines the dual role of businesses as both contributors to and potential solvers of pressing social and environmental challenges, including climate change and social inequality. She investigates especially how sustainability transitions are understood, managed,

and communicated. Laure's research spans a range of industries, including fashion, banking and financial services, the energy sector, and business and management education. Her research is published in top academic journals.

Mariana Pereira Silva is a writer, researcher and communicator in the field of fashion and sustainability. She holds a master's degree in Fashion Branding and Design and is currently pursuing a PhD in Development Studies at the University of Lisbon, applying a post-growth theoretical framework to apparel value chains. Mariana is the author of "Desfilar pela História", a children's book that takes young readers on a journey through the history of fashion and sustainability. Illustrated by Raquel Costa, it was published by Penguin Random House Portugal in October 2025. She has worked as guest lecturer at the University of Beira Interior, teaching Fashion Sustainability in the Fashion Design degree programme, and as a researcher for Católica-Lisbon School of Business and Economics, as well as University College Dublin, exploring social and environmental sustainability in the textile and clothing sector. Outside academia, Mariana continues to spread the knowledge gained from years of study through Ethica — Sustainable Fashion Hub, an online platform sharing resources and scientific evidence to help shape a more informed fashion community.

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