Towards Circular Textile Waste Management in Macaronesia: A Comparative Policy and Infrastructure Analysis

Zaida Ortega[1]*, Pablo Bordón[2], Rubén Paz[2]

Available online: https://onlinelibrary.wiley.com/doi/10.1002/tqem.70225

doi: https://doi.org/10.1002/tqem.70225

How to cite: Ortega, Z., P. Bordón, and R. Paz. 2025. "Toward Circular Textile Waste Management in Macaronesia: A Comparative Policy and Infrastructure Analysis." Environmental Quality Management 35, no. 2: e70225. https://doi.org/10.1002/tqem.70225

1 Departamento de Ingeniería de Procesos, Universidad de Las Palmas de Gran Canaria

2 Departamento de Ingeniería Mecánica, Universidad de Las Palmas de Gran Canaria

* Corresponding autor: Zaida Ortega, Edificio de Fabricación Integrada, Parque Científico – Tecnológico de la ULPGC, Campus universitario de Tafira Baja, 35017, Las Palmas de Gran Canaria, Las Palmas, Spain. zaida.ortega@ulpgc.es, +34 928459641

Abstract

The increasing volume of textile waste in Europe presents a critical environmental and economic challenge, particularly in isolated regions such as the Canary Islands and the broader Macaronesian region. This study presents a comprehensive review of textile waste generation, legislation, and management strategies across Europe, with a special focus in this isolated territory, comprising Canary Islands, Madeira, Azores and Cape Verde. An assessment of the specificities of this region, its low market volume and relatively lower technological development compared to continental Europe, the difficulties in logistics, together with its high biodiversity and fragile territory makes it necessary to undertake specific actions adapted to the territory. The comparative analysis performed allows to determine a number of challenges and opportunities for textile circularity in the Macaronesian region, which should target a decentralized infrastructure, improve data systems, and produce or adapt targeted policy measures to advance towards textile waste valorization in insular and isolated environments.

Keywords: Textile Waste, Circular Economy, Macaronesia, Waste Management, Canary Islands, Recycling

1. Introduction

The management of textile waste has become an increasingly pressing environmental concern. The linear consumption model, together with the rise of fast fashion, has made the production and disposal of textiles grow significantly, leading to environmental pollution and resource depletion. Textile waste includes discarded clothing, household textiles, and industrial fabrics, which often end up in landfills or are incinerated, and with recycling ratios that still need to be further improved to reach the objectives set by 2030. This report provides an overview of textile waste in Europe, Spain, the Canary Islands, and the Macaronesian region, with an emphasis on the types of waste generated, current management practices, and strategies to improve waste valorization. The limitations in the availability of data make it difficult to analyze the actual production of such type of residues, especially in the Macaronesian region. This is in fact one of the main objectives of initiatives such as the TEXTIL project (MAC/2/2.6/0096), which aims to bring an updated picture on the state of collection, separation and valorization of such materials in these isolated territories (Macaronesia).

Legislation and public policy play a critical role in aligning the fast fashion industry with more sustainable practices. Emerging regulations worldwide are set to enforce higher recycling standards and establish a set of objectives for textile waste management (European Commission 2022; Watkins et al. 2024). While the potential impact of these policies is still unfolding, they are expected to encourage brands to adopt sustainable practices and integrate recycling into their supply chains more thoroughly.

The European Union (EU) has also recognized the need for improved management of textile waste and has introduced policies, such as the EU strategy for sustainable and circular textiles in (European Commission 2022), aimed at transitioning towards a circular greener economy. These policies include directives and strategies that encourage recycling, reuse, and sustainable production practices, being the main ones:

- Waste Framework Directive (2008/98/EC): It requires the member states to apply the waste hierarchy, prioritizing prevention, reuse, and recycling over disposal.
- Circular Economy Action Plan (2020): it focuses on sustainable production and consumption, including mandatory requirements for recycled content in textiles, although not completely in place yet.
- EU Directive on Green Claims (2023): to prevent misleading or false environmental claims made by companies, ensuring that green claims are based on credible evidence, avoiding green washing and fake claims.
- EU Strategy for Sustainable and Circular Textiles (2022): with the objective of ensuring that textiles placed on the EU market are durable, repairable, and recyclable by 2030.
- Revision of the Waste Framework Directive (2023): it aims at including Extended Producer Responsibility schemes into the textile sector.

The new legislation also mandates separate collection of textile waste by 2025, which is expected to significantly increase their recycling rates (European Commission 2022).

Textile recycling is a critical component of sustainable waste management, intimately linked to the goals of a circular economy aimed at minimizing waste and reducing environmental impact. The textile industry, characterized by its rapid growth and heavy reliance on synthetic fibers, generates significant amounts of waste, needing effective recycling strategies. As outlined by Indrie et al., successful management of post-consumer textile waste is imperative for achieving zero-waste targets and improving sustainability across industries (Indrie et al. 2023). Effective recycling involves not only the conversion of textiles into new products but also their reuse to enhance value retention and reduce the need for virgin materials (Ashish Karnad 2023).

Fast fashion contributes to increased consumer demand and textile waste, opening discussions around sustainable recycling practices to mitigate environmental damage. Fast fashion, typified by rapid production cycles and low-cost garments, contributes significantly to global textile waste. It is estimated that approximately 92 million tons of textile waste are generated annually, with a substantial proportion ending up in landfills or being incinerated, reflecting a very low global recycling rate of less than 1% for textiles (Wagaw and Babu 2023; Zhai et al. 2022). The disposable culture fostered by fast fashion promotes shorter garment lifespans, with many consumers purchasing items to wear only a few times before discarding them (Ruiz-Caldas et al. 2022); research suggests that consumer attitudes show a recognition of the low quality of fast fashion textiles (Polajnar Horvat and Šrimpf Vendramin 2021).

This decrease in textile reutilization reinforces a linear economy where waste is the norm rather than an exception (Juanga-Labayen, Labayen, and Yuan 2022a; Valtere, Bezrucko, and Blumberga 2023a). Consumer attitudes towards fast fashion complicate the recycling situation, as individuals express disillusionment regarding the quality of fast fashion textiles and a desire for the durability seen in past products (Polajnar Horvat and Šrimpf Vendramin 2021), while aiming, at the same time, at prioritizing trends, aesthetics and cost, diminishing the perceived value of sustainable practices such as reusing or recycling (Anjimoon et al. 2024). Although consumers may express awareness of their responsibility in managing textile waste, practical barriers to recycling persist (Ponnambalam et al. 2023).

The growing environmental and social concerns regarding fast fashion are forcing innovative approaches in textile recycling. Research is increasingly focused on enhancing recycling technologies, such as enzymatic processes and methods like catalytic hydrolysis for recovering valuable raw materials from blended textiles (Ruuth et al. 2022; Wu et al. 2024), while the potential use of these residues for composites production is also gaining attention (Huang, Ye, and Zhao 2025). These advancements aim to address the challenges posed by complex fabrics, supporting the transition towards a more sustainable, circular textile economy, wherein materials can be regenerated with minimal loss of quality.

Fast fashion profoundly influences the landscape of textile recycling, presenting numerous challenges while simultaneously fostering innovative solutions. As consumers become increasingly aware of the environmental repercussions of their purchasing habits, the dialogue surrounding sustainable recycling practices continues to get increased attention. Coordinated efforts, including advanced recycling technologies and strong legislative frameworks, among others, to avoid green washing strategies, are essential for transitioning the textile industry toward a more circular and sustainable future.

2. Methodological approach, scope and limitations of the work

The preparation of this work mainly involved the search in different databases to clarify the picture about the status of textile wastes in the Macaronesia region. It performs a comparative review, integrating policy analysis, infrastructure assessment, and regional contextualization. The approach combines qualitative analysis of legislative frameworks with quantitative data on waste generation and collection rates, which are very limited, aiming to identify gaps, challenges, and opportunities for circular textile waste management in outermost regions. Several reports about the status of the collection, separation and potential recyclability of the textile fraction have been analyzed and compared to the few statistical data available. For the moment, as it is shown later in this document, the databases about wastes collection and separation are not including the textile fraction in a separated way, and therefore it is not possible to provide agglutinated data about the evolution of textile wastes, even less in isolated regions, such as the ones that are within the scope of the work, i.e. Macaronesia.

The main objective of this review is to analyze the current state of textile waste management in the Macaronesia region, identifying specific challenges and opportunities for implementing circular economy strategies. The study seeks to propose territory-adapted solutions that consider the insular nature, limited infrastructure, and ecological sensitivity of the region, contributing to the development of sustainable and scalable waste valorization models.

2.1. Scope

This work focuses on:

- The Macaronesian region (Canary Islands, Madeira, Azores, Cape Verde), with comparative references to continental Europe.
- Textile waste management, including collection, sorting, recycling technologies, and policy frameworks.
- Circular economy strategies, emphasizing reuse, recycling, and downcycling applications.
- Pilot initiatives and commercial applications relevant to insular and isolated territories.

