Sustainability in fashion

Innovation and competitiveness in Portugal



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For many, the "*Made in Portugal*" label is a synonymous for sustainability. But is that really the case? In this study, we analyze seven innovations developed in Portugal aimed at reducing the environmental impact of fashion products. We examine the value chain to observe collaboration mechanisms between brands and manufacturers, uncovering the success factors and challenges behind sustainability-focused innovation in the country. We also present recommendations to boost the sector's economic competitiveness, as the future of the "*Sustainably Made in Portugal*" brand holds the greatest promise of all.

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Globally, textile and clothing (also referred to, in this study, as the fashion industry) constitute a 2.4 trillion-dollar industry, contributing between 2% and 8% of the world's greenhouse gas emissions, depending on the estimates. Its significant economic, environmental and social impacts position it at the forefront of the need for innovation, especially as sustainability becomes not only a challenge but also an opportunity for businesses. Considering the complexity of the sector's value chains, this study aims to analyse how suppliers collaborate with other actors of the textile and clothing industry to create **sustainability-oriented innovations** (SOI) and derive mutual benefits. To answer this research question, we draw on the relational view originally introduced by Dyer and Singh (1998) in strategic management. The authors argue that because the most valuable resources of a firm may reside outside its organisational boundaries, effective collaboration becomes essential for gaining a competitive advantage. In this context, relational rents, which are supra-normal profits generated through successful collaboration, are achieved by leveraging the contributions of the different partners. Empirically, we conducted a multiple case study on SOI processes involving Portuguese suppliers and other actors of the value chain. The focus on Portugal stems from its significant contribution of the textile and clothing industry to the country's GDP (approximately 1.7%) and its international recognition as a sustainable production hub. In 2020, Portuguese suppliers invested over 9 million euros in sustainability-oriented innovations (about 3.1% of the national average), particularly aimed at recycling waste, water or materials, reducing energy use or CO_2 emissions and replacing conventional materials with less polluting alternatives. Our research found that collaboration among value chain actors primarily occurs through extensive knowledge sharing, information exchange, and the integration of complementary resources. These factors consistently emerge as key enablers of successful innovation processes. Additionally, governance mechanisms and investments in relationship-specific assets play a crucial role in supporting and facilitating knowledge exchange and the use of complementary resources in the innovation process.

Introduction

If there is one word to describe the textile and clothing industry since the beginning of the current decade, it is uncertainty. At least, that is the term selected by a team of experts at Business of Fashion and McKinsey & Company to characterise the state of the textile and clothing industry in their 2024 report (Business of Fashion and McKinsey & Company, 2023). While several factors may contribute to this choice — in recent years, businesses have weathered the COVID-19 pandemic, geopolitical crises, and economic volatility — one theme seems to stand out: sustainability (Business of Fashion and McKinsey & Company, 2023).

In fact, industry leaders surveyed by Business of Fashion for "The State of Fashion 2024" (Business of Fashion and McKinsey & Company, 2023) consider sustainability both a primary opportunity and a significant challenge in the current landscape. As a consequence, firms in this industry are seeking solutions to navigate the challenges of a world entering its "global boiling" era, as described by the United Nations' Secretary-General António Guterres (Kent, 2023).

Climate change-related phenomena significantly impact the textile and clothing industry. Floods, droughts, wildfires and storms have disrupted the global textile and clothing value chain, resulting in human casualties and economic distress (Kent, 2023; Smith, 2024). The geographical location of textile and clothing production facilities renders them particularly vulnerable to these events, as countries in the Global South are typically more affected by climate change (Mishra et al., 2023). It is estimated that, by 2030, four key countries in apparel manufacturing — Bangladesh, Cambodia, Pakistan, and Vietnam — lose 65 billion dollars in clothing exports and one million garment-manufacturing jobs due to extreme weather occurrences (Judd et al., 2023).

Textile and clothing production is a significant contributor to climate change, accounting for 2% to 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 fibres, as approximately 64% of global textile production relies on synthetic fibres derived from fossil fuels (Textile Exchange, 2022). According to recent estimates put forward by the Ellen MacArthur Foundation, over 100 billion garments are produced annually. However, as the average number of wears per garment continues to decline, high levels of textile waste have become the norm (Ellen MacArthur Foundation, 2017).

Given these issues, companies operating in this sector must consider how they can help mitigate the impact of climate change on their supply chains, as well as do what is within their power to keep global warming under 2°C above pre-industrial levels. Until recently, these actions were voluntary. But with the industry's greenhouse gas emissions, resource consumption and waste generation remaining at all-time highs, legislators are now looking to regulate the behaviour of textile and clothing players and phase out fast fashion (Business of Fashion and McKinsey & Company, 2023; WRAP, 2023).

Leading the way in sustainable textile and clothing regulation is the European Union, which has adopted, proposed or drafted multiple pieces of legislation as part of the EU Strategy for Sustainable and Circular Textiles, aiming "to create a greener, more competitive sector that is more resistant to global shocks" (European Commission, 2024). Sustainability legislation for this industry encompasses a range of measures, including promoting circular design strategies, limiting greenwashing in communication, improving waste management and disclosing relevant information to policymakers and consumers (Business of Fashion and McKinsey & Company, 2023). Other countries, such as the United States and the United Kingdom, have also proposed their own sustainability directives. Nonetheless, the EU regulations are expected to have a global impact, as they apply to any product sold within the region, regardless of its place of manufacture (Business of Fashion and McKinsey & Company, 2023).

While sustainability regulations may impose constraints on the textile and clothing industry, they should not be viewed negatively. Challenges often drive innovation (Talbi, 2017), and with the sector moving 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 instrument in driving such a transition. Actors across the textile and clothing value chain must work together in order to tackle the sector's most pressing challenges. Achieving milestones such as fashion supply chain decarbonisation — which is estimated to cost over one trillion dollars — will hinge on long-term commitments between brands and suppliers (Business of Fashion and McKinsey & Company, 2024). Consumers also have a critical role to play, namely by aligning their purchasing behaviours with their sustainability intentions, opting for greener alternatives in the market. Ultimately, the successful transition towards sustainability in fashion depends on the interconnected efforts of all stakeholders, bringing the importance of collaboration to the centre stage (Business of Fashion and McKinsey & Company, 2024).

1.1. Study objectives

This study aims to achieve several objectives: (1) better define what constitutes sustainability-oriented innovation in the textile and clothing industry; (2) understand the role of manufacturers and suppliers in sustainability-oriented innovations; (3) explore the collaboration between international brands, retailers, and Portuguese manufacturers and suppliers; and (4) develop sufficient knowledge to offer recommendations to policymakers and industry actors in Portugal. Given the complexity of the textile and clothing value chain, which involves multiple actors, most innovations in the industry result from collaborative efforts. Successful collaborations are, therefore, vital to enhancing the global competitiveness of the Portuguese textile and clothing industry, which, in turn, positively impacts the national economy. In 2024, the sector accounted for 1.7% of the country's GDP. As Portugal gains recognition as a sustainable textile and clothing production hub, 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 explored through a three-dimension approach, encompassing environmental, social and economic impacts. Nonetheless, considering that Portuguese textile producers are primarily investing in innovations aimed at reducing their ecological footprints, this study will chiefly

focus on environmental aspects. Overall, the results will be critical for the strategic decisions of Portuguese manufacturers and suppliers, enabling them to seize sustainability opportunities by identifying how they can proactively meet the sustainability needs of brands and retailers.

1.2. Structure

The remainder of the report is structured in six chapters. Chapter 1 begins by examining the economic relevance of the textile and clothing industry on a global scale, progressively focusing on the European Union and finally zooming in on Portugal. Chapters 2 and 3 offer a definition of sustainability in the textile and clothing industry context, detailing its three main pillars — environmental, social and economic — and outlining the necessary actions to achieve sustainability in each domain. Moving forward, Chapter 4 explores the concept of sustainability-oriented innovation, emphasising the importance of collaborations in successfully developing these innovations amidst the complexities of the industry's value chains. It introduces the theoretical framework and methodology underpinning the study, followed by Chapter 5, which focuses on the data collected and the case studies. Here, we discuss the case study results, employing both intra-case and inter-case analysis. Finally, Chapter 6 concludes with strategic recommendations for industry professionals and policymakers to enhance the competitiveness of the Portuguese textile and clothing industry.

Chapter 1
The textile and clothing industry

The textile and clothing industry is an important component of the world economy, creating employment and delivering products that satisfy a variety of needs, including primary ones. Textiles take many forms, from home textiles such as towels and bed linens to technical textiles like fireproof uniforms. However, for the purpose of this study, we will focus on textiles that contribute directly to clothing production, thereby linking the two industries. The organisation of the textile and apparel industry is marked by the complexity of its supply chain (Cao et al., 2008). Burns and Bryant (2016) proposed a recognised eight-step model for establishing a clothing line, which can be condensed into four primary steps: product development, sourcing and buying, production and distribution, and retailing (Cao et al., 2008). Each stage is typically executed by a different participant. However, the brand is perceived as the initiator of the process, overseeing the entire supply chain. The textile value chain begins with fibre production, originating from natural (for instance cotton, hemp, and wool), synthetic (polyester, polyamide) or manmade sources (like viscose) derived from natural materials that are chemically processed (Kumar & Joshiba, 2020a; Textile Exchange, 2022). Then, the fibres are transformed into yarn through a process called spinning. There are two primary types of spinning: hand spinning, involving techniques such as carding, twisting, and roving; and mechanical spinning, which is predominantly used in current industry practices (Kumar & Joshiba, 2020b). After their production, yarns are assembled, which is the fabric production step. It could be done through weaving, which consists in interlacing two yarns to create a woven fabric (Adanur, 2020), or through knitting, which is achieved by interlocking sets, known as loops, using one or more yarns (Spencer, 2001). Nonwoven fabrics, in contrast, 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 (Shaker et al., 2016). Before dyeing and printing, fabrics typically undergo pre-treatments such as washing or bleaching in preparation for the final stages (Kumar & Joshiba, 2020a). Following this, dyeing consists in applying various colouring techniques, using either natural or synthetic dyes. Finally, the fabric is subjected to finishing methods, often chemically derived, to add utilitarian properties like water repellence or UV protection (Gobalakrishnan et al., 2020). The product development process is concluded in the manufacturing stage, where garments are cut and sewn (Kumar & Joshiba, 2020a).

Today, textile and clothing supply chains are highly globalised. In Europe, particularly, this sector has a long history and now plays a significant role in countries like Portugal. In this chapter, we present a macroeconomic overview of the textile industry, at the global, European and Portuguese levels.

1.1. The global level

The textile and clothing industry is a global industry, generating 2.4 trillion dollars and employing 300 million people worldwide (UN

Fashion Alliance, 2024). If compared with the GDP of the countries, it would be considered the seventh largest economy in the world (Business of Fashion and McKinsey & Company, 2016). To understand this impact in the global economy, we can compare these numbers to one of the largest economic sectors: oil and gas. Despite generating 3.5 trillion dollars annually, its workforce only comprises 12 million workers worldwide (International Energy Agency, 2024).

The textile and clothing industry accounts for almost 4% of the world's total exports (World Integrated Trade Solutions, 2024). Table 1 and 2 show the textile and clothing export values, respectively, between 2017 and 2022, from the top five textile exporters in 2022.

Table 1 Top five textile exporters worldwide from 2017 to 2022 (World Trade Organization, 2018, 2019, 2020, 2021, 2022, 2023)

	Value of exports in billion dollars					
	2017	2018	2019	2020	2021	2022
China[1]	110	119	120	154	146	148
EU	69	74	66	64	73	71
Extra-EU exports	21	23	24	22	25	25
India	17	18	17	15	22	19
Turkey	11	12	12	12	15	15
United States of America	14	14	13	11	13	14
Total from above	221	234	228	246	269	267

Table 2 Top five clothing exporters worldwide from 2017 to 2022 (World Trade Organization, 2018, 2019, 2020, 2021, 2022, 2023)

	Value of exports in billion dollars					
	2017	2018	2019	2020	2021	2022
China[1]	158	158	152	142	176	182
EU	130	143	136	125	151	156
Extra-EU exports	31	34	43	38	43	45
Bangladesh	29	32	34	28	34	45
Vietnam	27	32	31	29	31	35
Turkey	15	16	16	15	19	20
Total from above	359	381	369	339	411	438

The total value of textile exports of the regions considered has generally been increasing, growing, on average, 5.1% per year, between 2017 and 2021, and slightly decreasing in 2022. On the other hand, the total value of clothing exports has been fluctuating. However, it has increased 6.1% from 2021 to 2022. There is an overall increase in exports of textiles and clothing from the regions considered between 2017 and 2022. China and the EU have maintained their top positions as textile and clothing exporters.

Table 3 and 4 show the textile and clothing imports values, respectively, between 2017 and 2022, from the top five importers in 2022. In both textiles and clothing, EU imports from outside the bloc (extra-EU) show a general upward trend between 2017 and 2022, particularly recovering after the 2020 pandemic dip — indicating growing dependence on external suppliers. Even though intra-EU textile imports remained relatively stable, clothing imports in the EU rose sharply in 2022, suggesting an increased internal demand or a reorganisation of sourcing within the region.

Table 3 Top five textile importers worldwide from 2017 to 2022 (World Trade Organization, 2018, 2019, 2020, 2021, 2022, 2023)

	Value of imports in billion dollars					
	2017	2018	2019	2020	2021	2022
EU	74	77	67	87	79	78
Extra-EU imports	31	33	30	50	37	38
United States of America	28	30	31	45	40	39
Vietnam	14	18	16	16	19	19
Bangladesh	9	11	10	9	15	15
China[1]	17	18	16	14	16	12
Total	142	154	140	171	169	163

Table 4 Top five clothing importers worldwide from 2017 to 2022 (World Trade Organization, 2018, 2019, 2020, 2021, 2022, 2023)

	Value of imports in billion dollars					
	2017	2018	2019	2020	2021	2022
EU	187	204	180	168	195	215
Extra-EU imports	99	106	95	86	97	111
United States of America	88	92	95	82	106	116
Japan	28	30	30	26	27	27
United Kingdom[2]	-	-	26	26	23	26
China[1]	7	8	9	9	12	11
Total from above	310	334	340	311	363	395

The overall value of textile imports from the regions studied has increased by 5%, on average, every year from 2017 to 2021, slightly decreasing in 2022. Moreover, the total value of clothing imports in the considered regions has been rising, having increased by 8.1% from 2021 to 2022 in particular. There is an overall growth in the imports of

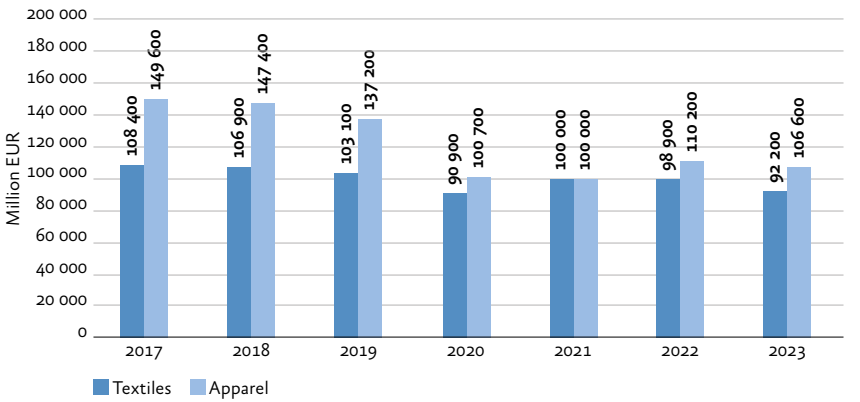
textiles and clothing from the regions above between 2017 and 2022. The EU and the United States of America have retained their top positions as textile and clothing importers.