2.2. Limitations

As already mentioned, the work has some limitations, summarized in:

- Data availability: There is a lack of consistent and updated data on textile waste generation and management in Macaronesia, which limits the precision of quantitative comparisons.
- Technological constraints: Many recycling technologies are not yet adapted to small-scale or low-volume waste streams typical of insular regions.
- Economic viability: The cost-effectiveness of recycling solutions is challenged by limited market size and logistical barriers.
- Policy implementation: While EU directives provide a framework, their application in outermost regions faces structural and administrative hurdles.

3. Fate of Textile Waste: synthetic versus natural fibers

Europe generates approximately 5.8 million tons of textile waste annually (European Environment Agency 2024). This waste comes from various sources, including post-consumer products (clothing and household textiles) and pre-consumer waste from the manufacturing process. The increase in fast fashion consumption has resulted in higher production of short-lived textile products, leading to a growing waste problem.

According to the European Environment Agency (EEA), about 87% of textile waste generated in Europe is sent to landfill or incinerated, with only a small fraction being recycled or reused (European Environment Agency 2024). The most common types of textile waste include:

- Clothing and apparel (e.g., shirts, trousers, dresses)
- Household textiles (e.g., bed linen, curtains, carpets)
- Industrial textiles (e.g., protective clothing, geotextiles)

The fate of textile waste is a pressing issue in modern waste management, driven largely by the rapid increase in textile consumption characterized by the fast fashion model. The overwhelming volume of textile waste presents numerous environmental challenges, as textiles are often non-biodegradable and can remain in landfills for hundreds of years, contributing to pollution and resource depletion. Most commonly, textile products end:

- Landfilling: Textile waste often ends up in landfills, taking years to decompose (if happening). Over 44,2% of post-consumer textile waste ended up in landfills in the EU in 2019 (Napolano et al. 2025).
- Incineration: 46,1% of this post-consumer waste was used for energy recovery (Napolano et al. 2025).
- Recycling: Textile recycling rates in Europe remain low (EU has estimated that less than 1% of textile wastes are transformed into new textile products (European Commission 2022)). Mechanical recycling is the most common method, where fabrics are shredded to produce fibers for new products. Chemical recycling, though less common, breaks down textiles into their raw materials for reuse, and it's a promising strategy for the future management of residues, particularly for mixed fractions.
- Reuse: Second-hand clothing markets and charitable organizations play a significant role in extending the lifespan of textile products (Valtere, Bezrucko, and Blumberga 2023b).

It should be highlighted that the composition of textile products plays a crucial role in determining their fate after disposal. Different materials require different recycling processes, and their environmental impact varies significantly (Juanga-Labayen, Labayen, and Yuan 2022b).

Understanding the differences in the material's behavior is crucial for developing effective waste management strategies and enhancing recycling practices in the textile industry. Therefore, their potential recycling or decomposition capabilities should be considered when settling a path for end-of-life planning of such products.

Natural fibers such as cotton, wool, and bamboo are generally more biodegradable than their synthetic counterparts. When disposed of in landfills, natural fibers can decompose through microbial activity; however, this process may lead to greenhouse gas emissions such as methane and carbon dioxide, depending on environmental conditions (Weber, Lynes, and Young 2017). For instance, cotton and other natural fibers may produce acid leachate that can contaminate soil and groundwater (Weber et al. 2017). In contrast, synthetic fibers, including polyester, nylon, and acrylic, are derived from petrochemical sources and are resistant to biodegradation. This resistance means that synthetic textiles can persist in landfills for hundreds of years, contributing to significant environmental pollution and soil degradation (Indrie et al. 2023). Their breakdown is typically limited to physical degradation rather than biological processes, leading to microplastic pollution (Tang 2023). However, they are more durable and can be recycled into new products if processed correctly (Akram 2024).

Blended fabrics, which combine natural and synthetic fibers, present significant recycling challenges. Separating the fibers is a complex process that requires advanced technology. As a result, most blended fabrics are either incinerated or landfilled.

The recycling of textile waste is more advanced for some natural fibers than for synthetic materials. While natural fibers can be composted or enzymatically processed for recycling, synthetic fibers often require more complex and energy-intensive methods, such as chemical recycling that involves high temperatures and solvents (Damayanti et al. 2021; Tang 2023). For example, the composting process for natural fibers promotes sustainable waste management practices, allowing these materials to naturally decompose and return nutrients to the soil (Ashish Karnad 2023). Meanwhile, recycling technologies for synthetic fibers are still developing, entailing significant challenges related to the recovery of the fibers and maintaining their quality during processing (Indrie et al. 2023).

Post-consumer textile waste is more challenging to recycle than pre-consumer waste due to its mixed-material composition, which can include various fiber blends and synthetic additives that hinder effective processing (Todor et al. 2022). The lack of efficient sorting technologies, and their high cost, further complicates the recycling of mixed or contaminated textile waste, leading to the conclusion that much of it ends up in landfills or incineration (Zandberga, Kalnins, and Gusca 2023). Notably, the global recycling rate for textiles is less than 1% for worn clothes, with a significant amount of waste being improperly managed due to complex material compositions that challenge recycling efficacy (Abrishami et al. 2024).

Emerging policies focused on sustainability and circular economy principles aim to improve the fates of textile waste from both natural and synthetic sources. Initiatives include extended producer responsibility (EPR), and mandatory recycling targets intended to divert waste from landfills and promote higher recycling rates (Ishchuck, Ivanishena, and Grekhova 2023). Sustainable fashion practices emphasize the use of organic and recycled fibers, reflecting a growing awareness of the necessity of reducing textile waste generated by consumer behavior tied to fast fashion models (Ishchuck et al. 2023). As part of these principles, natural fibers can be strategically managed to minimize their environmental footprints through composting and other eco-friendly treatments, while advanced recycling methods for synthetic fibers could mitigate their long-term persistence in waste (Tang 2023).

A holistic approach that incorporates sustainable practices, improved recycling technologies, and proactive legislation is vital for effectively managing textile waste across different fiber types.

4. Textile Waste in Macaronesia

4.1. Context

Macaronesia consists of several archipelagos located in the North Atlantic Ocean, including the Azores, Madeira, the Canary Islands, and Cape Verde. These islands represent a unique biogeographical region characterized by their isolation and distinct biodiversity, with many endemic species resulting from a complex colonization history and evolutionary dynamics (Durán et al. 2020; Vieira et al. 2019). The geographical characteristics range from volcanic landscapes in the Canary Islands to the arid structures of Cape Verde, underscoring the diverse ecosystems present across the region (Calado et al. 2019; Durán et al. 2020).

Macaronesia is classified as an outermost region of the European Union, which comes with distinct political and economic implications. Being under the jurisdiction of EU policies allows for specific funding and developmental aids, leading to initiatives designed to reduce disparities with mainland Europe. This political framework also facilitates collaboration on safeguarding its unique environmental heritage while addressing local challenges stemming from isolation and limited resources (OECD 2023). Additionally, the socio-political dynamics often involve discussions on managing biodiversity, sustainable tourism, and environmental conservation strategies critical for the region's economic viability. This specific framework considers the particularities of this region, namely its strategic position, its high and unique biodiversity, but also its main limitations, such as the distance to the continent, the limited market size, the reduced technological development, or the dependence on external resources.

The unusual aspect of Macaronesia lies in its highly contrasting ecosystems and unique biodiversity, which includes a wealth of endemic species such as the Macaronesian dragon trees and various forms of vegetation adapted to arid conditions (Durán et al. 2020; Martín-Hernanz et al. 2023). The islands also serve as key locations for studying the evolution of species due to their remoteness and distinct climatic conditions that enhance biodiversity (Martín-Hernanz et al. 2023; Vieira et al. 2019). Along with flora, endemic fauna such as unique species of marine invertebrates thrive in these waters, making Macaronesia a biodiversity hotspot facing conservation challenges (Castro et al. 2022; Jiménez et al. 2017; Zamora-Marín et al. 2023)

Strategically, Macaronesia serves as a crucial maritime crossroads between Europe, Africa, and the Americas. Its position enhances its potential as a hub for scientific research, particularly in fields such as marine biology, ecology, and climate studies. This strategic significance is notable for the development of emerging technologies and practices that can influence other outermost regions (OECD 2023; Vieira et al. 2019). The islands are increasingly viewed as valuable sites for testing and deploying innovative ecological management strategies that could be replicated elsewhere.

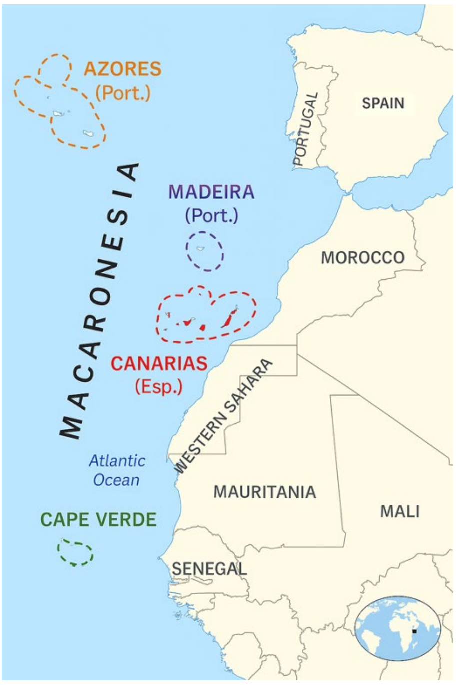

Figure 1. Map on the Macaronesia region (created on ChatGPT 4.0 – free version; adapted from (Wikipedia 2025))

The insularity of the Macaronesian islands poses significant challenges, including limited accessibility to resources, economic vulnerabilities, and increased dependence on tourism. Isolation can hinder the dissemination of technological advancements and best practices in areas like waste management and biodiversity conservation (OECD 2023). Moreover, the islands face environmental threats such as climate change impacts leading to habitat degradation, invasive species proliferation, and alterations in local ecosystems, which turn very fragile. Similarly, there are undeniable limitations from the point of view of market scale, technological development and access to resources. In the context of this work, dealing with waste treatment, the limitation of the amount of residues, paradoxically hinders the establishment of industrial establishment for their valorization and the establishing a value chain around resources recovery.

The Macaronesian islands have considerable potential to become reference points for sustainable practices in emerging technologies, particularly due to their unique ecological challenges and isolation. Initiatives in biodiversity preservation, waste management, and climate adaptation are already showing promise, with studies documenting innovative approaches to tackle environmental pressures (Atchoi et al. 2021; OECD 2023). Furthermore, technological collaborations aimed at developing eco-friendly practices can be effectively translated to other isolated territories, enhancing overall sustainability. As such, Macaronesia stands to play a pivotal role in advancing ecological research and management practices that can inform policies globally.

4.2. Textile Waste in Spain

Once established a general framework for the work, it is needed to take a step back and analyze the state of the art of textile waste collection and treatment in the continent, before focusing on the Macaronesian region. This is an important step to fully address and consider the unique confluence of geographical, ecological, and socio-political characteristics that not only highlight its individual challenges and opportunities but also position it as a vital area for the implementation and dissemination of sustainable initiatives.

It is well-known that textile industry is responsible for 10% of the carbon dioxide emissions and 20% of polluted industrial waters (Moda-RE, Anthesis Lavola, and InTexter - Universitat Poltécnica de Catalunya 2021; Morell-Delgado, Talens Peiró, and Toboso-Chavero 2024). On the other hand, it is interesting to highlight that from all textile products imported into the EU, only a third was sold at its original price, while another third was sold at sales price, with the remaining third not sold (Moda-RE et al. 2021). This same report estimates that in the last 50 years the world production of textile fibers has been folded by 4, while the population has increased by 2. In particular, between 1996 and 2012 the amount of clothes acquired in the EU increased by 40%; in particular, this means that the annual consumption of textile products has increased from 7 to 13 kg/person, arriving to a total of 100 million tons of textile products yearly, with a forecast of 130 million tons for 2025 (Mishra et al. 2022). Most of these will be discarded as a waste within a short period of time. A recent work analyses the textile waste recycling in Spain, categorizing the processes in manual sorting, mechanical recycling, and chemical recycling, each with distinct advantages and limitations (Lanz et al. 2024). Mechanical methods are mature but yield lower-quality fibers, while chemical recycling, though capable of producing virgin-grade outputs, remains costly and less developed. Automated sorting technologies show promise but require greater implementation. The article also discusses European and Spanish policies promoting circularity, including Spain's upcoming mandate for separate textile collection and ambitious reuse/recycling targets. The authors emphasize that achieving an effective circular economy for textiles will require a combined approach involving improved sorting, technological investment, and regulatory support. However, no mentions are done in this work to the particularities of Canary Islands or other isolated regions in Europe, and therefore the limitations regarding size and availability of technology.

Textile residues are produced mainly in two different ways, either by the textile producers (pre-consumption) either by consumers (post-consumer wastes). Some examples of pre-consumption residues are scraps from cutting or short fibers that cannot be processed into the yarns (Serra et al. 2019); items that have never been sold are also considered as pre-consumption residues. Post-consumer residues are those products that have been used and are discarded either because they are age-worn or because the consumer is no longer using them.

Spain generates approximately 900,000 tons of textile waste annually (Statista 2025). However, only about 12% of this waste is separately collected for recycling or reuse (Figure 2). The majority of textile waste in Spain is landfilled or incinerated.

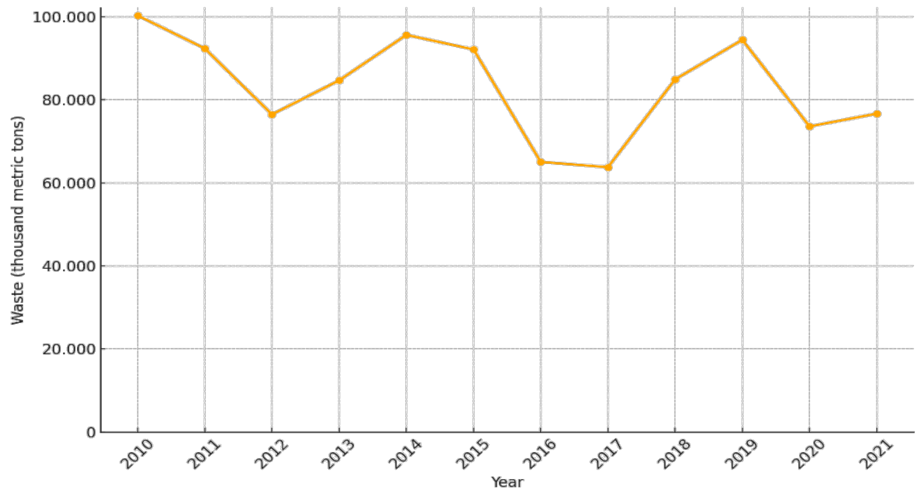

Figure 2. Annual textile waste managed in Spain from 2010 to 2021 (in metric tons) (Statista 2025)

The Spanish Ministry for Ecological Transition (MITECO) has identified textile waste as a priority area and has set targets to increase recycling rates. The country has also introduced extended producer responsibility (EPR) schemes for textile products (ETC/WMGE and ETC/CE 2022), in order to improve the management of waste. In this sense, in 2025, a pilot program called RE-VISTE will be launched in collaboration with major retailers such as Inditex, H&M, El Corte Inglés, Mango, Ikea, etc. The program aims to facilitate the collection and recycling of discarded clothing (Akram 2024; Pons 2024; RE-VISTE 2025).

According to the report issued by Moda-re (assessment of clothes collection in Spain): "only the 15 % of post-consumer textile wastes were collected separately for their recycling in 2015, while less than 1% of the total production (0.5 million tons) were recycled in a closed system" (Moda-RE et al. 2021). In 2019 there were only 21,822 systems to collect textile residues, including dropsites and specific containers, according to this same report. Therefore, there is insufficient infrastructure to achieve the challenges settled.

Only 15% of post-consumer residues collected in Spain in 2015 were recycled (Moda-RE et al. 2021), while some studies consider that most textile products are fully recyclable (Hawley 2008). Most of these products were recycled in applications with a lower value (downcycling), being transformed into isolating material for building applications, wipers or filling for mattresses. In addition, about 1.1 million tons of material was lost during the collection and processing (Moda-RE et al. 2021). It is important to highlight that the recycling of textile products is relatively recent and the technologies to carry it out are still economically not accessible. In fact, the first records on Scopus about textile residues start from 1972, in a review paper where urban residues include the textile ones, estimating a share of 2.7% (Kupchik 1972). The fact that for both industrially and from a scientific point of view the recycling of textiles is relatively recent does not mean that individuals has not carried out the reuse or recycling of such products; it is thought that the technique known as *Patchwork*, consisting in joining several pieces of discarded fabric to make a new product, was already being in use in ancient Egypt or China, that is, about 3,000 years b.C., with the first registers appearing in Europe in the 12th century (Eskridge 2017).

Some works state that an increase of 12% in the reuse of clothes in good conditions and a 15% in the recycling can reduce the impact of textile products by 8 % in the EU, assuming the recycled material substitutes virgin one (Morell-Delgado et al. 2024). On the other hand, the approach to Zero waste strategies generates more job opportunities than incineration or landfilling (Patel, Sahu, and Rajak 2022). In any case, the approach providing more benefits would be undoubtedly the reduction in the quantity of textile products sold; their design for durability and an adequate planning of the product's lifecycle can reduce up to 80 % of its overall impact (Hur and Cassidy 2019). In this line the movement *Slow Fashion* arises (Nerurkar 2016), which main philosophy is to produce high-quality durable clothes, aiming at getting special long-lasting items; that way, the user would need less clothes and would thus produce lower residues.