1.2. The European level

1.2.1. Production

For the past years, the EU has been amongst the biggest textile and clothing exporters worldwide. Nonetheless, as shown in Figure 1, the production values have been gradually decreasing since 2017. In 2023, the combined production of textile and clothing reached 198.800 million euros.

Figure 1 EU Production (manufacture of textiles and wearing apparel) from 2017 to 2023 (Eurostat, 2024)

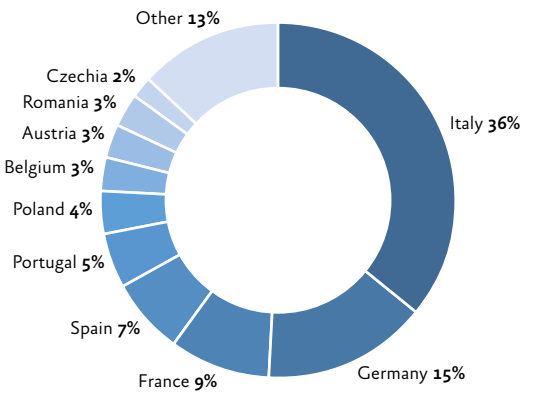


Italy, France, Germany, Spain and Portugal are the biggest producers in the EU textile and clothing industry, accounting for about three-quarters of the total production (European Commission, 2022a). While countries in Southern and Eastern Europe, such as Italy, Greece, Portugal, Romania, Bulgaria, Spain and France, have higher shares of clothing production, northern countries, such as Germany, Belgium, the Netherlands and Austria, have higher shares of textile production, particularly in technical textiles (European Commission, 2022a).

In 2019, the industry generated a turnover of 162 billion euros in the EU (European Commission, 2022a). However, the COVID-19 pandemic has had a detrimental impact on the industry, resulting in a 9.2% contraction in textile turnover and an 18.1% contraction in clothing turnover in 2020, compared to 2019 (European Commission, 2022a). Nonetheless, the industry has been slowly recovering. According to EURATEX estimates, in 2023, the turnover of the textile and clothing industry in the EU-27 region increased by 2%, compared to 2022, to 170 billion euros (54% from the textile industry and 46% from clothing).

Figure 2 shows the distribution of the turnover shares by member state, for 2023, representing each country's proportion of total industry revenue. Italy stands out as the top performer, followed by Germany, France and Spain. Portugal is positioned in fifth place, contributing to 5% of the EU turnover share.

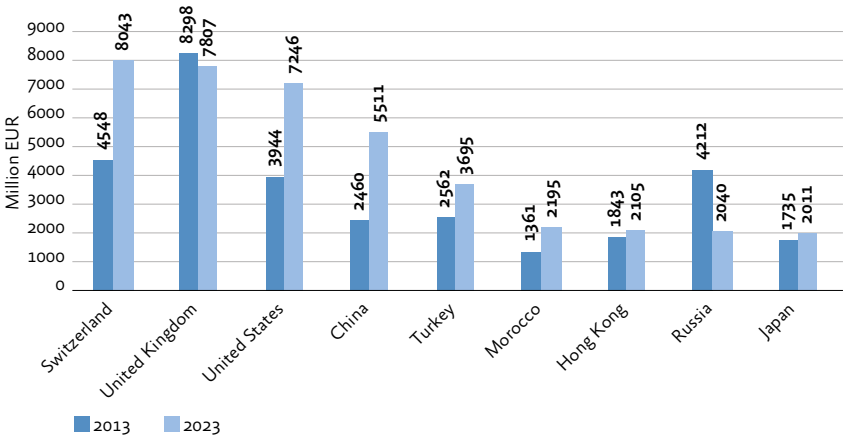
Figure 2 EU turnover share (total industry revenue per country) in 2023 (EURATEX, 2024)



1.2.2. Buyers

This industry is highly globalised, with 37.7% of the turnover coming from exports in 2023 (EURATEX, 2024). As shown in Figure 3, Switzerland, the United Kingdom, the United States of America and China were the main EU export markets in 2023, followed by Turkey and Morocco.

Figure 3 Main EU textile and clothing (T&C) buyers (EURATEX, 2024)



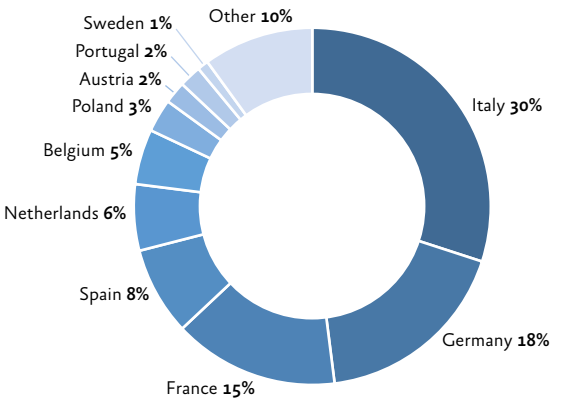
EURATEX states that EU exports increased by 37% between 2013 and 2023, while imports increased by 40% (EURATEX, 2024). Table 5 shows the EU textile and clothing export values between 2017 and 2023.

Table 5 EU clothing and textile exports from 2017 to 2023 (Eurostat, 2022; EURATEX, 2024)

Exports (Billions of €)	2017	2018	2019	2020	2021	2022	2023
Clothing[3]	31	33	36	30	33		
Textiles[3]	25	25	26	22	25	67 (+16%)	64 (-4%)
Total/Change compared to the previous year	56	58 (+4%)	62 (+5%)	52 (-14%)	58 (+11%)		

Taking a closer look at the EU members share on exports, in Figure 4, Italy was the highest contributor to the industry in 2023.

Figure 4 EU export shares by country in 2023 (EURATEX, 2024)



1.2.3. Main EU suppliers

In 2023, the top 10 EU suppliers had an 82% share in total imports (€94.3 billion of EU textile and clothing imports). As shown in Figure 5, one third of the textile and clothing products were sold from China to the EU markets (EURATEX, 2024).

Figure 5 Main EU textile and clothing (T&C) suppliers (EURATEX, 2024)

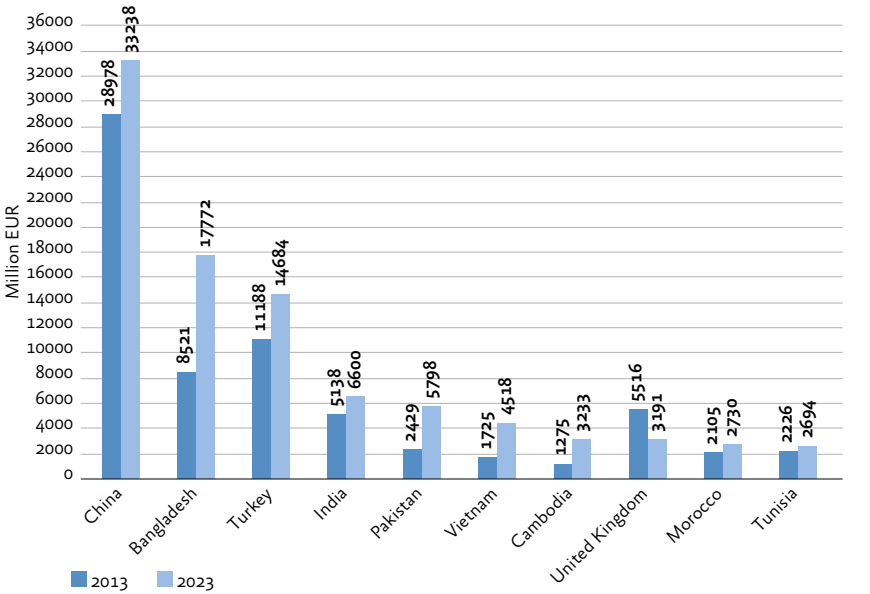


Table 6 shows the monetary value of EU imports between 2017 and 2023. Overall, the imports have increased 13% on average.

Table 6 EU clothing and textile exports from 2017 to 2023 (Eurostat, 2022; EURATEX, 2024)

Imports (Billions of €)	2017	2018	2019	2020	2021	2022	2023
Clothing[3]	74	77	80	68	72	137 (+29%)	115 (-16%)
Textile[3]	28	29	29	46	34		
Total / Change compared to the previous year	102	106 (+3%)	109 (+3%)	115 (+5%)	106 (-8%)		

1.2.4. Employment

In 2024, the EU textile and clothing sector was composed of around 194.00 companies, employing close to 1.3 million individuals, 1.1% less than in 2022 (EURATEX, 2024; EURATEX, 2026). In 2019, the number of companies was more than 160.000, employing 1.5 million individuals (European Commission, 2022a). Most of the companies are small businesses. Companies employing less than 50 people represent 89% of the European textile and clothing sector. Only 0.3% employ 250 workers or more (EURATEX, 2024).

When looking at consumption in the EU, in 2022, Europeans spent an average of 630 euros in clothing per household, (a total of 228 billion euros), an increase of 15% compared to 2021 (EURATEX, 2024).

1.3. Portugal

In addition to its relevance in the European context, the Portuguese textile and clothing industry is also a key sector in the national economy, representing around 1.7% of the country's GDP in 2024 (INE, 2025). According to the Portuguese Office for Strategy and Studies (GEE) (2024), the textile and clothing industry accounts for 7.8% of the total Portuguese exports, 17.3% of the manufacturing industry employment, and 9.9% (2.7 billion euros) of the manufacturing industry gross added value. In 2023, clothing and textile imports in the Portuguese industry slightly exceeded 5 million euros, representing a 5.4% decrease compared to the previous year. More than 50% of these imports were 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% of total imports, respectively, in 2022 (GEE, 2024).

Most of textile and clothing manufacturers are located in the North of Portugal (Porto, Braga, Guimarães and Famalicão) with 87% of the turnover and 85% of employment in 2019. In the Central Region, Aveiro (3% of total turnover) and Beiras and Serra da Estrela (about 3% of the business of the textile and clothing industry) should also be highlighted (ATP, 2019).

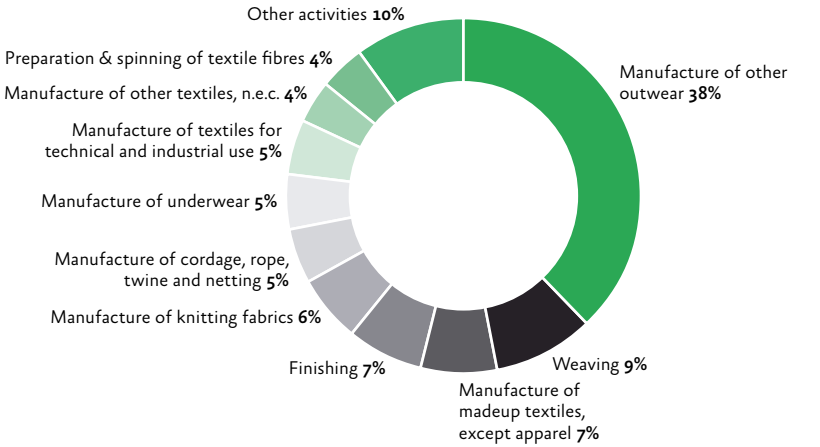
Moreover, as observed in Table 7, in 2022, there were in total 12 208 companies manufacturing textiles (30%) and wearing apparel (70%) in Portugal. These companies employed over 120 000 employees, generated a turnover of more than 8 billion of euros and a gross value added of over 2.7 billion of euros (INE, 2024a). 99.7% of the Portuguese textile and clothing companies are SMEs (GEE, 2024).

Table 7 Number of Enterprises, Gross Value Added (€) of Enterprises, Turnover (€) of Enterprises and Employees (No.) in Portugal, between 2018 and 2022, in the Textile and Wearing Apparel Industry (INE, 2024a)

Year	CAE	No. of Enterprises	Turnover of Enterprises (€)	Gross Value Added (€)	No. of Employees
2024	Manufacture of textiles	3 675	4 212 730 957	1 337 448 088	45 837
	Manufacture of wearing apparel	8 290	3 998 234 076	1 425 570 574	72 632
2023	Manufacture of textiles	3 620	4 187 831 133	1 267 638 130	46 542
	Manufacture of wearing apparel	8 511	4 177 400 020	1 492 199 548	77 994
2022	Manufacture of textiles	3621	4 421 705 679	1 225 197 565	44432
	Manufacture of wearing apparel	8587	4 414 250 754	1 485 828 049	76264
2021	Manufacture of textiles	3527	4 044 928 175	1 227 278 199	43850
	Manufacture of wearing apparel	8308	3 964 106 495	1 329 231 786	76532
2020	Manufacture of textiles	3463	3 408 680 307	1 064 462 474	43778
	Manufacture of wearing apparel	8480	3 532 061 304	1 203 197 348	77952
2019	Manufacture of textiles	3578	3 697 928 515	1 093 968 538	45126
	Manufacture of wearing apparel	8747	3 984 630 657	1 336 081 357	84114
2018	Manufacture of textiles	3542	3 801 231 873	1 101 960 957	45946
	Manufacture of wearing apparel	8754	3 998 766 902	1 347 055 487	86387

When examining the percentage of turnover by activity, in 2019, Figure 6, there is an evenly distribution of the several textile activities, such as preparation and spinning of textile fibres, manufacturing of textiles for technical and industrial use and finishings.

Figure 6 Turnover by activity (ATP, 2019, p. 9)



In terms of innovation, textile and apparel companies represent 2% of the Portuguese corporate investment in R&D, and employ 3.6% of all workers in this field and 3.7% of all researchers (GEE, 2024). From 2010 to 2021, the number of textile and clothing enterprises engaged in R&D activities increased by 153%, from 64 to 162, with their investment reaching 42.8 million euros in 2021, an increase of 80%. Around 30% of these innovation efforts were linked to processing activities, namely of fibres, yarns and fabrics, while 15.5% were focused on product development (GEE, 2024). It is also worth noting that, in 2020, Portuguese textile and clothing companies invested over 9 million euros in sustainability-oriented innovations (about 3.1% of the national average). These investments were particularly aimed at recycling waste, water or materials, reducing energy use or CO_2 emissions, and replacing conventional materials with less polluting alternatives (GEE, 2024).

As an overall tendency, greenhouse gas (GHG) emissions have decreased 36.4% in the textile and clothing production in Portugal since 2005. Nearly all of the emissions of this industry in Portugal (97.5%) stem from the burning of fossil fuels, with textile producing companies accounting for 88.1% of the sector's GHG emissions. However, there is reason to believe that Portuguese textile and apparel companies are on the path to decarbonisation, since the sector has experienced a decrease of almost 30% in carbon intensity (GEE, 2024).

Despite the challenges caused by the high labour costs and intense competition, the sector continues to be a substantial contribution to EU countries, generating jobs and exports. As the global economy evolves, the European and Portuguese textile industries will confront new challenges and possibilities. However, the sector is well-positioned to grow in the future by using its trained workforce, availability of high-quality raw materials, and advantageous trade rules.

Chapter 2
Social and economic sustainability in textiles and clothing

The contemporary understanding of sustainability originates from the report titled "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).