The information collected shows that, as said, textile wastes collected in Spain are about 80,000 tons/year, with a clear deficit of specific systems for collection of these items. Table 1 shows the amount of textile products collected in each Spanish region in 2019, with big differences due not only to the population or economic model but also to the availability of specific management and collection systems.

Table 1. Textile wastes collected in 2019 in Spain (in tons) by region (Moda-RE et al. 2021)

To achieve the intended objectives by 2030 many regions plan to increase the number of municipal containers; for instance, Vigo has increased its number of bins from 50 to 300, and Málaga plans to increase theirs from 2 to 233 (Medina 2023).

Once the textile products have been collected, apart from the problems related to obtain a separate collection, there is a further problem: the huge variety of materials and the difficulties in distinguishing them. Besides, recycling procedures need to remove non-textile materials, such as zippers, buttons or bags. Generally, these processes are done manually, with the subsequent high costs (Moda-RE et al. 2021). Some initiatives to solve these problems have been investigated, such as the use of smart labels, sensors, Big Data, IoT, etc. The costs of these systems are still not in use due to the high costs and the lack of appropriate systems for sorting.

Some further sorting would be by condition (suitable to be reused or not), materials, or colors. Some technological systems used in materials sorting are near infrared (NIR), hyperspectral images, or artificial intelligence, among others (Tang 2023). The most common method among them is the use of NIR, although for hybrid materials, made of a blend of materials (especially with low percentages of one material), or layered products, this technology is not useful (Moda-RE et al. 2021). A different method quite extended is the use of radiofrequency identification (RFID); it consists of the incorporation of a microchip containing useful data, such as composition. This is currently done in the labels, although they are mostly cut or degraded at the end of their lifetime. The advantage of RFID is that they are not visible, being placed generally on the seams or hidden places, thus being kept throughout the entire lifetime of the textile product.

For example, in Ribarroja (Valencia) there is plant to manage 6,000 tons of textile items yearly, mainly coming from over 700 collection points established by Cáritas. Items are classified firstly according to their reuse possibilities, being 10% of the collected items resold in Spain. Another 10% is transformed into short fibers to make new yarns, while most of the collected material (70%) is sent to different countries (Medina 2023).

On the other hand, the recycling process needs to consider the colors of the items fed; Uchimaru and collaborators proposed that the items introduced in a same batch for recycling should not be separated more than 85º in the Munsell scale (Uchimaru, Kimura, and Sato 2013).

The methods for recycling textiles can be classified into mechanical, chemical, and biochemical processes (Baloyi et al. 2024; Damayanti et al. 2021). As mentioned before, mechanical recycling typically involves shredding textiles into smaller pieces, while chemical recycling focuses on breaking down fibers into their fundamental chemical structures to produce new raw materials. For instance, chemical processes such as pyrolysis and enzymatic hydrolysis are gaining attention due to their ability to handle complex blended fabrics that are common in textile products nowadays (Choudhury, Tsianou, and Alexandridis 2024; Ndagano et al. 2025). Biochemical recycling, which utilizes microorganisms and enzymes, offers a promising direction for sustainable practices by potentially reducing reliance on harsh chemicals (Piribauer, Bartl, and Ipsmiller 2021; Tang 2023). Advances in sorting technologies have enhanced the efficiency of these recycling processes, crucial for separating the diverse materials often found in textile waste.

On the other hand, consumer perceptions of recycled textiles significantly influence recycling efforts. As stated by Wagner and Heinzel, public awareness regarding the sustainability of products has propelled brands to align with recycling practices, thus promoting a shift toward circular fashion (Wagner and Heinzel 2020). The role of consumers, as highlighted in recent discussions, is pivotal in implementing these sustainable practices and earning them recognition as key stakeholders in the recycling process (Riemens et al. 2021).

Despite the advancements and available technologies in textile recycling, several challenges persist. The complexity of textile compositions, which includes various blends of fibers, presents technical obstacles for recycling facilities (Ndagano et al. 2025; Wojnowska-Baryła et al. 2024). Moreover, legislative frameworks, such as the European Union's directives mandating the separation of textiles by 2025, seek to enhance recycling rates but also pose implementation challenges for stakeholders within the recycling ecosystem (European Commission 2022; European Environment Agency 2024; Piribauer et al. 2021; Zandberga et al. 2023). The joint effort of industry leaders, policymakers, and consumers is essential for overcoming these barriers and optimizing textile recycling processes, ultimately contributing to the sustainability of the textile industry.

While diverse and evolving technologies offer potential pathways for recycling, ongoing challenges related to material complexity and legislative compliance must be addressed collaboratively by all stakeholders to achieve meaningful progress toward a circular economy model in the textile industry.

4.3. Current Situation in the Canary Islands

The Macaronesian region has similar challenges in managing textile waste. The insular nature of these territories makes transportation and processing of waste difficult, and the market is medium or low size, which poses another particular challenge due to the potential lack of enough material for the appropriate management or a market suitable to absorb such recycled items.

It is well accepted that the Canary Islands face unique challenges due to their insular and fragmented territory. The limited land area restricts the establishment of large-scale recycling facilities, while the costs associated with transporting textile waste to continental Europe for processing are significantly higher. For example, transporting textile waste from the Canary Islands to mainland Spain can increase costs by 30-50% compared to local processing due to logistical expenses and emissions from maritime transport (Das et al. 2025; Juanga-Labayen, Labayen, and Yuan 2022c). Additionally, transporting one ton of textile waste by ship can produce approximately 150 kg of CO_2 emissions, contributing to an increased carbon footprint of waste management (Valtere et al. 2023b). The lack of space for landfills and the reliance on imports also make it critical for these regions to develop local solutions, such as small-scale recycling plants and circular economy initiatives. Furthermore, the islands' reliance on imported goods makes the waste management still more complex, as textile products are not designed with local recycling capabilities or market demands in mind. Therefore, the need of innovative, localized solutions tailored to the specific needs of those isolated small territories, such as developing small-scale recycling plants or incentivizing sustainable fashion practices to reduce waste generation on the islands, is patent. Waste management infrastructure is limited, and textile waste is often sent to landfills, which are more and more saturated. However, the regional government has implemented measures to improve waste separation and recycling, such as plants for sorting and treating electric and electronic residues (MangoPress 2024); textile wastes are not included though for the moment in such initiatives.

In 2019, the Canary Islands collected approximately 1.3 million tons of waste, with textile waste accounting for a significant portion (about 10%, as shown in Table 1). The majority of this waste is unsorted, highlighting the need for improved collection systems.

In the Canary Islands there are mainly two companies collecting textile wastes: Canarias Recycling S.L. and Martinez Cano, although other associations or companies also participate: Ataretaco, Urbaser and Mancomunidad del Nordeste de Tenerife (Moda-RE et al. 2021). As found in Table 1, the ratio of collected/produced wastes in Canary Islands is 2.5% under the average for the country (9.68 vs. 12.16%). This could be related to the lack of updated data in this region and possibly to a deficient implementation and management of those wastes.

4.4. Current Situation in Madeira and Açores

According to the annual report of urban residues in the autonomous region of Madeira in 2021, there is no separate collection of textiles residues in this area, but an analysis of urban residues led to an 8.5% of residues related to sanitary textile products, while 4.4% were included within the textile category (Secretaria Regional de Ambiente and Climáticas 2022). Considering that the total amount of residues collected in the period of this report exceeded 115,000 t, these data emphasizes the need to perform an adequate valorization of these materials and plan a separated collection system to ease their later processing. Unfortunately, no more data has been found to date.

However, the new national plan for wastes management includes as an objective for 2030 the obligatoriness of a selective recovery of textile products, among other types of residues, which is also reflected in the wastes strategy settled for Madeira (Águas e Resíduos da Madeira 2023).

In Açores, the Direção Regional/Municípios have installed textile collection bins ("contentores de roupa usada") across all nine islands—at least one per municipality, often more in larger urban areas such as Terceira-. There are 7 containers in total, being the most of content of these bins directed to reuse, donation, or recycling, reducing landfill or incineration (Governo dos Açores 2025). Estimations indicate that about 4% of urban wastes correspond to textile products, as averaged for the rest of the country, with about 200,000 t/year disposed in the entire country (AJITER 2025).