Figure 7 The 17 Sustainable Development Goals (United Nations, 2015)



Nowadays, these ideas around sustainable development are embodied in the 2030 Agenda for Sustainable Development, a framework proposed by the United Nations that outlines 17 goals (Figure 7) intended to steer humanity towards planetary well-being, social prosperity, peace and global collaboration (United Nations, 2015). Several scholars have linked the UN's Sustainable Development Goals (SDGs) to the sustainable development of the textile and clothing industry, particularly highlighting the role of the sector in encouraging responsible consumption and production (SDG 12) (Gardetti & Muthu, 2020). However, textiles and clothing intersect directly, or indirectly, the 17 Sustainable Development Goals, extending their impact across the environmental, social and economic pillars of sustainability (Thakker & Sun, 2023).

With regard to its environmental dimension, the textile and clothing industry can contribute to the SDGs 6 and 7 — which address access to clean water and energy, respectively — by opting for less polluting and resource-intensive raw materials and production processes (Thakker & Sun, 2023). Similarly, the carbon footprint of the sector has repercussions on SDG 13 (Climate Action), while regenerative agricultural practices, increasingly adopted in crops like cotton, support multiple targets within SDG 15 (Life on Land).

The impact of fashion on the social pillar of sustainable development is equally vast and significant. Vijeyarasa and Liu (2022) argue that the industry has the potential to promote gender equality, as outlined in SDG 5. Thakker and Sun (2023) bring forward SDG 1 (No Poverty), emphasising how garment workers, primarily in developing countries, often receive poverty-level wages. This issue can also impact SDGs 3 (Good Health and Well-Being), 4 (Quality Education), and 10 (Reduced Inequalities).

Lastly, from an economic and governance perspective, the textile and clothing industry represents a trillion-dollar sector with the potential to drive economic growth and provide decent work opportunities, as defined in the targets of SDG 8 (Thakker & Sun, 2023). Moreover, the sector's focus on innovation aligns closely with SDG 9 (Industry, Innovation, and Infrastructure).

Tackling the underlying challenges of sustainability, therefore, implies examining the intersection of environmental, social and economic factors, crossing disciplinary lines, and embracing a holistic systems-oriented approach (Abson et al., 2017).

2.1. The sustainability of the textile and clothing industry

Because of its substantial impact on the environment, society and the economy, the textile and clothing industry is undergoing a growing analysis through the lens of sustainable development (Fletcher, 2008; Clark, 2008; Jung & Jin, 2014; Mukendi et al., 2020; Daukantiene, 2023). Kate Fletcher's *Sustainable fashion and textiles: Design journeys* (2008) was one of the first books to explore the relationship between sustainability and the textile and clothing industry. The same can be said for Hazel Clark's article *SLOW + FASHION — and Oxymoron — or a Promise for the Future...?* (2008), published in Fashion Studies: The Journal of Dress, Body and Culture.

Despite its growing relevance, a widely accepted and clear definition of sustainable fashion remains elusive, primarily due to its subjective nature and extensive scope of research (Henninger et al., 2016; Reimers et al., 2016). Reimers et al. (2016) highlighted that there are different concepts falling under the sustainable fashion umbrella, such as slow fashion, green fashion, ethical fashion, and eco-fashion.

To explore how sustainability can be achieved in the clothing industry, we will focus on each of the three pillars previously mentioned. Although we separate these pillars for clarity, we recognise that they are intricately linked.

Firstly, we will focus on the influence of social practices on sustainable textile and clothing supply chains, specifically through ethical labour initiatives. This includes implementing living wages, ensuring safe working conditions, and adopting tools to enhance transparency and traceability. The social chapter will conclude by emphasizing the importance of diversity, equity and inclusion practices. Secondly, as we focus on the economic dimension of sustainability, we will examine the relevance of business ethics and innovation. This section includes an overview of the development of new business models, advancements in technology and the latest legislative measures and initiatives aimed at enhancing consumer education. Finally, in the following chapter, we will provide an in-depth exploration of environmental sustainability, as this theme is also the primary focus of our research.

2.2. Social sustainability

Although most studies on textile and clothing sustainability primarily focus on investigating the environmental impacts of the industry (see, for example, Bailey et al., 2022; Niinimäki et al., 2020; Jacometti, 2019), there is growing scrutiny of brands due to their social practices (Gualandris et al., 2015). This scrutiny intensified after the Rana Plaza incident in 2013, where over 1100 garment workers were killed in a factory building collapse in Dhaka, Bangladesh (Burke, 2013). Although it was not the first fatal accident linked to the textile and clothing sector (Hobson, 2013), it significantly increased interest in the social sustainability practices of this industry, especially in terms of ensuring safe working conditions and establishing fair wages (Henninger et al., 2016).

However, social sustainability has been part of the sustainability research in the textile and clothing sector since its pioneering works, often referred to as "ethical" fashion (Clark, 2008; Fletcher, 2008, 2010). In the following sections, we will use this term when exploring the social impacts of the textile and clothing industry, particularly focusing on wages, working conditions, supply chain transparency and traceability, and diversity, inclusion and equity practices.

2.2.1. Ethical labour practices

2.2.1.1. Living wages

Wages play a pivotal role in ensuring the well-being of garment workers, and can contribute to addressing broader issues, such as narrowing gender wage gaps and achieving inclusive economic growth (Bhattacharjee & Roy, 2016). Nonetheless, most workers, particularly those in textile and clothing supply chains in the Global South, receive compensation aligned with the national minimum wage, which, in numerous countries, fails to meet the essential costs of living (Bhattacharjee & Roy, 2016).

Bhattacharjee and Roy (2016) highlight three reasons for this issue. Firstly, textile and clothing brands and retailers are striving to maximise their profits, leading them to seek ways to minimise production costs. Secondly, manufacturers are willing to accept low profit margins due to the abundance of garment factories and workers in the Global South. If some manufacturers decline the brand's profit margins, other suppliers will be ready to step in. Thirdly, governments aim to keep minimum wages low, as this is seen as a competitive advantage in attracting foreign investment. As a consequence of aiming to reduce the retail price of clothing sold in the Global North, the well-being of garment workers is often overlooked, and wages are kept at a minimum (Bhattacharjee & Roy, 2016).

In 2023, protests erupted over the proposed minimum wage increase in Bangladesh. Throughout the preceding five years, the government had established a minimum wage of 8000 taka (€67) per month, and was now considering increasing it to 12,500 taka (€104). Trade unions, however, argued that workers required a minimum of 23,000 taka (€192) to prevent themselves and their families from starvation. Despite these pleas, in 2023, no agreement had been reached to ensure that Bangladeshis garment workers — among the lowest-paid in the world — were guaranteed a living wage (Begun & Ahmed, 2023).

There are various definitions for the concept of "living wage", but the predominant focus is on the idea that it provides the amount a worker

needs to afford a decent standard of living (Pollin, 2008). This includes the ability to cover "food, water, housing, education, health care, transportation, clothing, and other essential needs including provision for unexpected events" (Global Living Wage Coalition, n.d.). The concept of a living wage can be traced back to Adam Smith's *The Wealth of Nations* (1776), where the economist argues that the well-being of workers is contingent upon their ability to afford specific goods, and the cost of these goods should be taken into account when establishing wage levels (Mair et al., 2019).

The social sustainability of the textile and clothing industry depends on brands and manufacturers paying their workers a living wage (Fletcher, 2010). Considering that wages constitute a slim percentage of the clothing retail price — approximately one to three per cent — wage increases could be implemented without negative consequences for consumers (Bhattacharjee & Roy, 2016).

2.2.1.2. Safe working conditions

The Rana Plaza incident, which we mentioned earlier, is just one example of how poor working conditions, prevalent across the global textile and clothing supply chain, can jeopardise the safety of garment workers (Bhattacharjee & Roy, 2016). In the aftermath of the disaster in Dhaka, Hobson (2013) emphasised that the Bangladeshi government had previously admitted that around 90% of the country's capital high-rise buildings did not comply with national construction standards. Other fatal incidents linked to textile and clothing have involved factory fires, such as the Tazreen factory fire in Bangladesh, which took the lives of, at least, 112 garment workers (Clean Clothes Campaign, n.d.), and the Karachi fire in Pakistan, where the death toll surpassed 289 people, both disasters occurring in 2012 (BBC, 2012).

Consequently, in 2013, more than 50 brands and retailers developed and signed the Bangladesh Accord on Fire and Building Safety, a five-year agreement aimed at enhancing the safety of garment factories, primarily through more frequent factory inspections and safety training (Accord on Fire and Building Safety in Bangladesh, 2013). This accord is now known as the International Accord for Health and Safety in the Textile and Garment Industry, and it has expanded to include factories in Pakistan, gaining the support of almost 100 clothing companies (International Accord, n.d.).

However, other issues contribute to compromise the well-being of garment workers in textile and clothing factories, especially in countries in the global south. These include prolonged working hours, often exceeding the 48-hour work week recommended by the Asia Floor Wage Alliance, and work carried out in cramped spaces under conditions that put workers' health at risk (Yuan et al., 2022; Asia Floor Wage Alliance, 2009). Prior research has shown that garment workers are especially susceptible to work-related stress due to their vulnerabilities in the workplace, leading to both physical and mental health issues (Yuan et al., 2022; Akram, 2014). Respiratory diseases are particularly prevalent in this context (Hobson, 2013), alongside safety risks related to operating machinery without adequate protection and exposure to hazardous chemicals (Gupta et al., 2015).

To ensure safe working conditions in their supply chains, textile and clothing brands and retailers have established codes of conduct, addressing various issues from working hours to wages and prohibiting

the use of child and forced labour in their subcontracted facilities (see, for example, H&M, 2010). However, Yu (2008, p. 527) deems these tools inadequate, arguing that they "should be recognized as supplement initiatives rather than alternatives to traditional regulatory approaches, [like] state legislation and international law".

2.2.1.3. Supply chain transparency and traceability

Transparency and traceability are frequently mentioned when analysing the sustainability of the textile and clothing supply chain. While these two concepts are closely intertwined, it is important to distinguish their meanings (Garcia-Torres et al., 2022; Agrawal & Pal, 2019). Transparency involves making information accessible to the public (Marshall et al., 2015), while traceability is the capability to retrieve that information (Olsen & Borit, 2013). Transparency is sometimes seen as a catalyst for traceability (Garcia-Torres et al., 2019). However, for the concept to be comprehensive, it is not sufficient for a company to possess internal knowledge — that information must also be communicated externally (Gardner et al., 2019).

In sustainable supply chains, ethical labour practices should be both transparent and traceable. This imperative arises from the increasing demand of consumers and stakeholders, and it plays a pivotal role in fostering the sustainable development of the industry (Gardner et al., 2019). Transparency and traceability enable consumers to choose products that align with their values, facilitating the assessment of the social and environmental practices of a brand and, consequently, perceive it as more trustworthy (Egels-Zandén et al., 2015). For brands, this commitment contributes not only to ensure compliance with the legislation in place, but also to enhance their social and environmental performance, paving the way for more efficient and sustainable supply chains (Fritz et al., 2017).

However, the intricate, fragmented and multi-tiered nature of textile and clothing supply chains presents a challenge to achieving transparency and traceability (Köksal & Strähle, 2021; Clean Clothes Campaign, 2020). Adding to that is the fact that brands find a competitive advantage in not publicly disclosing their supply chain strategies (Clean Clothes Campaign, 2020). But given the increasing importance of transparency to today's consumers, brands are incorporating traceability tools, like independent certifications, to enhance the credibility of their sustainable practices (Köksal & Strähle, 2021). Despite that, Köksal and Strähle (2021) illustrate various cases where audits conducted by external organisations did not lead to actual changes in social practices. Notably, they highlight that two factories within the Rana Plaza building had been audited by the Business Social Compliance Initiative — a leading social audit protocol — a few months before the incident in 2013, underscoring the limitations of such assessments (Köksal & Strähle, 2021).

There are other tools that contribute to enhancing the transparency and traceability of textile and clothing supply chains. The activist organisation Fashion Revolution has been publishing its Transparency Index since 2017, scrutinising 250 of the largest apparel brands based on how transparent they are regarding their social and environmental practices (Fashion Revolution, 2023). On the legislative front, the European Union has adopted the Corporate Sustainability Due Diligence directive, compelling brands to undertake actions such as "identifying, bringing to an end, preventing, mitigating and accounting for negative human rights and environmental impacts in the company's

own operations, their subsidiaries and their value chains" (European Commission, 2022c). In its initial phase, the Corporate Sustainability Due Diligence directive will be implemented in EU companies with more than 5000 employees and a global turnover exceeding 150 million euros worldwide (European Commission, 2022).

2.2.2. Diversity, equity and inclusion

Despite being frequently neglected in sustainability discussions, Tsing (2009) contends that a comprehensive understanding of supply chain dynamics requires the analysis of cultural factors inherent to its labour, such as gender, race, and ethnicity. Vijeyarasa and Liu (2022) expand on this notion to explain that gender justice and sustainability in the textile and clothing sector are deeply intertwined, and one of the primary obstacles to achieving equal rights in the industry is the failure to analyse it through a gendered perspective.

In fact, women make up most of the workforce in the textile, apparel and footwear industry, particularly in the manufacturing stage, often located in the Global South (International Labour Organization, 2023). In spite of this, their involvement in the decision-making processes of the industry remains limited, as men hold dominant positions at the executive, financial, factory ownership and design levels (Athreya, 2022; Vijeyarasa & Liu, 2022). This represents not only an equality concern but also a sustainability issue.

At the supply chain level, gender inequality is notably evident in wages, with female garment workers earning less than their male counterparts, as they are often viewed as secondary earners, less inclined to negotiate their salaries or participate in labour unions (Mezzadri, 2016). Indeed, the majority of women in textile and apparel supply chains remain nonunionised, and they have been known to underreport human rights abuses in the workplace for fear of facing retaliation (Vijeyarasa & Liu, 2022). These abuses encompass gender-based violence, sexual harassment and challenges in accessing reproductive health services and products (George et al., 2017). Athreya (2022) notes that Black and Brown women are particularly susceptible to these misconducts, given the global division of textile and clothing's supply chain.

As sustainable clothing brands implement diversity, equity and inclusion programs to reduce gender and ethnicity gaps, it is crucial that their impacts are felt across all levels of the industry, spanning from marketing and design to supply chains (British Fashion Council, 2022).

2.3. Economic sustainability

Sustainability principles are reshaping conventional business models. In the apparel sector, new business models are developed, centred around reselling, renting or repairing clothes, which present significant innovations for the industry (Fletcher & Tham, 2019). Niinimäki (2015) highlights two other relevant forms of innovation propelling sustainable business models: technological advances and legislative changes.

2.3.1. New business models

The current "take-make-waste" system, under which the present-day 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 prevalent as a result of the

industrialisation of the textile and apparel sector, which led to the production of clothing in large quantities, and a substantial decrease in prices. Under this system, global fibre production has reached historical records, practically doubling from 58 million tonnes in 2000 to 113 million tonnes in 2021 (Textile Exchange, 2022). This trend is expected to persist, with Textile Exchange (2022) estimating that nearly 150 million tonnes of fibres will be produced in 2030 if textile and clothing business models remain unchanged.

As outlined by Fletcher and Tham (2019), the current pace of growth in the textile and clothing industry renders any efforts to reduce its negative impacts fruitless, especially on the environment. This is due to the fact that, historically, when resource use becomes more efficient, industries tend to increase their overall resource consumption, leading to only marginal improvements in total material efficiency (Kallis, 2017). Hence, on a planet with finite resources (Rockström et al., 2009), defying the growth logic is essential to attain a more sustainable textile and clothing industry, as it enhances the efficiency of other environmental practices like recycling or fibre choices (Fletcher & Tham, 2019).