5. Global Pilot Strategies for Textile Waste Valorization

Several pilot strategies have been implemented worldwide to improve textile waste management:

- The Swedish Chemical Recycling Project (Luleå University of Technology 2025): Aims to develop chemical recycling methods to recover fibers from mixed textile waste. The project utilizes advanced chemical processes to break down both natural and synthetic fibers into their fundamental components, which can then be reused to create new textiles. The pilot has shown promising results in reducing textile waste and recovering high-quality fibers suitable for the production of new garments. It also addresses challenges such as separating blended fabrics and removing contaminants, making the recycling process more efficient and scalable.
- The Fibersort Project (Netherlands) (Fibersort 2025): Uses automated sorting technology to separate textile waste by fiber type, enabling more efficient recycling. The project employs near-infrared (NIR) technology to distinguish between different fiber types, allowing for precise sorting and better downstream recycling outcomes. This method has proven effective in separating natural and synthetic fibers, as well as blended fabrics, making it easier to process them into new textile products.
- The Worn Again Technologies (UK): Focuses on chemical recycling to convert textiles into new fibers and polymers. The technology focuses on the recycling of blended fabrics, particularly on the separation of polyester and cotton fibers from discarded textiles. The recovered materials are then processed into new raw materials for the fashion and textile industries. The company has partnered with major brands like H&M and Kering to scale up its operations and promote closed-loop recycling systems. The H&M Conscious Collection (Akram 2024) is a global initiative to collect and recycle used clothing in H&M stores.
- RE-VISTE: The Association for the Management of Textile and Footwear Waste has been presented in October in Spain and will operate under the SCRAP system (Collective System of Extended Producer Responsibility). The pilot test is expected to begin in April 2025, with the collaboration of the Spanish Federation of Municipalities and Provinces. Around 300,000 citizens from six urban, rural and semi-urban municipalities in different regions of Spain will participate in the pilot project (MangoPress 2024).

  According to RE-VISTE association (RE-VISTE 2025), the idea on this proposal is to analyze different options for textile collection and adapt them to different municipal contexts; the collection routes will include the installation of specific containers on public roads and at municipal clean points. Moreover, collection points will be set up in private spaces such as shopping centers, shops or schools, thus making them available in different environments to boost the participation of citizens. After their collection, the discarded textile products will be transported to sorting plants, where they will be evaluated according to the waste hierarchy principle. Items that are in good condition will be destined for sale in second-hand shops, while those not suitable for reuse will be sorted according to their composition for their later recycling, with the aim of transforming them into new textiles.
  The pilot project will last at least one year. At the end of the project, the aim is to produce a guide of recommendations that will include the good practices identified, in order to provide local authorities with tools and guidelines that will enable them to successfully implement selective textile collection in their territories.

6. Challenges to Increasing Circularity and Sustainability in the Textile Industry

The textile industry faces several challenges in transitioning to a more circular and sustainable model:

1. Complexity of Recycling Processes: The diversity of textile materials and the prevalence of blended fabrics make recycling challenging. Mechanical recycling processes often degrade the quality of fibers, while chemical recycling is expensive and energy-intensive.
2. Consumer Behavior: Fast fashion culture promotes the rapid disposal of clothing. Changing the consumer behavior to encourage longer use of textile products and responsible disposal is critical for improving sustainability in this sector.
3. Lack of Infrastructure: Many regions lack the necessary infrastructure for collecting, sorting, and recycling textile waste. This is especially true in isolated regions such as the Canary Islands, or the Macaronesian region in general, where waste management is further complicated by transportation challenges. Furthermore, the region's reliance on imported textiles with no end-of-life planning reinforces a linear economy.
4. Economic Viability: The cost of recycling textiles often exceeds the value of the recycled materials. Developing economically viable recycling methods is essential for increasing circularity. The lack of consistent data on the amount of textile wastes generated and their actual fate is a first issue to solve to design a cost-effective approach for the reuse and recycle of textile items.
5. Legislation and Incentives: While EU legislation is pushing for more sustainable practices, there is a need for stronger incentives to promote recycling and reuse within the industry.

7. Current commercial applications of products derived from circular textile waste

In addition to the various pilot strategies mentioned earlier, numerous companies are already working on commercial solutions for textile waste, currently offering real solutions and developing both semi-finished and final products for various economic sectors.

7.1. Recovered fibers for general applications

Currently, mechanical and chemical recycling processes are the most widely used technologies for producing semi-processed products. Mechanical recycling typically involves shredding used fabrics to obtain reusable fibers. Companies such as Texlimca, Acorcertex o Recover Textile Systems, in Spain, employ this method to produce and commercialize industrial rags, stuffing materials o new recycled fibers (Alcocertex n.d.; Recover Textile Systems 2025; Texlimca 2025). Although these methods are low cost and mature technology, the fiber quality deteriorates with each cycle, limiting its use to low-grade products such as insulation or padding.

Moreover, chemical recycling breaks down fibers at the molecular level to regenerate virgin-quality materials. For instance, Eastman and the Inditex-BASF partnership have developed technologies to recycle complex blends like cotton-polyester or nylon-elastane (Inditex 2025). While this method enables the recycling of textiles unsuitable for mechanical processing, it is energy-intensive, requires prior material separation, and remains in the industrial scaling phase. Gr3n, headquartered in Switzerland and Italy, has pioneered a chemical recycling technology that enables the depolymerization of polyester-based textiles into their original monomeric components. This process facilitates the production of high-quality raw materials suitable for reintroduction into the textile manufacturing cycle (GR3N 2025). In parallel, Worn Again

Technologies, as mentioned previously, has developed a proprietary chemical separation process capable of isolating and purifying polyester and cellulose from blended textile waste (Worn Again Technologies 2025). The resulting recycled outputs meet the quality standards required for reuse in new textile products. Both companies actively commercialize these chemically recovered materials, addressing waste streams that are not amenable to mechanical recycling.

Taking another approach, Renewcell's Circulose converts cotton waste into a cellulosic pulp suitable for viscose or lyocell production (Renewcell 2025). Similarly, Infinited Fiber Company has developed a technology that transforms cotton-rich waste into a cotton-like fiber using a cellulose carbamate process. These methods offer high-quality outputs and reduce reliance on virgin cotton. However, they require feedstock with high cellulosic content and involve complex industrial processes (Infinited Fiber Company 2025).

7.2. Construction and building applications

Textile waste fibers are being converted into composite materials for use in building, insulation, reinforcement, and geotechnical engineering, offering alternatives to traditional, resource-intensive materials and reducing landfill burden. One of the most prominent is Greenful, based in the Netherlands and Estonia. The company manufactures structural and insulating panels (SIP Panels) from recycled textile and plastic waste. Through compaction and thermal treatment, they produce materials with high mechanical strength, fire resistance, and thermal insulation properties, suitable for modular construction, cladding, and urban furniture. Their focus is on delivering scalable, sustainable solutions for both new builds and renovation projects (Greenful 2025). Métisse is a brand of thermal and acoustic insulation developed by the French Cooperative Le Relais, made exclusively from recycled cotton sourced from post-consumer clothing. Their product range includes insulation panels and rolls used in walls, ceilings, and floors, both in new construction and renovation. The production process involves collecting, sorting, disinfecting, and fireproofing the textiles, resulting in a material with high insulating capacity, low environmental impact, and excellent hydrothermal performance (LE RELAIS Métisse n.d.). In France, FabBRICK has developed a semi-industrial process to transform used clothing into decorative construction bricks. The textiles are shredded and mixed with an eco-friendly binder, then pressed into molds. These bricks are primarily used indoors for acoustic insulation, furniture, and wall coverings, combining functionality with sustainable design (Fabbrick 2025).

Also internationally, Recyc Leather, initially focused on recycled leather, has begun collaborating with architects and designers to integrate its materials into decorative panels and interior cladding (RECYC LEATHER 2025). They use post-consumer textile and leather fibers, bonded through low-emission processes to create durable and aesthetically appealing surfaces.

7.3. Advanced composites

Blended textile waste (including post-consumer and PPE waste) is used to create composites with strong mechanical properties, suitable for domestic products, automotive parts, and even ballistic applications, often outperforming wood and wood-plastic composites in cost and sustainability. Loop Industries has developed a proprietary chemical depolymerization technology that breaks down waste polyester textiles and PET plastics into their base monomers. These are then repolymerized into Loop™ PET resin, a high-purity polymer used in packaging and textiles. While their primary market is packaging, the resulting polymer is suitable for composite applications due to its structural integrity and recyclability (Loop Industries 2025). In Taipei, Miniwiz is a pioneer in upcycling textile and plastic waste into high-performance composite materials. They use thermoforming and injection molding to create a wide range of products, including modular wall panels, furniture, architectural elements, and consumer goods. Their materials often combine shredded textile fibers with recycled polymers to form durable, moldable composites that are both functional and aesthetically appealing (Miniwiz 2025).

7.4. Geotextiles and landscaping fabrics

Low-grade textile waste is also commonly processed into nonwoven fabrics used for soil stabilization, erosion control, drainage systems, and road construction. These materials are valued for their durability and permeability. Altex Textil Recycling specializes in transforming textile waste into high-performance recycled fibers, including those used in geotextile applications. Their sustainable production process supports infrastructure projects by providing durable, eco-friendly materials for soil stabilization, drainage, and erosion control (ALTEX Textil-Recycling 2025). Similarly, Fibras Renag, a Mexican company specializing in textile waste recycling, transform post-industrial and post-consumer textiles into high-quality materials suitable for soil stabilization, filtration, and erosion control with ISO 9001:2015 certification (FIBRAS RENAG 2025).