This economic perspective is commonly referred to as degrowth theory (see, for example, Kallis et al., 2012). According to Schneider et al. (2010, p. 512), sustainable degrowth is defined as "an equitable downscaling of production and consumption that increases human wellbeing and enhances ecological conditions at the local and global level, in the short and long term", ensuring that "human progress without economic growth is possible". Fletcher and Tham (2019) apply this principle to the textile and clothing industry by highlighting practices such as repairing and consistently reusing existing clothing. These actions surpass the traditional consumerist mindset in the textile and apparel industry, emphasising economic models that thrive on time, creativity, community and imagination. Or, as the two authors put it:

> They draw upon well-established practices including thrift, care for others, the gift economy, the informal hand-me-down channels through which clothes pass between friends and family. They stretch resources, making them go further, appreciating them in greater detail, infusing them with human warmth and memory, folding them into others' lives. (p. 46).

Textile and clothing business models rooted in these principles are closely connected with the circular economy, as they keep garments and textiles in circulation for an extended period. This can be achieved through practices such as extending product durability, repairing, reusing, repurposing and recycling (Coscieme et al., 2022).

When discussing degrowth theory, it is crucial to acknowledge potential economic challenges. Reduced production and consumption can decelerate the economy, historically leading to adverse social effects, particularly unemployment (Kallis, 2017). Nevertheless, Schneider et al. (2010) contend that sustainable degrowth entails a deliberate transition process, aiming to alleviate these problems and yield social and environmental benefits.

2.3.2. Drivers for sustainability in the textile and clothing industry

2.3.2.1. The use of technological innovations

Technological innovation is considered a pivotal driver of competitive advantage for businesses, especially within industries undergoing profound transformations (Anderson & Tushman, 1990), as is the case with the textile and clothing industry today. In the sustainability conversation, Niinimäki (2013) categorises innovations into two main segments: sustainable innovations and eco-innovations. The first adopts a systems-based approach, addressing all aspects of a business, from products to its organisational structure; eco-innovations pertain to "products, services or processes that offer value both for business and customer, but also to the environment through significant decrease in environmental impact" (p. 128). Similarly, Ottman (2011) suggests various strategies for sustainability-oriented innovations, some involving innovation at the systems level, such as developing new business models, and others focusing on the technological level, like the creation of new materials.

In the previous section, we addressed the importance of systemic sustainability-oriented innovations. However, textile and clothing sustainability studies extensively analyse technological improvements as well, recognising their pivotal role in promoting positive environmental and social practices within the industry (Ikram, 2022). Ikram (2022) specifically highlights the contributions of 3D printing and blockchain technology to the sustainability of the textile and apparel sector.

Additive technology, also known as 3D printing, has been particularly employed in the manufacturing of garments to minimise waste (Chakraborty & Biswas, 2020; Todeschini et al., 2017). According to Chakraborty and Biswas (2020, p. 2), "it is used to make an end product or part of it in a layer-by-layer fashion employing a digitised model using liquid or rigid substances". This is a more sustainable and cost-effective process when compared to conventional manufacturing because it uses just the right quantity of material for each layer and trims away any excess to achieve the desired shape (Chakraborty & Biswas, 2020).

Blockchain technology enhances traceability and transparency in the textile and clothing supply chain by helping retrieve detailed product information (Ikram, 2022; Brun et al., 2020). For example, Hugo Boss has adopted blockchain technology to trace the origin of their cotton products (Brun et al., 2020). Furthermore, clothing rental companies leverage this technological advancement to provide optimal product information to their users (Choi et al., 2020).

Textile Genesis and the future of traceability

With a mission to enhance supply chain transparency, Textile Genesis exemplifies how technology can be used to advance sustainability efforts in the textile and clothing industry. This platform meticulously traces every stage of a garment's journey, from raw material production to retail distribution, particularly for natural fibres such as cotton, wool, silk and cashmere, as well as recycled polyester. By creating a digital twin, Textile Genesis enables suppliers, brands and eventually consumers to monitor the journey of a traced fashion good in real-time, all from their screens. As the European Union implements the digital product passport in the textile and clothing sector, traceability technology will become more crucial than ever. And besides supporting clear and verifiable reporting, it also contributes to reducing the ecological footprint of production by identifying hotspots for innovation and decarbonisation.

There are other types of sustainability-oriented technological improvements that have emerged in the textile and clothing industry, whether based on materials (see, for example, Press, 2023) or design practices (Niinimäki, 2013). These topics will be further explored in Chapter 3. Nonetheless, to increase their efficiency, these practices should be integrated within a broader framework of sustainability-oriented innovation that challenges the norms of the entire industry (Niinimäki, 2013).

2.3.2.2. Legislation-driven sustainability

In the upcoming years, the textile and apparel industry is set to face a wave of regulation, led by the European Union (Gronholt-Pedersen, 2023). In the European Union, several pieces of legislation have been adopted, proposed or drafted under the EU Strategy for Sustainable and Circular Textiles. In contrast, regulatory efforts in the United States have primarily occurred at the federal level, with California and New York emerging as the most active states in advancing textile-related legislation (Business of Fashion and McKinsey & Company, 2023).

The European Union's vision for the textile and clothing industry balances economic, social and environmental considerations through four comprehensive commitments: enhancing the durability, repairability and recyclability of products; replacing fast fashion with high-quality, affordable alternatives; expanding services centred on reuse and repair; and enhancing the economic competitiveness and resilience of the sector (European Commission, n.d.-a).

Multiple pieces of legislation have already been adopted to meet these criteria. The Waste Framework Directive, which governs waste management in the EU, proposed an amendment that mandates Member States to establish textile waste collection systems by 2025 (European Commission, 2023a). This directive is also accountable for establishing extended producer responsibility (EPR) schemes, under which garment producers will financially contribute to the collection, sorting, reuse and recycling of textile waste (European Commission, 2023a). Other two directives have already been adopted, namely the Corporate Sustainability Reporting Directive (CSRD) and the Corporate Sustainability Due Diligence Directive (CSDDD), instructing companies to disclose information about their social and environmental practices (Business of Fashion and McKinsey & Company, 2023). Both pieces of legislation have attracted significant attention from EU businesses. The CSRD, an expansion of the Non-Financial Reporting Directive announced in 2014, establishes a standardised framework for EU-listed companies to report on environmental, social and governance topics, aligning with global standards like the Global Reporting Initiative. But, beyond reporting, the CSRD incorporates mechanisms to ensure the reliability of disclosed information, to foster trust between stakeholders (Celli et al., 2024). In addition, the CSDDD, seeks to balance the mitigation of the negative impact of EU companies on the environment and the preservation of their competitive edge. It integrates a wide array of sustainability initiatives, with a strong emphasis on climate targets aligned with the Paris Agreement. Several iterations of this directive were proposed, though critiques led to the adoption of a less strict version of the CSDDD, whereby compliance is required only for a narrower group of EU firms (Marx, 2025).

Additionally, four regulations have been proposed in the EU. The Ecodesign for Sustainable Products Regulation sets forth criteria to

enhance circularity and environmental sustainability in the manufacturing process and recommends the development of digital product passports to facilitate sustainability communication (European Commission, n.d.-b). There is also a provisional political agreement on updated rules for waste shipments, prohibiting or restricting member states from exporting waste to the Global South (Council of the European Union, 2023). The management of textile waste will also be influenced by the EU's proposal to ban the destruction of unsold textiles and footwear (European Parliament, 2023a). The fourth proposal addresses marketing and publicity concerns through the Green Claims Directive, which aims to eradicate greenwashing in sustainability communication (European Commission, 2023b).

Legislation on microplastics, which seeks to minimise their release during the manufacturing stage, is also in the drafting process within the EU (Business of Fashion and McKinsey & Company, 2023). Simultaneously, the Textile Labelling Regulation is under revision "to introduce specifications for physical and digital labelling of textiles, including sustainability and circularity parameters based on requirements under the proposed Regulation on eco-design for sustainable products" (European Parliament, 2023b).

Although these measures are important for the sustainability of the textile and clothing industry, they must be accompanied by a shift in consumer culture (Niinimäki et al., 2020). In spite of the sector's efforts to minimise its environmental, social and economic impact, the overall positive changes have been largely eclipsed by rising levels of fast fashion consumption. This means that any shifts towards sustainability cannot arise solely from governments and companies; consumers must also play their part (Niinimäki et al., 2020).

2.3.2.3. The need for consumer education

As textile and clothing brands improve the social, environmental and economical sustainability of their supply chains, consumers are expected to alter their consumption habits to progressively include more eco-friendly products; however, that is not always the case (Todeschini et al., 2017; Bonini & Oppenheim, 2008). Bonini and Oppenheim (2008) argue that, although this gap is frequently attributed to the negative traits perceived by the consumers, it is businesses that often fall short in educating their customers about the advantages of sustainable products. With regards to textiles and clothing, consumer education plays a crucial role in steering behavioural changes toward sustainable consumption by fostering critical thinking about the industry (Shafie et al., 2021; Todeschini et al., 2017).

Consumer education refers to the way companies assist their customers in acquiring the skills and abilities needed to understand the information provided (Burton, 2022). Empowered consumers, with access to ample information from various sources, feel more in control and capable of making informed choices (McGregor, 2005). This can lead to several benefits for consumers, firms and the society. Firstly, as businesses invest more in educating their customers, they become more likely to trust the organisations offerings and become loyal consumers (Burton, 2002). Secondly, as co-creation becomes more prevalent in sustainable business models, educational efforts can add value by enabling knowledge transfers between consumers and firms (Palakshappa & Dodds, 2021). The better customers understand the advantages of a particular product or service, the more likely organisations are to provide greater value to their audience (Bell et al., 2017).

This notion becomes even more crucial in sustainability communication, as businesses are responsible for providing transparent, clear and evidence-based information to their consumers (UNEP & UNFCCC, 2023). To assist fashion communicators and marketers in this task, the United Nations Environment Programme (UNEP) and the United Nations Framework Convention on Climate Change (UFCCC) developed "The Sustainable Fashion Communication Playbook" (2023) with four key goals: counteracting misinformation and greenwashing, reducing messages that promote overconsumption, redirecting consumer aspiration towards sustainable lifestyles, and empowering consumer to demand action (UNEP & UNFCCC, 2023).

Another tool that has proven particularly crucial in empowering clothing consumers is the digital product passport (DPP), as proposed in recent EU legislation (Walden et al., 2021). According to Adisorn et al. (2021, p. 2), the DPP "is intended to provide consistent 'track and trace' information on the origin, composition, repair and dismantling options of a product, as well as on its handling at the end of its service life".

While there is still limited information on how this tool will apply to textile and clothing products, the European Union has already integrated the DPP into Battery Regulation. In this context, companies are required to provide consumers with details such as the carbon intensity of the manufacturing process, the origin and composition of materials, including raw materials and hazardous chemicals, the presence of renewable materials, information on repair, repurposing and dismantling operations, as well as the treatment, recycling and recovery processes that batteries may undergo at the end of their lifespan (Regulation 2023/1542). Walden et al. (2021) argue that the digital product passport will serve as a valuable tool to inform consumers and assist them in making more responsible choices.

Even though educating customers about their purchasing choices is immensely valuable in developing a more sustainable textile and clothing industry, companies should also empower consumers to fulfil their roles as active citizens and demand increased action from businesses and policymakers. Individual behavioural change is a crucial aspect in the journey toward sustainability in the textile and clothing industry, but governments and companies are also responsible for providing policies, services and products that address the broader societal, environmental and economic needs for a sustainable industry (UNEP & UNFCCC, 2023).

Chapter 3
Environmental sustainability in textiles and clothing

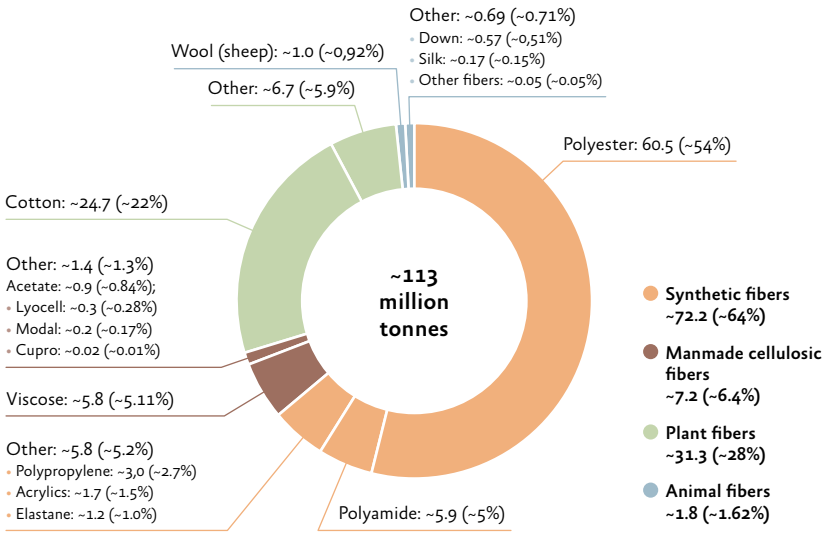
The environmental impacts of the textile and clothing industry are substantial and widespread, as detailed in reports such as the Ellen MacArthur's Foundation *A New Textiles Economy: Redesigning Fashion's Future* (2017) and McKinsey & Company's *Fashion on Climate: How the Fashion Industry Can Urgently Act to Reduce its Greenhouse Gas Emissions* (2020).

The rapid growth of textile production and clothing consumption in recent decades has played a major role in increasing global carbon emissions, water pollution, natural resource consumption and waste generation (Juanga-Labayen et al., 2022; Leal Filho et al., 2022; Textile Exchange, 2022; Niinimäki et al., 2020; Ellen MacArthur Foundation, 2017). For this reason, sustainability in textile and clothing is commonly depicted as an effort to mitigate these environmental impacts (Jung & Jin, 2014). Research indicates that to mitigate these impacts, textile and clothing companies must focus on three key areas: materials (Niinimäki, 2010), resource consumption (Daukantiene, 2023), and transitioning from a linear economy to a circular economy (Ellen MacArthur Foundation, 2020).

3.1. Materials and fibre choices

Materials constitute the first key area on which textile and clothing companies must focus to become more sustainable. The annual Textile Exchange *Preferred Fiber and Materials Market Report* shows that, in 2021, global fibre production reached a record of 113 million tonnes. As seen in Figure 8, approximately 64% of fibre production consists of synthetic fibres, with polyester alone weighting 54% in the global market. Natural fibres like cotton, wool and silk account for nearly 30%, while the remaining share pertains to manmade cellulosic fibres, specifically viscose (Textile Exchange, 2022). Compared to previous years, there has been a steep increase in the use of synthetic fibres, to the detriment of natural sources (Textile Exchange, 2022).

Figure 8 Global fibre production in 2021 (Textile Exchange, 2022, p. 10)



Polyester is the most widely produced fibre globally, recognised, on the one hand, for its durability and low prices (Smelik, 2023) and, on the other hand, for its detrimental environmental impact. Like other synthetic fibres, polyester is derived from fossil fuels (Johnston & Hallett, 2014), largely the most polluting industry worldwide, accounting for 75% of global greenhouse gas emissions (United Nations, 2024a). Goyal and Nayak (2020) emphasise that the production of polyester requires higher energy consumption compared to natural fibres. Furthermore, several studies place synthetic fibres as one of the main sources of microplastic pollution (Browne et al., 2011; Cesa et al., 2017). These plastic particles are released in every step of a garment's lifecycle, from production to disposal, and even during domestic washings (Cesa et al., 2017).