8. Outlook

This work underscores the urgent need to tailor textile waste management strategies to the geographic, infrastructural, and economic realities of the Macaronesian region. While Europe (Spain and Portugal) are advancing in circular textile policy, the application of these frameworks in isolated territories remains inadequate. Novel contributions arising from this study include the identification of high-impact local interventions and a five-pillar policy framework that has to be specifically designed to overcome the structural and logistical barriers in the Macaronesian region.

By emphasizing regional specificity, promoting modular technologies, and integrating data-driven policy approaches, Macaronesia can become a case study in insular circular economy transformation. Closing the policy-practice gap in these regions is not only crucial for environmental sustainability but also for social and economic resilience.

Some insights for this policy framework proposal are:

- Localized Micro-Hubs: Establish modular recycling facilities capable of sorting and processing small volumes.
- Digital Traceability Systems: use of smart labeling on garments to facilitate sorting and material recovery.
- Targeted Fiscal Incentives: Subsidies for local reuse cooperatives, and tax relief for importers who comply with recyclability standards.
- Waste-to-Work Programs: Training and employing residents in sorting and remanufacturing to strengthen local green economies.
- Data and Reporting Mandate: Require textile waste reporting at the municipal level to feed into a Macaronesia-wide data platform.

This framework has some limitations and drawbacks, such as the high initial investment costs and technological adaptation barriers. Setting up modular hubs and smart technologies involves significant upfront investment, which may strain local budgets without national or EU-level funding, while the implementation of smart labeling and traceability systems would require a coordinated industry-public participation and consumer compliance, which might be difficult to enforce in early stages. Besides, there is a lack of technology adapted to the relatively low volume of waste streams to deal with, which means that technological development and innovation are also required.

Regarding fiscal incentives, it should be mentioned that Spain's Law 7/2022, from April 8 (Government of Spain 2022), on waste and contaminated soils for a circular economy, mandates that local entities must establish separate collection of textile waste (by the end of 2024) to facilitate preparation for reuse and high-quality recycling. Furthermore, for the collection, transport, and treatment of textile waste, public administration contracts will be preferentially tendered and awarded through reserved contracts, with at least 50% of the award amount allocated for Insertion Companies and Special Employment Centers of social initiative authorized for waste treatment. While this legal framework aims to boost social inclusion and improve waste management, its implications for regions such as Macaronesia are complex. This mandate can limit the participation of traditional companies in the sector, thereby reducing the already scarce economies of scale available in these island territories. To mitigate this, a more flexible regulatory framework should be considered to foster synergy and collaboration between social insertion companies and traditional textile waste management businesses.

Furthermore, given the variability of the second-hand clothing market, the inherent limitations for economically sustainable small-scale recycling solutions with local demand, and the difficulty in competing with non-recycled products, the authors conclude that it is imperative to establish a supportive regulatory framework that actively benefits circular-economy activities within the textile sector in outermost regions. Such a framework is essential to overcome market inefficiencies and ensure the long-term viability of sustainable textile waste management in regions facing similar structural and logistical challenges.

To address these challenges, it is crucial to understand the intricate operational complexities of textile waste management in the Macaronesian region. The following flowchart (*Figure* 3) illustrates the journey of textiles from collection to their destination, highlighting the limitations of the process steps that must be considered to improve the textile waste management in outermost regions.

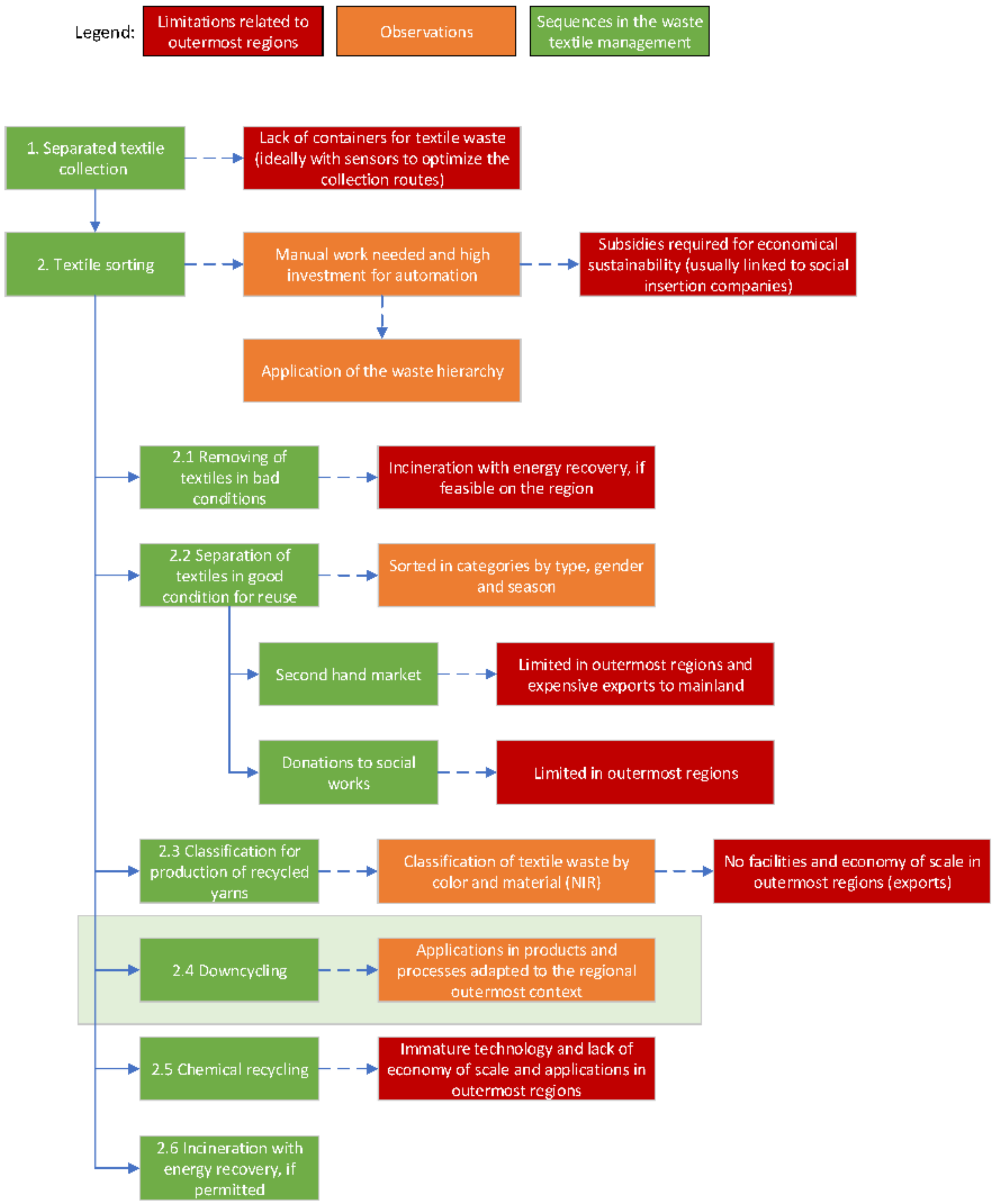

Figure 3. Representative flow chart of the textile waste life cycle applying the waste hierarchy, and main constraints of the different stages for the outermost regions

In addition to promoting the reduction of clothing consumption, based on the life cycle of textile waste and taking into account the limitations for reuse and recycling into new yarns, it seems that the key to promoting a circular economy lies in the search for applications of textile waste in products in demand in the regions (downcycling) and with simple, economical production processes adapted to the technological and productive level of each region.

Despite all these difficulties, there is also a significant opportunity to serve as a success pilot processing, which could be the basis for a scalable model for other insular or peripheral regions facing similar constraints. The synergies of this approach with the EU goals would foster the stimulation of innovation and entrepreneurship, also contributing to social initiatives focused on fashion reuse and recycling for a proper consecution of SDGs and the triple bottom line of sustainability: people, planet and profit.

9. Conclusions

Textile waste management in Europe, and more particularly in the Macaronesian region, presents significant challenges and opportunities. While legislative measures and pilot programs both at EU and national levels are steps in the right direction, achieving higher recycling and reuse rates will require continued efforts in infrastructure development, public awareness, and policy enforcement.

Of particular relevance is the lack of data in the European territories but more particularly in the Macaronesia, that is, in Canary Islands, Madeira and Açores. The implementation of adequate strategies for the collection and management of such wastes is imperative to reach the objectives settled for this type of products and to effectively advance into a more sustainable textile industry, tailored to the specificities of this outermost regions, generally at lower technological development than the mainland territory.

Raising the awareness of consumers about fast fashion and its environmental impact, while, at the same time, enhancing the visibility and availability of high-quality second-hand clothes, changing the mentality of consumers and the prejudices around it, have been proven absolutely vital to improve the environmental footprint of the sector. Only by reducing and reusing textile products would be an effective way to advance towards a more sustainable industry, while developing at the same time cost-effective strategies for sorting and recycling these products at their end of life.