In contrast, natural fibres are considered a more sustainable alternative for several reasons. Firstly, they originate from renewable resources, such as plants and animals (Goyal & Nayak, 2020). Secondly, they are biodegradable, thereby eliminating the issue of waste generation associated with synthetic fibres (Muthu et al., 2012). However, natural fibres, particularly cotton, have also notable negative environmental impacts. Cotton is not only a water-intensive crop, but it is also associated with the use of hazardous chemicals that pose a risk to the health of farmers and contribute to soil degradation and water contamination (Mancini et al., 2008; Jung and Jin, 2014).

To address these challenges, there has been a growing interest in adopting organic and regenerative practices for the cultivation of natural fibres. Organically grown cotton, for instance, is free from any synthetically compounded chemicals, such as pesticides, which improves soil quality (Murugesh Babu et al., 2013).

Regenerative agriculture, on the other hand, lacks a widely accepted definition (Elevitch et al., 2018); but it is often characterised by practices aimed at improving soil quality, managing resources efficiently and mitigating the impacts of climate change by capturing carbon (Schreefel et al., 2020).

In addition to these more conventional types of fibres, certain manmade materials have been promoted by sustainable textile and clothing brands as a more environmentally friendly option, though at a smaller production scale. For example, Piñatex is an alternative to animal leather. It is composed of 80% pineapple leaf fibres and 20% polylactic acid fibres (Mazotto, 2022). A similar process is employed for Apple Skin (derived from apple waste) and Mylo, cultivated

from mycelium cells. Whilst these plant-based materials may exhibit sustainable attributes, notably aiding in reducing waste generated by the food industry, they still have significant environmental impacts. Specifically, their plastic-derived components prevent them from being fully biodegradable (Mazotto, 2022) and make them prone to releasing microplastics.

Moreover, emerging innovative materials, often referred to as next-gen 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, equating to approximately 13 million tonnes (BCG & Fashion for Good, 2025). The adoption of such materials not only has the potential to significantly reduce the environmental footprint of the textile and apparel industry but also to lower production costs for brands and suppliers (BCG & Fashion for Good, 2025).

Organic cotton — myths and facts

Although initially perceived as an eco-friendly option, organic cotton is often subject to misinformation and mixed opinions. In this section, we address some of the most common myths and facts about this fibre in terms of its sustainability performance.

Water use: In the "Organic Cotton Market Report 2017", Textile Exchange presented a life cycle assessment (LCA) of organic cotton farming, stating that this fibre consumes 91% less water than conventional cotton (2017, p. 54). Several experts defied this number, culminating in the Transformers Foundation 2021 report "Cotton: A Case Study in Misinformation", where it reads that the numbers obtained by Textile Exchange were achieved "by comparing organic fields that happen to be largely rainfed (green water) to conventional cotton fields that happen to use irrigation (blue water)" (2021, p. 43). In the same year, Textile Exchange removed this LCA from their 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 known critically-reviewed correlation between organic cotton farming and reduced water consumption in cotton farming" (2021, p. 42). And that still holds true until today.

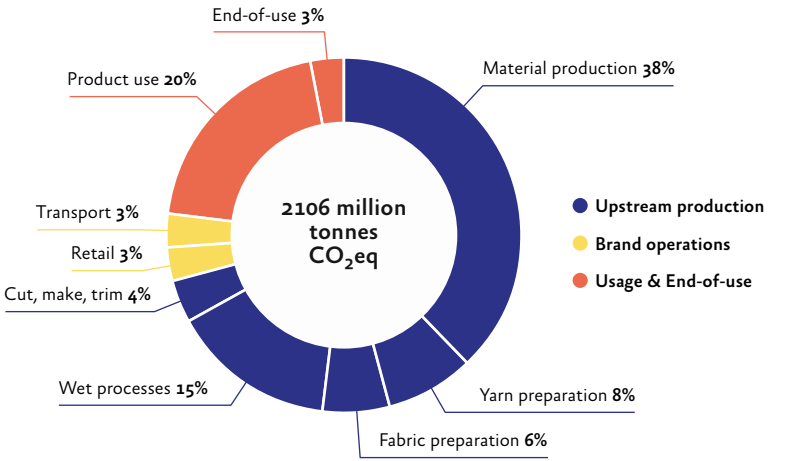
Certifications: Organic cotton is frequently certified by independent entities like Better Cotton and the Global Organic Textile Standard (GOTS). Their mission is to develop, implement and evaluate certification schemes related to organic farming methods, specifically for cotton production (GOTS, n.d). Consumers generally trust these labels; however, recent allegations of corruption have diminished their reliability. Better Cotton-certified products, for instance, have been linked to deforestation and labour exploitation in Brazil (Earthsight, 2024). Additionally, the European Center for Constitutional and Human Rights revealed that GOTS-certified cotton had been sourced from Xinjiang, a Chinese province associated with forced labour (ECCHR, 2021). This led to a ban on cotton from this region, which has been in effect for GOTS products since August 2022 (GOTS, 2022). These and other cases have called into question the validity of certifications that classify organic cotton as sustainable.

3.2. Reducing greenhouse gas emissions

Fibre production is not the only stage in the supply chain responsible for the detrimental impact of textile and clothing on the environment. This industry is widely recognised as one of the most polluting globally (Niinimäki et al., 2020; Daukantiene, 2023). One significant form of pollution generated by the industry is carbon emission, and more broadly greenhouse gas emissions. Research conducted by McKinsey & Company (2020) revealed that textile and clothing was responsible for over two billion metric tonnes of greenhouse gas (GHG) emissions in 2018, accounting for 4% of the world's total. Other sources paint a more concerning picture, suggesting that this figure could be as high as 10% of the global GHG emissions (European Parliament, 2020). In contrast, the Apparel Impact Institute (2023) estimates the contribution of the apparel sector at 1.8%.

Figure 9 details the contribution of different sectors within the textile and clothing value chain for the industry's greenhouse gas emissions according to McKinsey & Company. Material production and wet processes, like dyeing, emerge as the most impactful stages, accounting for 38% and 15% of emissions, respectively. Furthermore, the product use phase, involving consumer activities such as washing and ironing, also contributes significantly to the sector's carbon footprint, standing at 20% (McKinsey & Company, 2020).

Figure 9 Greenhouse gas emissions of the apparel and footwear value chain in 2018 (McKinsey & Company, 2020, p. 5)



Also referred to as decarbonisation, the process of mitigating greenhouse gas emissions can be accomplished by reducing overproduction, investing in energy efficiency improvements and embracing renewable sources of energy, among other changes (McKinsey & Company, 2020).

In line with the Paris Agreement goal to limit the temperature increase to 1.5°C above pre-industrial levels (Paris Agreement, 2015), fashion stakeholders have united in their efforts to reduce emissions and transition towards a net-zero industry, where nature is capable of capturing the residual levels of greenhouse gas produced (United Nations, 2024b; Fashion Industry Charter for Climate Action, 2021). These commitments are outlined in the "Fashion Industry Charter for Climate Action", which features 100 signatories from 23 countries and nine industry sectors (United Nations Framework Convention on

Climate Change, n.d.). To meet this goal, McKinsey & Company (2020) estimate that the textile and clothing industry needs to cut its GHG emissions by half by 2030.

3.3. Better managing natural resources

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 primary drivers of deforestation associated with textiles is the production of manmade cellulosic fibres, such as viscose, lyocell and modal, which are derived from wood (Granskog et al., 2020; Textile Exchange, 2022). Canopy (n.d.), a global leader in forest protection, estimates that over 300 million trees are logged annually for textile production, with 30% sourced from endangered and ancient forests.

Another contribution of this industry to biodiversity loss is through the intensive use of synthetic pesticides in crops like cotton, which causes soil degradation and water contamination (Muthu & Gardetti, 2016). However, the environmental footprint linked to water and chemicals extends well beyond the raw material production phase. According to Kant (2012, p. 23), "the daily water consumption of an average sized textile mill, having a production of about 8000 kg of fabric per day, is about 1.6 million litters". The dyeing process alone consumes, on average 16%, of this volume and contributes up to 20% of the mill's wastewater (Kant, 2012). Throughout the entire garment manufacturing stage, more than 1900 chemicals can be utilised, with 165 of them classified by the European Union as hazardous to both human health and the environment (Šajn, 2019).

3.4. Reducing the environmental impact of packaging and transport

Another widespread issue affecting the textile and clothing sector, as well as various other industries, is the environmental impact of packaging. In the European Union, packaging is estimated to be a major consumer of virgin materials, accounting for up to 40% of the total plastic production and 50% of paper use (European Commission, 2022b). But the adverse environmental effects of packaging surpass its resource consumption; the packaging industry also produces substantial amounts of waste, as many materials are not recyclable (Jestratijevic & Vrabič-Brodnjak, 2022). Jestratijevic et al. (2022) have identified seven strategies for the textile and clothing industry to reduce the environmental impact of packaging. These strategies include: rethinking packaging solutions, reducing packaging size, refusing plastic packaging, reusing and recycling packaging materials, repurposing components, and rotting or composting the package.

Another crucial, but often overlooked, issue is transportation. According to data from McKinsey & Company (2020), transportation in the apparel and footwear value chain accounts for approximately 3% of its greenhous gas emissions. The report asserts that adopting more sustainable transportation modes — specifically, increasing sea transport from 83% to 90% and reducing air transport from 17% to 10% — could cut up to 39 million tonnes of greenhouse gas emissions (McKinsey & Company, 2020), since the carbon footprint of air transport can be up to 14 times greater than that of sea transport (Systain, 2009). Despite this knowledge, clothing brands still prioritise air transport for its speed. For instance, the Inditex group operates an average

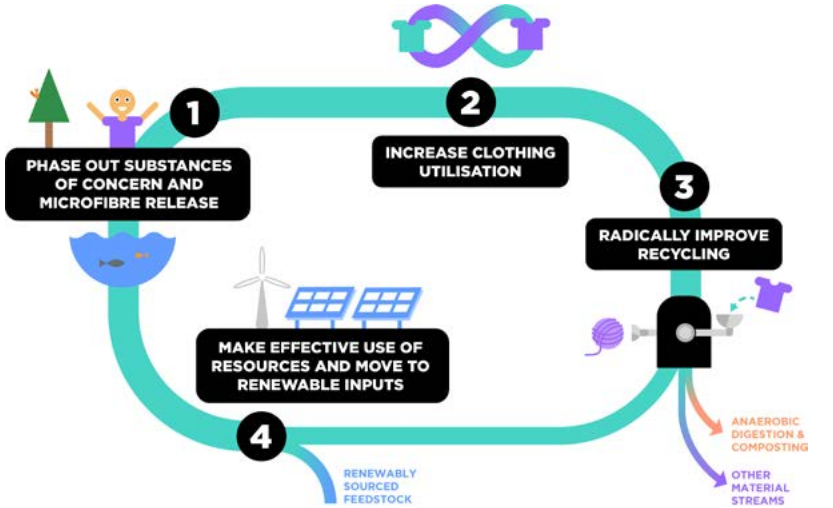
of 32 flights per week at the Zaragoza airport near its headquarters (Hachfeld & Regenass, 2023).

3.5. Transitioning to circular practices

The Ellen MacArthur Foundation has played a crucial role in advancing circularity within the textile and clothing industry by applying the principles of the circular economy, as outlined by The British Standard Institution (2017), to address the unique challenges within the clothing and textile sector. This blueprint for circular fashion is outlined in the Ellen MacArthur Foundation's *Vision of a circular economy for fashion* (2020, p. 2), stating that "in a circular economy for fashion, products (apparel, footwear and accessories) are used more, made to be made again, made from safe and recycled or renewable inputs." These principles oppose our existing linear economy, also known as a "take-make-waste" system (Ellen MacArthur Foundation, n.d.), where materials are extracted from the environment and transformed into products that are eventually discarded at the end of their lifecycle. This creates two significant issues at both ends of the system: an excessive consumption of resources and a substantial amount of waste production (Neves & Marques, 2022).

A circular economy, as exemplified in Figure 10, is based on three primary actions: maintaining products and materials within the value chain; minimizing waste and pollution; and regenerating nature (Ellen MacArthur Foundation, n.d.). In textiles, clothing and various other industries, this can be accomplished by extending the lifecycle of products and following directives such as reducing, reusing and recycling (Kirchherr et al., 2017), as we will examine next.

Figure 10 Example of a circular textile economy (Ellen MacArthur Foundation, 2021a)



3.5.1. Designing products for a circular economy

Achieving circularity for textile and clothing products begins at the outset of the supply chain — the design stage — where the European Commission (2020) estimates that 80% of the environmental impact of a product is established. To mitigate this impact, the Ellen MacArthur Foundation (2020, p. 7) recommends designing for disassembly, which is a principle "that enables the product to be taken apart in such a way that allows components and materials to be reused, remade or recycled". Additional circular clothing design approaches involve designing to minimise waste, through zero-waste pattern cutting, or fully-fashioned construction, among other practices (Dan et al., 2023).

After incorporating circularity into the design process, it is crucial to ensure that garments are built to last a considerable amount of time. In textile and clothing, product durability can manifest in two forms: physical durability, encompassing the material qualities that render the garment resistant to damage and wear, and emotional durability, which relates to the enduring relevance and desirability of a garment (Ellen MacArthur Foundation, 2020). Fletcher (2017) argues that physical durability can be achieved by using long-lasting and robust materials; however, in the realm of emotional durability, design approaches alone are insufficient to counteract the perceived obsolescence of garments — it calls for a behavioural change from consumers.

The increasing adoption of services that improve product durability, particularly on the emotional front, is evidence that consumer behaviours are indeed changing. In 2021, clothing business models that provided rental, resale, repair and remaking services represented a market worth 73 billion dollars (Ellen MacArthur Foundation, 2021b). These circular models are expected to continue growing. The Ellen MacArthur Foundation (2021b) estimates that, by 2030, they will represent 23% of the global clothing market. And while all these services play a crucial role in maintaining products and materials in circulation, it is important to note that the most sustainable action for textile and clothing circularity is reusing (Ellen MacArthur Foundation, 2020).

3.5.2. Minimising waste and pollution

Textile waste can be defined as "discarded or unwanted material from the production and use of fibre, textile and clothing" (Juanga-Labayen et al, 2022, p. 176). Textile waste falls into three categories (Chavan, 2014): pre-consumer waste (or clean waste), mostly composed of factory raw material waste; post-consumer waste, which consists in garments and textiles discarded by consumers; and industrial waste (or dirty waste), which originates from commercial and industrial textile applications and is most likely to be chemically contaminated. Post-consumer waste is especially alarming for the industry, as 73% of the discarded garments end up in landfills or are incinerated. Additionally, 10% of textile materials are lost during garment production due to processes such as factory offcuts (Ellen MacArthur Foundation, 2017).

It is estimated that less than 1% of materials used in clothing production, whether discarded in pre- or post-consumer stages, are recycled into new clothing. This recycling rate is notably lower compared to other industries, such as the single-use plastic packaging industry, with a recycling rate of approximately 2% (Ellen MacArthur Foundation, 2017).

Many of the measures that help minimise waste and pollution in the textile and clothing industry also contribute to maintaining materials and products in circulation, as they facilitate the transformation of old materials into new ones (Ellen MacArthur Foundation, 2020). Besides employing design practices that mitigate waste generation, as detailed in previous paragraphs, it is also essential to address post-consumer waste through initiatives like remaking and recycling.

The Ellen MacArthur Foundation (2020, p. 8) defines remaking as an "operation by which a product is created from existing products or components", exemplified by actions like disassembling, re-dyeing or restyling. Recycling, on the other hand, reverts the garment to its material level, which can be achieved through either mechanical or chemical processes (Juanga-Labayen et al., 2022). In mechanical textile

recycling, garments are shredded with the aim of recovering fibres, typically resulting in a reduction in their quality. Chemical textile recycling extracts resources through chemical treatments, and the fibres can generally maintain a quality level comparable to virgin materials (Juanga-Labayen et al., 2022; Ellen MacArthur Foundation, 2017). Textile recycling practices can also be categorised as upcycling — when the product crafted from the recycled material holds greater value than its original version —, or downcycling — where the opposite happens. These practices may operate within closed-loop systems, indicating that the recycled result closely resembles the discarded product, or in open-loop systems, when the outcome is distinct (Juanga-Labayen et al., 2022).

Despite its advantages in waste reduction, textile recycling faces significant challenges. One major issue is the difficulty in recycling mixed fibres, particularly when synthetic and natural fibres are combined. Additionally, incorporating accessories made from various materials, such as buttons, zippers and sewing threads, complicates the recycling process (Daukantiene, 2023). These challenges highlight the importance of designing for disassembly to achieve textile and clothing circularity.

Chapter 4
Sustainability-oriented innovation

4.1. Defining SOI

Recent research works call for a focus on innovation for sustainability (Brockhaus et al., 2019; Juntunen et al., 2019; Lee & Zhang, 2019; Van Wassenhove, 2019), as innovations "are needed to incorporate environmental, social, and economic considerations into the production and consumption patterns of business and society" (Juntunen et al., 2019, p. 332). In the 1990s, the term eco-innovation was commonly used to refer to environmentally sustainable innovation (Viale et al., 2022). Nowadays, terms such as "green innovation", "eco-innovation", "environmental innovation" and "sustainability-oriented innovation" are also prevalent in research to designate environmentally sustainable innovations (Schiederig et al., 2012). In this research, we adopt the term sustainability-oriented innovation (SOI). The term SOI emerged in the 2000s (e.g. Hansen, 2009; Weaver, 2005) and is defined as "making intentional changes to an organisation's philosophy and values, as well as to its products, processes or practices, to serve the specific purpose of creating and realizing social and environmental value in addition to economic returns" (Adams et al., 2016, p. 181). It has been argued that the term sustainability-oriented innovation better reflects the process nature of innovation (Cholez et al., 2023). This term gained more and more attention in textile and clothing (Brun & Ciccullo, 2022; Ermini et al., 2024; Franzè et al., 2024; Saha et al., 2024).

The literature on production research identifies two main types of environmentally SOI: green product innovation and green process innovation (Wong et al., 2020). Today, green product innovation includes incorporating environmentally friendly raw materials, minimizing material and resource usage, and adopt circular or green design principles to enhance recyclability (Melander & Pazirandeh, 2019; Wong et al., 2020). Green process innovation refers to modifications made to manufacturing processes and systems in an effort to ensure energy savings, pollution prevention and waste recycling. These changes do not involve the redesign of the product. Instead, they focus on reducing emissions, reducing the use of materials and resources, recycling and green sourcing (Wong et al., 2020).

The literature on innovation and strategy has further highlighted sustainable business model innovations. To summarise, SOI include production processes that consume less resources or generate less pollution, new sustainable business models and product innovations (Fehrer & Wieland, 2021; Mehrabi et al., 2024; Melander, 2017; Melander & Pazirandeh, 2019; Testa et al., 2022).

The path to cellulosic fibres made in Iberia

Contrary to common belief, a "Made in Portugal" label does not mean that all stages of the supply chain, from raw material extraction to manufacturing, occur in Portugal. In fact, in most cases, only a small fraction of clothing production takes place in the country mentioned on the label. And when it comes to Portugal, that fraction almost never includes raw materials, simply because there is virtually no material production in the country or even in the Iberian region. But this may soon change. Altri, a leading Portuguese producer of cellulosic fibre, is building a bio-factory in Galizia, Spain, which is expected to supply "around 200,000 tonnes of cellulosic-based textile fibres annually, starting initially with the production of approximately 60,000 tonnes of lyocell" (Altri, 2022). Even though it would not represent a substantial percentage of total raw material consumption, the 750-million- euro investment, partly funded by the European Union, could provide a significant competitive advantage for the sustainability of the Portuguese and Spanish textile industries. This is because lyocell is known for its environmentally friendly characteristics, notably its closed-loop production process and its ability to reduce the industry's dependence on fossil fuels. Furthermore, producing substantial volumes of raw material closer to Portuguese factories could help reduce their transportation carbon footprint.

Prior research has mostly focused on the product innovation outputs and their impact in terms of sustainability (Adams et al., 2016; Klein et al., 2021). It also showed that environmental innovations depend on heightened collaboration with external stakeholders compared to other types of innovation (Dangelico et al., 2013; Juntunen et al., 2019). This result is also backed up by the research on sustainable open innovation, which argues that successful sustainable innovation processes go beyond organisational boundaries (Bogers et al., 2020; Kennedy et al., 2017; Wang et al., 2023). Similarly, the literature on sustainability partnerships highlights that firms often engage in competence-oriented partnerships to access skills and knowledge they lack (Dzhengiz et al., 2023; Golini & Gualandris, 2018; Riandita, 2022; Villena & Gioia, 2018).

Among the various external stakeholders, suppliers play a particularly crucial role. SOI increases technical and organisational interdependencies with suppliers as it relies on complex tasks, skills and knowledge that the industry does not have (De Marchi, 2012; Inigo et al., 2020; Shou et al., 2018). Moreover, earlier involvement of suppliers in innovation exposes the focal firm to more ideas, concepts or potential technology, and gives it access to important products and complementary resources (Andersén, 2021; Suurmond et al., 2020). However, our understanding of how actors organise innovation processes and collaborate for sustainability within their value chains remains limited (Adams et al., 2016; Fontoura & Coelho, 2022; Franzè et al., 2024; Neutzling et al., 2018), particularly due to scarce information on the diverse forms of collaboration and the range of partners involved.

Tintex Textiles — Pioneering sustainable dyeing innovations

Dyeing is one of the most polluting stages of textile and clothing production (McKinsey & Company, 2020) and, therefore constitutes a significant opportunity for sustainability-oriented innovations. 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 cellulosic

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

4.2. Collaboration for sustainability-oriented innovation

Vurro et al. (2024) define sustainability-oriented collaboration as "collaborative approaches where firms join in partnership with an explicit social and/or environmental intent, in addition to the conventional economic and competitive purpose" (Vurro et al., 2024, p. 9). External stakeholders can play different roles in this collaboration: stimulator, initiator, broker/mediator, concept refiner, legitimator, educator, context enabler and impact extender (Goodman et al., 2017).

Collaboration poses significant challenges. A key challenge is trust, particularly when involving external partners in green product innovation. Firms need strong relational capabilities and high levels of trust to facilitate knowledge sharing (Melander, 2018). Limited experience with collaboration partners often results in lower trust, while concerns about knowledge spill-over and future competition can further hinder trust-building. Ortiz-Avram et al. (2024) also highlight that SOI requires a specific type of dynamic capability known as systemic transformation. This refers to a firm's ability to develop new products, transform business models, and drive internal process innovation while integrating stakeholders' concerns into decision-making and innovation processes. Finally, SOI requires strategies to bridge differences between actors (Watson et al., 2018).

Our understanding of the role of the suppliers in collaborating with buyers and other partners towards sustainability innovation is still limited (Adams et al., 2016; Testa et al., 2022). This gap can be attributed to the dominance of the buyer's perspective in both supply chain management and innovation literature. Most studies on sustainability focus on how buyers drive change, overlooking the critical contributions, challenges and perspectives of suppliers and other stakeholders. To generate more relevant and actionable knowledge on sustainability-oriented innovation, it is essential to adopt a more holistic approach that considers the perspectives of all actors involved (Ghadimi et al., 2016; Saunders et al., 2020). To overcome this gap, some recent studies call researchers and practitioners to consider them as actors (e.g. Watson et al., 2018). In this connection, we propose to answer the following research question:

> *How do suppliers and other actors of the value chain work together to create sustainability-oriented innovations in the textile and clothing industry?*

4.3. Requirements for successful collaboration

The relational view developed initially by Dyer and Singh (1998, 2018) identifies which factors might contribute to a successful collaborative relationship. Because innovation often requires access to diverse knowledge, resources and capabilities that no single firm possesses, the authors identify four key factors for successful collaborations:

1) Complementary resources. Unlocking this value requires strategic and organisational compatibility, especially in areas like decision-making;
2) Knowledge-sharing routines. These are critical for transferring both codified knowledge and tacit know-how, they often emerge through repeated, trust-based interactions and are essential for the co-creation and recombination of novel ideas (Grant & Baden-Fuller, 2004);
3) Investment in relationship-specific assets. These include site, physical and human asset specificity — ranging from shared locations to customised machinery. These assets are tailored to the partnership and can generate innovation-related advantages that are hard to replicate or transfer elsewhere (Williamson, 1985);
4) Effective governance mechanisms. These can include formal contracts or informal norms, and also play a central role in facilitating collaboration by minimizing opportunism and promoting transparency.

Play Up — Portuguese style with a circular twist

In spite of having been established over twenty years ago, everything changed for Play Up in 2017, when Susana Correia took creative control of the childrenswear brand, transforming it into a sustainability success story. Play Up was born within a family-owned textile manufacturing company, Etfor, with a deep understanding of the textile and clothing industry. In 2023, the Portuguese brand, headquartered in Esposende, generated eight million euros in revenue, representing 35% of Etfor's total turnover. Susana Correia emphasised that the "Made in Portugal" label plays a significant role in this outcome; nonetheless, the brand's core strategy is driven by its circular practices. To start, 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 program, by using items collected through their Take Back program, which allows customers to return old purchases. Nonetheless, most garments returned are typically in good condition and are therefore repaired and sold on their second-hand online platform. "We've had a very small, very timid box [of post-consumer waste to recycle] since we have started, because the garments really do come to us in very good condition, which we're also happy about, because it means that 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 beginning. "For example, a baby's bodysuit, instead of having one level of springs, has two," reveals the creative director to demonstrate how Play Up's products are designed to grow with the wearer and increase their durability. Other examples include pants with multiple strap adjustments and garments that can easily detach a leg or sleeve, turning 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 a crossover with art, a focus on sustainability and on doing better and better. In other words, Play Up almost has an activist voice in a very low-profile way, but which then conveys a lot of what we are and what we value."

4.4. Sustainability-oriented innovation in Portugal

To answer the research question, we adopt a qualitative approach, which is the most appropriate to understand a complex phenomenon that is scarcely explored (Bansal, 2019; Eisenhardt, 1989). Among the different qualitative methods, we propose to compare multiple case studies, as these methods are appropriate to answer a "how" question (Yin, 2009) and allow us to improve the validity of the findings. In this research, all cases are focused on the development process of specific sustainability-oriented or circular innovations.

To identify and select the cases, we used two types of sources: professional events such as the EURATEX[4] annual conference, where Portuguese suppliers were present, and professional magazines focused on the textile industry such as *Portugal Têxtil*. While we empirically focus on Portuguese suppliers, we did not focus on specific nationalities for the other participants in the innovation processes. We selected 7 cases. The cases were selected because of their innovative nature and their contribution to sustainability. Each case is a sustainability-oriented innovation in terms of products and/or processes.

The curious life of a football scarf

It's the final game of the championship. Two teams are competing for the sought-after title, and their fans are eager to wear their team's celebratory football scarf. But there's one problem: only one team will be the winner. So, what happens to the unsold scarves of the would-be champions? Most will likely 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 second life through its LOOP project. In collaboration with partners in the Portuguese textile industry, the items are recycled and spun into new yarn, which can then be used by the same teams that originally discarded the waste. Not only is this process more environmentally sustainable but it also makes good business sense. Brands (or teams, in this case) can transform their unsold products into new materials at a lower cost, creating value from waste. Despite being in its preliminary stages, FORTeams Lab's LOOP project is already being tested by football companies.

Chapter 5
SOI in the Portuguese textile and clothing industry

5.1. Data collection

We started by conducting interviews with 13 industry experts such as professional associations, brand managers, consultancies and certification companies (see Table 8), to better understand the sustainability issues in the textile and clothing industry, as well as identify potential cases. We also attended five professional events with the same purpose. We then collected data for each case by combining primary and secondary data: semi-structured interviews, observation, archival data, newspaper articles and reports of consultancies and public organisations. For each case, we interviewed, at least, two interviewees, one on the supplier's side and the other on the partner's side, to attain both perspectives. We also conducted several follow-ups with informants to fill in missing data. We have conducted a total of 45 interviews, all of which have been transcribed.

Table 8 Interviews with industry experts and professional events attended

Sustainability Manager	Organisation	Position
Interview	Large international clothing brand	Sustainability Manager
	Small Portuguese sustainable clothing brand	Founder
	ATP (Textile Association of Portugal)	Director
	ATP (Textile Association of Portugal)	Former Director
	CITEVE	General Director
	GOTS	Head of Regional Representatives and GOTS Representative to Global Brands
	Portuguese supplier	Head of Innovation
	Portuguese supplier	Innovation Department Manager
	Portuguese supplier	Sustainability Manager
	Portuguese supplier	Commercial Director
	Small Portuguese sustainable clothing brand	Creative Director
	Lectra	Head of Innovation
	Textile Genesis	CEO
Professional event	Lectra Working Group	
	EURATEX annual conference	
	Modtissimo 2023	
	Modtissimo 2024	
	Intertex 2024	

5.2. Case studies

We analysed seven case studies, each being the creation of a sustainability-oriented innovation involving different members of the textile and clothing supply chain. The aim was to cover different steps of garment production, from fibre production to retailing, by identifying the collaborations that fulfil the industry's complex relational chains, as shown in Table 9. Some companies did not answer our contacts or chose not to participate in the study. Furthermore, as with all qualitative case studies, the present data is limited by the number of cases studied, the selective participation of companies and potential gaps in available information. However, we sought to mitigate these limitations by triangulating multiple data sources (e.g., industry reports, expert interviews, presentations in professional conferences), conducting follow-up interviews and ensuring representation from both suppliers and their partners in each case.

SOI 1: Regenerative cotton

The first case study is a collaboration between two Portuguese companies: RDD Textiles, a fabric supplier specialising in production, dyeing and finishing, and ISTO., a clothing brand. Together, they developed a t-shirt made from regenerative cotton. This represents a sustainability-oriented innovation, as the final product is fully recyclable and produced using environmentally responsible processes pioneered by the supplier. Currently, RDD Textiles has 15 employees, while ISTO. has ten.

SOI 2: Recycled polyester with repellent

The second case study focuses on the production of pants made from recycled polyester and finished with a special repellent treatment. The supply chain behind this sustainability-oriented innovation, which promotes water and resource savings using recycled materials, is composed by Company U — a US fibre producer with 2800 employees — Riopele — a Portuguese supplier involved in the products spinning to finishing stages, with 1181 employees — and Shaping New Tomorrow (SNT) — a Danish brand with 141 employees.