10. Data statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

11. References

Abrishami, Shayan, Armineh Shirali, Nicole Sharples, Gulsah Ekin Kartal, Lisa Macintyre, and Omid Doustdar. 2024. "Textile Recycling and Recovery: An Eco-Friendly Perspective on Textile and Garment Industries Challenges." *Textile Research Journal* 94(23–24):2815–34. doi:10.1177/00405175241247806.

Águas e Resíduos da Madeira, S. A. 2023. *Plano de Ação Da Estratégia de Resíduos Urbanos Da ARM*.

AJITER. 2025. "Lições Do Passado e Investigação Científica Chave Da Sustentabilidade Têxtil." https://www.ajiter.pt/index.php?codnoticia=110&next_ecran=1&op=noticias&pag=1&pag_ant=noticias.

Akram, Rabia. 2024. "How Fashion Retailers Are Driving Sustainability in Spain." https://impakter.com/fashion-retailers-driving-sustainability-in-spain-textile-waste/.

Anjimoon, Shaik, Asha V, Jaicky Gurnani, Irfan Khan, Surovi Paul, and Hassan M. Al-Jawahry. 2024. "Innovations and Opportunities in Sustainable Textile Recycling" edited by A. Fande. *E3S Web of Conferences* 507:01065. doi:10.1051/e3sconf/202450701065.

Ashish Karnad, Vishaka. 2023. “Evaluation of Potential for Textile Waste Management Using the PROMETHEE Method.” *Environmental Science and Engineering* 2(3):15–24. doi:10.46632/ese/2/3/3.

Atchoi, Elizabeth, Airam Rodríguez, Tânia Pipa, Carlos Silva, Azucena Martín, Yarci Acosta, Cátia Gouveia, Gilberto Carreira, Sofia Garcia, and Dília Menezes. 2021. “LuMinAves: Cooperative Research and Mitigation of Light Pollution Impacts in Seabirds.” *International Journal of Sustainable Lighting* 23(1):33–41. doi:10.26607/ijsl.v23i1.107.

Baloyi, Rivalani Baloyi, Oluwatoyin Joseph Gbadeyan, Bruce Sithole, and Viren Chunilall. 2024. “Recent Advances in Recycling Technologies for Waste Textile Fabrics: A Review.” *Textile Research Journal* 94(3–4):508–29. doi:10.1177/00405175231210239.

Calado, Helena Maria Gregório Pina, Mario Caña Varona, Juan Luis Suárez de Vivero, Fabiana Cordeiro Moniz, Firdaous Halim, Daniela de Lima Gabriel, Cláudia Luísa Salvador Hipólito, Elisabetta Menini, Diogo Kramel, Marta Horta de Sousa Vergílio, and Maria Adelaide Ferreira. 2019. “ISLAND GEOGRAPHY SHAPING MARITIME SPACE IN MACARONESIA.” *Europa XXI* 36. doi:10.7163/Eu21.2019.36.8.

Castro, Nuno, James T. Carlton, Ana C. Costa, Carolina S. Marques, Chad L. Hewitt, Eva Cacabelos, Evandro Lopes, Francesca Gizzi, Ignacio Gestoso, João G. Monteiro, José L. Costa, Manuela Parente, Patrício Ramalhosa, Paul Fofonoff, Paula Chainho, Ricardo Haroun, Ricardo S. Santos, Rogelio Herrera, Tiago A. Marques, Gregory M. Ruiz, and João Canning-Clode. 2022. “Diversity and Patterns of Marine Non-Native Species in the Archipelagos of Macaronesia.” *Diversity and Distributions* 28(4). doi:10.1111/ddi.13465.

Choudhury, Khaliquzzaman, Marina Tsianou, and Paschalis Alexandridis. 2024. “Recycling of Blended Fabrics for a Circular Economy of Textiles: Separation of Cotton, Polyester, and Elastane Fibers.” *Sustainability* 16(14):6206. doi:10.3390/su16146206.

Damayanti, Damayanti, Latasya Adelia Wulandari, Adhanto Bagaskoro, Aditya Rianjanu, and Ho-Shing Wu. 2021. “Possibility Routes for Textile Recycling Technology.” *Polymers* 13(21):3834. doi:10.3390/polym13213834.

Das, Anik Kumar, Md. Farhad Hossain, Borhan Uddin Khan, Md. Mahfuzur Rahman, M. A. Z. Asad, and Mahmuda Akter. 2025. “Circular Economy: A Sustainable Model for Waste Reduction and Wealth Creation in the Textile Supply Chain.” *SPE Polymers* 6(1). doi:10.1002/pls2.10171.

Durán, Iván, Águedo Marrero, Fouad Msanda, Cherif Harrouni, Michael Gruenstaeudl, Jairo Patiño, Juli Caujapé-Castells, and Carlos García-Verdugo. 2020. “Iconic, Threatened, but Largely Unknown: Biogeography of the Macaronesian Dragon Trees (Dracaena Spp.) as Inferred from Plastid DNA Markers.” *Taxon* 69(2). doi:10.1002/tax.12215.

Eskridge, Molly. 2017. “Arts & Sciences Research Paper #18: Early Quilting and Patchwork: A Short Introduction.” https://eastkingdomgazette.org/2017/03/03/arts-sciences-research-paper-17-early-quilting-and-patchwork-a-short-introduction.

ETC/WMGE, and ETC/CE. 2022. *Early Warning Assessment Related to the 2025 Targets for Municipal Waste and Packaging Waste. Spain*.

European Commission. 2022. “EU Strategy for Sustainable and Circular Textiles.” https://environment.ec.europa.eu/strategy/textiles-strategy_en.

European Environment Agency. 2024. “Management of Used and Waste Textiles in Europe’s Circular Economy.” https://www.eea.europa.eu/publications/management-of-used-and-waste-textiles.

Fabbrick. 2025. “From Textile to Design.” https://www.fab-brick.com/en.

Fibersort. 2025. “Sorting of Textiles Based on Fiber and Color .” https://www.fibersort.com/.

FIBRAS RENAG. 2025. “Reciclador de Desechos Textiles.” https://fibrasrenag.com/.

Government of Spain. 2022. *Law 7/2022, of April 8, on Waste and Contaminated Soils for a Circular Economy.* Spain: Official State Gazette (BOE). https://www.boe.es/eli/es/l/2022/04/08/7.

Governo dos Açores. 2025. “Pontos de Recolha de Resíduos Têxteis Dos Açores.”

GR3N. 2025. “A New Recycling Concept.” https://gr3n-recycling.com/.

Greenful. 2025. “Closing the Loop at an Industrial Scale.” https://greenful.com/.

Hawley, Jana M. 2008. *Textile Recycling: A Systems Perspective*.

Worn Again Technologies. 2025. “Worn Again Technologies.” https://wornagain.co.uk/.

Huang, Xinxin, Runling Ye, and Lin Zhao. 2025. “Research Progresses of Composites with Natural Fibers Recycled from Textiles Waste.” *Journal of Engineered Fibers and Fabrics* 20. doi:10.1177/15589250251338265.

Hur, Eunsuk, and Tom Cassidy. 2019. “Perceptions and Attitudes towards Sustainable Fashion Design: Challenges and Opportunities for Implementing Sustainability in Fashion.” *International Journal of Fashion Design, Technology and Education* 12(2):208–17. doi:10.1080/17543266.2019.1572789.

Inditex. 2025. “BASF e Inditex Avanzan En El Reciclaje Textil a Textil Con Loopamid, El Primer Nailon 6 Que Procede Íntegramente de Residuos Textiles.” https://www.inditex.com/itxcomweb/es/es/prensa/detalle-noticias/1afc4625-e9cc-4da1-bd13-0f029a42e7be/basf-e-inditex-avanzan-en-el-reciclaje-textil-a-textil-con-loopamid-el-primer-nailon-6-que-procede-ntegramente-de-residuos-textiles-.

Indrie, Liliana, Julieta Ilieva, Zlatin Zlatev, Simona Tripa, and Amalia Sturza. 2023. “Development of an Algorithm for Textile Waste Arrangement.” *Sustainability* 15(14):11399. doi:10.3390/su151411399.

Infinited Fiber Company. 2025. “Our Technology - Infinited Fiber.” https://infinitedfiber.com/our-technology/.

Ishchuck, Tetiana, Tetiana Ivanishena, and Victoria Grekhova. 2023. “Managing Textile Waste as a Prerequisite for Implementing Circular Economy Principles in Ukraine.” in *2023 4th International Scientific Conference “Chemical Technology and Engineering”. Proceedings*. Lviv Polytechnic National University.