Table 9 Case studies according to their position in the supply chain

Case	SOI	Fibre production	Spinning	Fabric production	Dyeing and printing	Finishing	Manufacturing	Brand/Retailer
1	Regenerative cotton			RDD Textiles	RDD Textiles	RDD Textiles		ISTO
2	Recycled polyester with repellent	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 with micro-organisms			RDD Textiles	RDD Textiles/Colorifix	RDD Textiles		Company V
7	Pad-Dry/Ox finishing			Somelos	Somelos/Archroma	Somelos		

SOI 3: Lyocell textiles

Two companies were involved in the third sustainability-oriented innovation — a sports t-shirt made from lyocell Tencel textiles —, the supplier (Company A), a company based in Portugal, with 336 employees, handled the fabric production, dyeing and finishing stages; and the brand (Winqs) based in Germany, with six workers designed the T-shirt. It is important to note that the production of lyocell textiles requires less water, energy, and overall resources compared to conventional materials.

SOI 4: Regenerative cotton

In the fourth case study, which followed a Portuguese supply chain involved in the production of garments made from regenerative cotton, we analysed four companies. The largest company is Silsa, the manufacturing partner (with 206 workers), followed by Acatel, the dyeing and finishing facility (with 172 workers), Inovafil, the spinners (with 120 workers) and, finally, Casa da Malha, the knitters in the fabric production stage (with 63 workers). This sustainability-oriented innovation positively impacts land and soil through the application of regenerative agricultural practices and enhances garment traceability by using a tracker that follows the cotton fibre from soil to store.

SOI 5: PLA textiles

The fifth sustainability-oriented innovation includes the same four Portuguese suppliers from the previous case, with the addition of two members: one at the fibre production stage — NOOSA, a Belgian company with eight employees —and a French brand (Company N) with ten employees. This supply chain focuses on producing polylactic acid (PLA)-based textiles made from sugar sources, which require less water and emits less CO_2 during production.

SOI 6: Dyeing with microorganisms

Three companies make up the supply chain of the sixth sustainability-oriented innovation case: Colorifix, a British company with 89 employees, which created a dyeing process called Colorifix that uses microorganisms to biologically dye textiles, using less water and no harmful chemicals compared to traditional techniques. Its partner, RDD Textiles, also featured in the first case, involved in the fabric production, dyeing and finishing stages, and the company to which the product was developed, Company V, a brand based in the United Kingdom with 31 employees.

SOI 7: Pad-Dry/Ox finishing

The final case study features composition a similar to the previous supply chain, combining two suppliers working on a sustainable dyeing and finishing process for denim textiles called Pad-Dry/Ox. The dyestuff was developed by Archroma, a Swiss company with around 4500 employees, and the technique was implemented by Somelos, a vertically integrated Portuguese supplier, whose group employs 730 workers. In addition to requiring less water than conventional practices, the Pad-Dry/Ox finishing process does not produce any wastewater.

5.3. Data analysis

To analyse the data, we followed a two-stage coding process. In a first step, we coded each case by using the following codes: buyer's location and size, suppliers' location and size, who had the initiative for the production process, and the selection criteria of the supplier by the buyer. We also examined the type of innovation, distinguishing between product innovations — when the SOI emerged from novel textile fibres, for instance— and process innovations, which focused on production methods such as dyeing and finishing. We further specified if the innovation included a service such as recycling or traceability and, finally, we detailed the sustainability characteristics of each innovation. More specifically, how they enable brands and suppliers to reduce their environmental impact. This information is presented in Tables 10 and 11.

Table 10 First-stage coding on collaboration

	Location	Size (number of employees)	Partner who had the initiative	Selection criteria
Case 1	Portugal	RDD: 15 ISTO: 10	Both	Location and innovativeness of the supplier
Case 2	Spain, Portugal and Denmark	Company U: 2500 Riopele: 1014 SNT: 141	Both	Innovativeness of the supplier
Case 3	Portugal and Germany	Company A: 336 Winqs: 6	Winqs	Position of Portugal in the global value chain
Case 4	Portugal	Inovafil: 120 Casa da Malha: 63 Acatel: 172 Silsa: 206	Inovafil and Casa da Malha	Previous connection and trust among 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	Innovativeness of the supplier and previous connection and trust among partners
Case 6	Portugal and United Kingdom	RDD: 15 Colorifix: 100 Company V: 31	Both	Both were looking for partners and the supplier had a specific license
Case 7	Portugal and Spain	Somelos: 730 Archroma: 4500	Somelos	Previous connection and trust among partners

Table 11 Type of sustainability-oriented innovation

	Innovation	Type of innovation	Sustainability characteristics of the innovation
Case 1	Regenerative cotton	Product	Positive impact on soil and increased carbon sequestration
Case 2	Pants in recycled polyester with repellent	Product and process	Water savings during production, long lasting product and use of recycled material
Case 3	Sports T-shirt made from Lyocell	Product	Production needs less energy, water and resources
Case 4	Regenerative cotton	Product and service	Positive impact on soil, increased carbon sequestration and traceability
Case 5	Polylactic acid (PLA) fibres	Product, process and service	Production needs less water, reduced CO_2 emissions and recycled after consumer use
Case 6	Colorifix: fabric dyeing with bacteria DNA	Process	Production needs less water and does not use harmful chemicals
Case 7	Pad-Dry/Ox finishing on denim	Process	Production needs less water and does not produce wastewater

The first-stage coding helped us contextualise the relationships between the buyers and suppliers of each case. In our second-stage coding, we used the relationship between the brand and the supplier as the unit of analysis, consistently with the relational view (Mesquita & Lazzarini, 2008). We used the constructs of Dyer and Singh's framework as codes to analyse each case separately.

SOI 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, working in the dyeing and finishing stages as well, and a Portuguese fashion brand, ISTO. Although a manufacturer was involved, its contribution was minor and not included within the scope of this research. In this case, the fabric supplier held a central role in the brand's innovation activities, serving as a key partner in the identification and development of new products.

In terms of governance, the collaborative relationship was primarily governed by trust and transparency, supported by smooth and effective communication between the supplier and the brand. Apart from ISTO's need 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 exert control over the process. However, while RDD proposed various fabric options, the final decisions were made solely by the brand.

These governance mechanisms supported intense knowledge and information exchange. This was especially important for the buyer, who was in the process of building knowledge around sustainable practices in fashion. To ensure alignment with its existing quality standards, ISTO provided samples from previous collections, while the supplier showcased relevant innovations from its portfolio to meet those expectations. Geographical proximity between the two partners also facilitated this knowledge and information exchange.

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

Finally, complementary resources were particularly important on RDD's side, because of how its acquired experience, knowledge, multidisciplinary team and R&D investment were translated into this sustainability-oriented innovation. RDD also leveraged its integration within a larger textile company to establish a network of partners capable of meeting both ISTO's and the innovation's specific requirements. On the brand's side, these resources were mostly intangible (yet no less important), such as its sustainability mindset and clear vision. Offering visibility to suppliers, by promoting them in its marketing channels, is also an important complementary resource from the buyer. To sum up, for a successful collaboration, the brand relied heavily on substantial knowledge and information exchange, while the supplier stood out due to its complementary resources.

SOI 2: Recycled polyester with repellent

In case study 2, two suppliers — a fibre producer, Riopele, and a fabric production, dyeing and finishing company, Company U — collaborated with the fashion brand SNT to create recycled polyester pants with repellent. Unlike the first case, there were some structural governance mechanisms to governing the collaboration. Riopele and SNT signed a non-disclosure agreement to secure SNT's exclusivity over the developed formula and fabric composition. However, Riopele was allowed to offer different versions of the formula to other clients. The partners also agreed on small minimum order quantities. Governance was also achieved through informal mechanisms, most notably 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 exchange, Riopele guided the material selection, providing SNT with its expertise in the properties, performance and sustainability of different materials. This exchange of technical knowledge allowed the brand to make informed decisions. On the other hand, SNT played a central role in guiding the development of the product formula by specifying particular performance standards. It requested multiple rounds of sample testing, followed by iterative modifications to meet expectations. Prototypes were crucial in these iterations and, more broadly, played a significant role in the overall knowledge and information exchange process. Significant knowledge and information were also exchanged between the two suppliers, albeit to a lesser extent and mainly prior to this specific collaboration. Nonetheless, Company U emphasised that Riopele's testing processes and technical recommendations were instrumental in enhancing the quality of the recycled polyester fibre.

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

Complementary resources played a significant role in the success of the collaborative innovation. Company U contributed with 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, supported by advanced equipment, an established reputation, a strategic location within the Portuguese textile cluster, and its portfolio of innovations. SNT brought its capacity to test samples with consumers, its knowledge of the fashion market, as well as its radical innovative mindset.

SOI 3: Lyocell textiles

The third SOI examined in this study is a product made from TENCEL™ Lyocell fibres, resulting from a collaboration between a Portuguese fabric producer, Company A, also responsible for dyeing and finishing, and a German brand, Winqs. As in previous cases, the governance structure remained light, with both parties choosing not to pursue exclusivity. In fact, Winqs explicitly expressed a desire for the SOI's widespread adoption. The partners did, nonetheless, sign an NDA, to protect the confidentiality of the first stages of the innovation process. This agreement restricted the sharing of specific details with third parties, while allowing collaboration with other involved partners, such as the fibre producer, who also contributed to the development efforts.

Regarding knowledge exchange, it is important to stress that the partnership was at its most active during the COVID-19 pandemic, resulting in minimal in-person interactions. Communication was primarily led by the brand, which, from the outset, made precise material and product requests, later complemented by ideas put forward by the supplier. This initiated a lengthy process of prototype exchange and feedback, with input from both the brand and its athlete consumers, who tested the performance of the innovation.

Company A had to make new investments for this collaboration, having to rethink its development operation from scratch. The fact that Winqs solicited an entirely plastic-free product, for instance, led the Portuguese factory to source new suppliers and techniques for natural threads, pigments and finishing formulas. Besides pushing their partner to be more innovative, the brand also invested in communication tools to promote the innovation.

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

SOI 4: Regenerative cotton

The fourth case study is the development of garments made from regenerative cotton by four Portuguese suppliers, covering nearly all stages of the textile value chain, from spinning to manufacturing. The yarn supplier was at the initiative of the innovation process. In terms of governance, because the different partners had a long history of collaboration, most of the information mechanisms remained informal. Moreover, all suppliers are located close to one another, which

facilitates interaction and transparency, and they share similar values, particularly around sustainability.

Unlike the previous cases, this collaboration involved limited knowledge and information exchange between the partners, as the innovation was closely aligned with existing production processes. According to the Portuguese suppliers, manufacturing garments with regenerative cotton required no significant adjustments compared to conventional cotton.

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

Investment in relation-specific assets included the purchase of a scanner to trace the cotton, and a certification acquired by Acatel, the dying supplier. There were many other complementary resources that enabled the success of this SOI such as the R&D department, machines and equipment, certifications and traceability services.

SOI 5: PLA textiles

The development of polylactic acid (PLA) textiles was conducted by a supply chain similar to the one in the fourth case, with the addition of a Belgium-based fibre producer, NOOSA, and a French sportswear brand. This sustainability-oriented innovation posed different collaboration challenges compared to the use of regenerative cotton, due to the higher novelty of the PLA fibre. In the governance structure, NOOSA required all partners to sign a permanent NDA to prevent them from sharing details about the material and its development process. Besides the NDA, no additional contracts were signed and the governance mostly relied on informal mechanisms such as transparency and trust.

Due to the complexity of the innovation, all partners engaged in substantial knowledge and information exchange. NOOSA visited the Portuguese factories annually, met with partners at international textile fairs, and provided written guidelines 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 continuous contact was maintained 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 relationship-specific assets was limited to the presence of NOOSA in international fairs to attract brands and reach more clients. Once again, the contribution of complementary resources was key. On the suppliers' side, the resources were similar to those identified earlier. However, NOOSA brought a range of complementary resources such as a patented recycling technology and a recycling program 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. Additionally, NOOSA had in-house laboratory facilities to test new developments and played a key role in collecting waste from suppliers and brands for recycling.

SOI 6: Dyeing with microorganisms

The sixth case study focuses on the development of an innovative dyeing process using micro-organisms. Three companies participated in the innovation process: two suppliers, RRD Textiles and Colorifix, and a fashion brand. The governance of the relationship was underpinned by a non-exclusivity policy, allowing partners to collaborate with other companies. However, the brand had a formal contract with RDD.

Substantial knowledge and information were exchanged through multiple experiments until the dyeing technology was ready for scaling. RDD helped the biotechnology company to better understand different textiles and adapt the process according to their characteristics. On the other hand, 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 facilities, complemented by weekly online meetings.

The brand invested time. Colorifix invested in equipment and training, and opened a branch in Portugal at one point, even operating directly from RDD's facilities. RDD invested in the acquisition of the regulatory licence to work with genetically modified organisms, purchased equipment developed by the biotechnology company and trained its employees in the innovative dyeing process. Both suppliers promoted each other — RDD by featuring the dyeing innovation in its portfolio, and Colorifix by presenting the fabric supplier as their production partner.

In terms of complementary resources, RDD, integrated within a larger textile company, contributed with the mobilisation of a multidisciplinary team, expertise in new materials and technologies, a network of partners, and a strong focus on innovation and sustainability. Colorifix contributed with its specialised knowledge of the dyeing process, innovative equipment, infrastructure and research supported by public and private funding. The fashion brand brought a spirit of innovation and experimentation, as well as expertise gained from other sustainability-oriented innovations and an existing partnership with the fibre producer.

SOI 7: Pad-Dry/Ox finishing

The last case study examines a textile finishing technique that uses significantly less water compared to conventional methods. It was developed by a Portuguese fabric supplier, Somelos, and a Swiss chemical firm, Archroma. The governance relied on an NDA, complemented by informal mechanisms and trust, since the partners had a previous business relationship. Neither company sought exclusivity, and Archroma has since expanded its network to include other Portuguese suppliers. The partners engaged in substantial knowledge and information exchange. On Archroma's side, the innovation was overseen by a Spanish employee who frequently travelled to Portugal during the initial development stages. 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 the offerings by working with a new range of colourants from Archroma.

Since the chemical components needed for the innovation had already been created by Archroma, there was no significant investment in relationship-specific assets. However, Archroma engaged in relevant promotion, showcasing the SOI in international fairs and to their broad client base.

Finally, both partners contributed with substantial complementary resources. As explained earlier, Archroma provided the chemical components and its formula portfolio, while Somelos brought its water treatment infrastructure, certifications, technical expertise in textile production and network of partners in the textile Portuguese cluster.

5.4. Results

The cross-case analysis highlights that collaboration among value chain actors primarily occurs through extensive knowledge sharing, information exchange, and the integration of complementary resources. These factors consistently emerge as key enablers of successful innovation processes. Additionally, governance mechanisms and investments in relationship-specific assets play a crucial role in supporting and facilitating knowledge exchange and the use of complementary resources in the innovation process.

Investment in relationship-specific assets

The cross-case analysis reveals varying investment strategies among partners involved in sustainability-oriented innovation. In some instances, actors made strategic, long-term commitments, while others opted for shorter-term resource allocation. Across the cases, common investment areas include time, financial resources and efforts to promote their partners' initiatives. In three cases, companies specifically emphasised their investment of time, recognizing that the process of innovating for sustainability is resource-intensive and demands focused efforts from partners. Fewer cases reported investments in tangible assets, such as equipment, as well as in sourcing and process improvements. These investments suggest a commitment to evolving production processes, although they appear less common than those focused on promoting partner initiatives.

Some cases emphasised certifications, training and investment in new organisational processes, suggesting a long-term approach to sustainability-oriented innovation. Case 4 and Case 6 invested in new certifications and equipment, notably advanced machinery, highlighting an effort to meet industry standards and regulatory requirements. Similarly, Case 5 and Case 6 focused on training and organisational programs, pointing to capacity-building as a key enabler of sustainable innovation.

The fact that in four cases at least one partner actively invested in promoting their counterpart highlights that sustainability-oriented innovation extends beyond operational improvements and also serves as a strategic positioning effort. This investment in promotion supports good governance of the relationship by reinforcing trust and fostering long-term collaboration.

Overall, the findings highlight the varying degrees of commitment and strategic orientation among partners. Case 1 and Case 7 focused primarily on partner promotion and financial commitments. In contrast, Case 2 and Case 6 demonstrated the most diversified investment strategy, covering location, which enabled close collaboration and facilitated real-time communication, certification and training, suggesting a more holistic approach to sustainability integration.

Knowledge exchange and information-sharing routines

The analysis shows that mechanisms of knowledge exchange and information-sharing routines played a crucial role in the collaboration

for sustainability-oriented innovation. Cases 5, 6 and 7 showed an increased reliance on robust knowledge-sharing practices among suppliers. These cases involved innovations with a greater degree of complexity, where continuous collaboration and exchange of technical expertise were essential for overcoming challenges and achieving the desired outcomes. By contrast, in Case 4, knowledge exchange was less critical to success because the regenerative cotton production processes being implemented were not very dissimilar to established practices for conventional cotton.

Three primary mechanisms underpinned these exchanges: the transfer of material items, iterative feedback loops, and sustained communication. The first key mechanism is the exchange of material items such as samples and prototypes. Cases 1, 2, 3, 4 and 5 illustrate how product samples and prototypes were instrumental in sharing insights on the progression of innovation. This knowledge exchange was further reinforced through testing and ensuring alignment with performance expectations. Furthermore, the provision of previous detailed specifications helped enhance mutual understanding among partners. These material knowledge flows took the form of tangible artifacts such as prototypes, samples and physical models, which serve as concrete representations of innovation. By making knowledge exchange more visible, accessible and actionable, these artifacts facilitated deeper engagement and understanding among collaborating firms. Interacting with prototypes and samples allowed partners to better assess design choices, technological feasibility and sustainability implications. Prototypes and samples also functioned as a "platform for collaboration" (Lee and Amajadi, 2014), enabling firms to overcome spatial limitations despite geographical dispersion. Samples further encapsulated and materialised the knowledge of specific partners, transforming intangible expertise into a physical form that could be examined, tested and iterated upon. Beyond their role as tools for communication, prototypes were both the result and the embodiment of collaboration, reflecting shared efforts and expertise.

Feedback loops represent the second key mechanism, underscoring the importance of iterative refinement in innovation. These loops enabled continuous product and process improvement by integrating new insights over time. When it comes to feedback loops, fashion brands occupied a strategic position at the end of the value chain, which enabled them to act as intermediaries between the suppliers and the final customer. Their ability to gather feedback from end-users and communicate these insights upstream to suppliers was instrumental in refining and aligning sustainability-oriented innovations with market demands.

Finally, communication emerged as a fundamental mechanism facilitating seamless knowledge transfer. While not all cases benefited from in-person interactions, such as factory visits, these were effectively supplemented by continuous online communication via text messages and videoconferencing. Even so, brands reiterated the importance of physically visiting their suppliers, particularly when they did not have the chance to do so, as it happened in Case 3 because of the COVID-19 pandemic. Whether occurring physically or virtually, communication was further strengthened by investments in relationship-specific assets, including strategic placement of human resources near partners in the North of Portugal to facilitate coordination.

The variation in the depth and nature of the knowledge exchanged across cases suggests that balancing structured routines with flexible interactions can optimise innovation processes in sustainability-focused initiatives. By adapting mechanisms to the complexity of the innovation and the needs of collaborators, firms can enhance their capacity for sustainable transformation.

Governance

Knowledge sharing and integration of complementary resources were facilitated by diverse governance mechanisms. When formal governance structures were used, non-disclosure agreements (NDAs) were the most employed tool, but in some cases only during the early stages of innovation. NDAs played a crucial role in balancing transparency with the protection of proprietary knowledge, ensuring that sensitive information could be shared while safeguarding intellectual property. This approach was observed in four cases, highlighting its importance in establishing initial trust and mitigating risks in collaborative innovation efforts.

The most employed governance mechanism is a "no exclusivity" approach, observed in all the cases except one, which relied on partial exclusivity. This no exclusivity mechanism fosters flexible partnerships, enabling actors to engage in multiple collaborations simultaneously. Both suppliers and brands recognised the strategic benefits of being able to work on different sustainability-oriented innovations.

Finally, in four cases (1, 4, 5 and 7), we observe the absence of formal contracts and the prevalence of trust-based arrangements. This preference was mostly attributed to the previous history of collaboration between the partners, which allowed them to operate effectively based on trust.

This diversity highlights the adaptability of collaboration structures in sustainability-driven innovation, ensuring that governance mechanisms align with the unique needs of each innovation.

Complementary resources

Complementary resources played a crucial role in both partner selection and the success of innovation. In most cases, brands explicitly chose production partners based on the unique resources they could contribute with to the innovation process — ranging from intangible assets, like expertise and knowledge, to tangible ones, like specific equipment already owned by the partner before the beginning of the collaboration. A common theme across cases is access to specialised machinery, such as equipment tailored for sustainable materials. These resources were essential in developing innovative, sustainable, and customised textile solutions. While sustainability certifications are also important, brands generally view them as a baseline requirement rather than a distinguishing factor when selecting partners. Additionally, the location of suppliers within the textile cluster of northen Portugal appears to be a significant advantage. This geographical positioning not only facilitates logistics but also provides access to a network of complementary suppliers.

In contrast, brands themselves did not always contribute with substantial complementary resources beyond their innovation and sustainability-driven mindset, and understanding of final consumers and market dynamics. This market knowledge proved valuable in

identifying potential challenges and ensuring alignment between suppliers and consumer demands. When present, brands' in-house textile expertise also played a key role in facilitating communication and collaboration with suppliers.

A significant complementary resource provided by suppliers in several cases was their extensive network of partners. These partnerships, particularly with suppliers in other stages of the production process, enabled suppliers to offer comprehensive services to brands, including consultancy and supply chain organisation. This network not only strengthened suppliers' control over the innovation process, but also positioned some suppliers as intermediaries, connecting brands with the right production partners.

These differences also highlight varying service scopes in innovation processes. Some suppliers operate as one-stop-shop solutions, integrating design, prototyping and full-scale production to support brands from concept to final product. Others focus primarily on research and development, specializing in testing and refining new materials, techniques and sustainable alternatives.

Supplier offerings to brands can be categorised by degree of servitisation, which reflects the extent to which suppliers integrate services into sustainability-oriented innovation alongside the core product. At the highest level, full servitisation involves suppliers collaborating to deliver comprehensive solutions that support sustainability across the entire product lifecycle, from raw material sourcing and production to end-of-life processes, such as recycling. By embedding services into their offerings, suppliers positioned themselves as strategic partners of the brands to achieve their long-term sustainability goals. Partial servitisation involves suppliers that include one or more services that cover only some aspects or stages of the life cycle, such as sustainability tracking. At the other end of the spectrum, product-only suppliers focused solely on delivering specific inputs directly to the production of a product, with no service integration.

Chapter 6
Conclusion and recommendations

6.1. Recommendations for suppliers

To foster SOI, suppliers should adopt a strategic approach to investment in relationship-specific assets. In particular, investing in certifications, training and organisational processes supports long-term capacity-building and reflects a deeper commitment to sustainability transition. This implies dedicating time and financial resources. It also includes actively promoting their partners' sustainability initiatives to enhance visibility and trust.

Suppliers should also treat knowledge sharing as a central pillar of collaboration with brands as well as with other suppliers. Effective practices combine the exchange of physical items, like samples and prototypes, with iterative feedback loops and sustained communication, both virtual and in-person. Flexibility is essential, as the mechanisms of knowledge exchange should adapt to the specific needs and complexity of the innovation at hand.

Governance structures must also be tailored to the nature of the collaboration. While formal tools such as non-disclosure agreements are valuable in early stages for protecting proprietary knowledge, many cases demonstrated the effectiveness of trust-based arrangements, particularly when partners shared a history of working together. The widespread adoption of a "no exclusivity" approach across cases highlights the value of flexibility, allowing both brands and suppliers to engage in multiple sustainability initiatives without the constraints of exclusive arrangements.

Partner selection should focus on the complementary resources that each actor brings to the table. Suppliers should acquire and prioritise specialised machinery, sustainability certifications and strong networks of suppliers. Meanwhile, brands with market knowledge, consumer insights and a sustainability-oriented vision, which are essential for aligning innovation with broader market demands, are key partners for suppliers.

Finally, understanding the degree of servitisation in their offerings is crucial for suppliers because it shapes how they are perceived and positioned on the market by present and potential future clients. As sustainability becomes a strategic priority for fashion brands, suppliers that integrate services related to sustainability (e.g., recycling or material traceability) can increase their relevance in competitive supply chains and develop long-term relationships with brands. In contrast, suppliers who remain purely product-oriented may find themselves less differentiated. By understanding where they fall on the servitisation spectrum, whether offering full solutions, partial services or just products, suppliers can make informed strategic decisions: either by investing in service capabilities to increase their value proposition or by forming alliances that allow them to contribute to broader lifecycle solutions.

6.2. Competitiveness of the Portuguese textile and clothing industry

Although the textile and clothing sector in Portugal has faced significant challenges over the past decades, mainly due to increasing competition from China and South Asian countries — which benefit from large-scale manufacturing capacity and low labour costs — the Portuguese cluster has been showing signs of recovery and renewed strength, particularly thanks to the strategic integration of sustainability into its supply chains (GEE, 2024). The rise of these global competitors has exerted considerable pressure on the Portuguese textile sector, compelling suppliers to seek differentiation through the development of higher value-added products, innovation and sustainable practices. In this context, we will explore in this section some of the most significant opportunities and limitations influencing the competitiveness of the Portuguese textile and clothing sector worldwide. Moreover, we will provide strategic recommendations to industry leaders and policymakers aimed at maximising the cluster's key competitive advantages and ensuring long-term resilience in the face of this shifting landscape.

One of Portugal's key competitive advantages, consistently highlighted during interviews with both brands and suppliers for this study, is the talent and expertise embedded within the Portuguese textile and clothing supply chains. The industry is widely praised for its high-quality standards and the presence of a diverse range of factories, which collectively cover the main stages of the production process, from yarn to garment manufacturing. Furthermore, brands often cited the advanced equipment used by Portuguese suppliers, which is necessary for the development of sustainability-oriented innovations, paired with the sector's strong commitment to transparency. These characteristics help explain why Portugal has been positioning as a leading player in sustainable textile production at renowned international textile fairs, such as Première Vision in Paris, where Portuguese suppliers have been frequently acknowledged for its sustainability-oriented creations.

Another feature celebrated by both brands and suppliers is the geographical proximity of companies operating within the Portuguese textile and clothing sector. As one buyer noted during an interview, "you have everything on a 50 kilometres range. You have the sea to transport (...) worldwide. So, you have everything." This close geographical concentration is also highly valued by suppliers, who emphasise how it reinforces collaboration and facilitates more efficient communication and problem-solving throughout the production process. In an industry where supply chains are typically complex and dispersed across multiple continents, this clusterisation of Portuguese suppliers provides a strategic buffer against disruptions in global supply chains, which are increasingly common.

Looking at potential challenges to Portugal's competitiveness in the global textile market, one of the most cited issues is the significant investment required to drive sustainability-oriented innovation. Indeed, research and development in this area entail substantial costs, which pose a particular risk to Portuguese suppliers, notably when brands are reluctant to pass these innovations on to consumers due to their higher price points. This challenge is even more acute for small and medium-sized enterprises, which represent most of the Portuguese textile and clothing landscape, since they may lack the financial resources to make these investments upfront. Another cost

related to sustainability — often overlooked — is the expense of obtaining sustainability certifications. These certifications are essential for verifying sustainable practices and enhancing credibility in international markets. However, the associated costs can be prohibitive for smaller companies. To address these challenges, a strategic recommendation would be to support companies within the Portuguese textile cluster in securing funding for R&D and sustainability-related initiatives. This could be achieved through targeted financial support programs, particularly aimed at SMEs, and by improving access to information and guidance about available funding opportunities.

Beyond financial investment, other significant barriers to innovation in Portugal's textile and clothing industry include shortages in human resources and infrastructure, particularly during the scaling-up phase. As highlighted by the CEO of a Portuguese textile supplier: "there are companies that do a lot, but there are [other] companies that don't even have the human resources to do it, and don't have the capacity [to innovate] because they are really small." This reflects a structural challenge within 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 industry organisations, such as CITEVE, which was frequently mentioned as a valuable partner in supporting research and development. Universities were also identified as important players in fostering innovation. Strengthening these collaborative networks between private companies, industry organisations and academic institutions could contribute to 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 emerging from the European Union. This regulatory tsunami was perceived as a double challenge: first, because key competing textile-producing regions, such as China and South Asia, are not subject to similar environmental and social regulations, giving them a cost advantage in production; secondly, because EU legislation was described as confusing and frequently changing, creating uncertainty and operational challenges. Overall, Portuguese suppliers called for greater support and targeted incentives to help them adapt to this evolving regulatory landscape — a gap that could be covered by industry organisations. Brands producing in Portugal shared similar concerns, pointing to the bureaucratic difficulties involved in securing funding and other resources necessary for innovation. As one buyer puts it: "a lot of companies don't have the know-how, they need to hire consultancy companies to have support."

Another issue raised by brands and suppliers regarded communication. When brands seek to produce in the country without prior knowledge of the textile cluster, they struggle to find the information needed to select suitable suppliers. A common complaint from brands was the lack of promotion by suppliers, particularly on digital platforms. One international brand producing in Portugal stated:

> "I've found that a lot of factories don't promote themselves. If we look at the websites, they are terrible. It's really hard to understand what they do, it's really hard to navigate. A lot of them are really old websites. So, considering that the Portuguese factories are so advanced, I would consider taking that to the next level and promoting themselves as well."

Suppliers also acknowledged this issue, though to a lesser extent. Communication is particularly challenging for companies operating in the middle stages of the textile supply chain, given that they often lack direct contact with brands. Two possible recommendations emerge from this issue. On the one hand, Portuguese suppliers should invest in modernising their promotional platforms, namely their websites, to convey the cluster's growing reputation for sustainability and innovation. On the other hand, industry organisations could function as intermediaries between brands wanting to produce in Portugal and suppliers, by maintaining an up-to-date, centralised platform that provides detailed information about Portuguese textile companies.

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

In summary, the Portuguese textile and clothing supply chain has faced significant challenges due to rising global competition, but it has shown resilience by focusing on high-quality, sustainability-oriented production. The industry benefits from a skilled workforce, advanced technology and a connected supply chain, which enhance efficiency and transparency. Nonetheless, 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. Strengthening financial support for innovation, fostering collaboration with industry organisations and universities, as well as improving supplier visibility through digital promotion could contribute to strengthen the sector's competitiveness and long-term resilience.

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Notes

< 1. Includes significant shipments through processing zones.

< 2. No values for 2017 and 2018 as in those years the United Kingdom was still part of the EU.

< 3. After 2021, sources only provided the total exports and imports values of the textile and clothing industry.

< 4. EURATEX is the European Apparel and Textile Confederation.

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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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