Jiménez, Ares, Barbara Weigelt, Arnoldo Santos-Guerra, Juli Caujapé-Castells, José María Fernández-Palacios, and Elena Conti. 2017. “Surviving in Isolation: Genetic Variation, Bottlenecks and Reproductive Strategies in the Canarian Endemic Limonium Macrophyllum (Plumbaginaceae).” *Genetica* 145(1). doi:10.1007/s10709-017-9948-z.

Juanga-Labayen, Jeanger P., Ildefonso V. Labayen, and Qiuyan Yuan. 2022a. “A Review on Textile Recycling Practices and Challenges.” *Textiles* 2(1):174–88. doi:10.3390/textiles2010010.

Juanga-Labayen, Jeanger P., Ildefonso V. Labayen, and Qiuyan Yuan. 2022b. “A Review on Textile Recycling Practices and Challenges.” *Textiles* 2(1):174–88. doi:10.3390/textiles2010010.

Juanga-Labayen, Jeanger P., Ildefonso V. Labayen, and Qiuyan Yuan. 2022c. “A Review on Textile Recycling Practices and Challenges.” *Textiles* 2(1):174–88. doi:10.3390/textiles2010010.

Kupchik, George J. 1972. “Recycling and Reclamation.” *American Journal of Public Health* 62(8):1143–47. doi:10.2105/AJPH.62.8.1143.

Lanz, Inés Eugenia, Elena Laborda, Cecilia Chaine, and María Blecua. 2024. “A Mapping of Textile Waste Recycling Technologies in Europe and Spain.” *Textiles* 4(3):359–90. doi:10.3390/textiles4030022.

LE RELAIS Métisse. 2025. “Le Relais: Le Relais c’est Aussi.” https://www.lerelais.org/aussi.php?page=metisse.

Loop Industries. 2025. “Loop Industries Products.” https://loopindustries.com/product/.

Luleå University of Technology. 2025. “REVISED TEXT - Revitalising Mixed Textile Waste: A Second Life Through Chemical Recycling.”

MangoPress. 2024. “RE-VISTE Presents Its First Pilot for Textile Waste Collection in Spain.” https://www.mangofashiongroup.com/en/w/re-viste-presenta-su-primer-piloto-para-la-recogida-de-residuo-textil-en-españa.

Martín-Hernanz, Sara, Manuel Nogales, Luis Valente, Mario Fernández-Mazuecos, Fernando Pomeda-Gutiérrez, Emilio Cano, Patricia Marrero, Jens M. Olesen, Ruben Heleno, and Pablo Vargas. 2023. “Time-Calibrated Phylogenies Reveal Mediterranean and Pre-Mediterranean Origin of the Thermophilous Vegetation of the Canary Islands.” *Annals of Botany* 131(4). doi:10.1093/aob/mcac160.

Medina, Miguel Ángel. 2023. “Cómo Será El Auge Del Reciclaje Textil En 2025 y a Dónde Irá La Ropa Usada.” https://elpais.com/clima-y-medio-ambiente/2023-03-26/como-sera-el-bum-del-reciclaje-textil-en-2025-y-a-donde-ira-la-ropa-usada.html#:~:text=La nueva ley de residuos,van a duplicar los instalados.

Miniwiz. 2025. “Circular Upcycled Architecture Products.” https://www.miniwiz.com/solutions.php.

Mishra, Prince Kumar, Ansari Mohammed Dilsad Izrayeel, Bhupender Kumar Mahur, Arihant Ahuja, and Vibhore Kumar Rastogi. 2022. “A Comprehensive Review on Textile Waste Valorization Techniques and Their Applications.” *Environmental Science and Pollution Research* 29(44):65962–77. doi:10.1007/s11356-022-22222-6.

Moda-RE, Anthesis Lavola, and InTexter - Universitat Poltécnica de Catalunya. 2021. *Análisis de La Recogida de La Ropa Usada En España*.

Morell-Delgado, Gemma, Laura Talens Peiró, and Susana Toboso-Chavero. 2024. "Revealing the Management of Municipal Textile Waste and Citizen Practices: The Case of Catalonia." *Science of The Total Environment* 907:168093. doi:10.1016/j.scitotenv.2023.168093.

Napolano, Loredana, Jacopo Foschi, Carla Caldeira, Dries Huygens, and Serenella Sala. 2025. "Understanding Textile Value Chains: Dynamic Probabilistic Material Flow Analysis of Textile in the European Union." *Resources, Conservation and Recycling* 212:107888. doi:10.1016/J.RESCONREC.2024.107888.

Ndagano, Urbain Nshokano, Laura Cahill, Ciara Smullen, Jennifer Gaughran, and Susan M. Kelleher. 2025. "The Current State-of-the-Art of the Processes Involved in the Chemical Recycling of Textile Waste." *Molecules* 30(2):299. doi:10.3390/molecules30020299.

Nerurkar, Olive. 2016. "Designing Sustainable Fashion: Role of Psychosocial Factors of Fashion Consumption and the Challenges of Design." *Indian Journal of Science and Technology* 9(15). doi:10.17485/ijst/2016/v9i15/91980.

OECD. 2023. *Internationalisation, Specialisation and Technological Collaboration in the EU Outermost Regions*. doi:10.1787/7eac66d8-en.

Patel, Monika, Ankita Sahu, and Ravikant Rajak. 2022. "Solid Waste Management in Textile Industry." Pp. 1225–56 in *Handbook of Solid Waste Management*. Singapore: Springer Nature Singapore.

Piribauer, Benjamin, Andreas Bartl, and Wolfgang Ipsmiller. 2021. "Enzymatic Textile Recycling – Best Practices and Outlook." *Waste Management & Research: The Journal for a Sustainable Circular Economy* 39(10):1277–90. doi:10.1177/0734242X211029167.

Polajnar Horvat, Katarina, and Katarina Šrimpf Vendramin. 2021. "Issues Surrounding Behavior towards Discarded Textiles and Garments in Ljubljana." *Sustainability* 13(11):6491. doi:10.3390/su13116491.

Ponnambalam, S. G., Bathrinath Sankaranarayanan, Koppiahraj Karuppiah, Shakthi Thinakaran, Pranesh Chandravelu, and Hon Loong Lam. 2023. "Analysing the Barriers Involved in Recycling the Textile Waste in India Using Fuzzy DEMATEL." *Sustainability* 15(11):8864. doi:10.3390/su15118864.

Pons, Corina. 2024. "Spain's Top Fashion Retailers to Launch Trial to Collect Clothes Waste in 2025." https://www.reuters.com/sustainability/spains-top-fashion-retailers-launch-trial-collect-clothes-waste-2025-2024-10-10/.

Alcocertex. 2025. "Recovered Textile Fibers." https://alcocertex.com/productos/.

ALTEX Textil-Recycling. 2025. "Recycled Textile Fibres for Innovative Applications." https://www.altex-textil.com/produkte/.

Recover Textile Systems. 2025. "RPure | Recover™." https://recoverfiber.com/products/rpure.

RECYC LEATHER. 2025. "Recyc Leather™ | The Future of Leather Fibers." https://recycleather.com/.

Renewcell. 2025. "Circular Cellulose CIRCULOSE®." https://www.renewcell.com/en/circulose/.

RE-VISTE. 2025. “Asociación Para La Gestión Del Residuo Textil y El Calzado.” https://re-viste.org/.

RE-VISTE. 2025. *Usos, Costumbres y Nuevos Desafíos En La Industria Textil*. Madrid.

Riemens, Joséphine, Andrée-Anne Lemieux, Samir Lamouri, and Léonore Garnier. 2021. “A Delphi-Régnier Study Addressing the Challenges of Textile Recycling in Europe for the Fashion and Apparel Industry.” *Sustainability* 13(21):11700. doi:10.3390/su132111700.

Ruiz-Caldas, Maria-Ximena, Josefine Carlsson, Ioannis Sadiktsis, Aleksander Jaworski, Ulrika Nilsson, and Aji P. Mathew. 2022. “Cellulose Nanocrystals from Postconsumer Cotton and Blended Fabrics: A Study on Their Properties, Chemical Composition, and Process Efficiency.” *ACS Sustainable Chemistry & Engineering* 10(11):3787–98. doi:10.1021/acssuschemeng.2c00797.

Ruuth, Edvin, Miguel Sanchis-Sebastiá, Per Tomas Larsson, Anita Teleman, Amparo Jiménez-Quero, Sara Delestig, Viktor Sahlberg, Patricia Salén, Marjorie Sanchez Ortiz, Simran Vadher, and Ola Wallberg. 2022. “Reclaiming the Value of Cotton Waste Textiles: A New Improved Method to Recycle Cotton Waste Textiles via Acid Hydrolysis.” *Recycling* 7(4):57. doi:10.3390/recycling7040057.

Secretaria Regional de Ambiente, Recursos Naturais e Alterações Climáticas, and Direção Regional do Ambiente e Alterações Climáticas. 2022. *Relátorio Anual. Gestao de Resíduos Urbanos 2021. Regiao Autonoma Da Madeira*.

Serra, Albert, Quim Tarrés, Miquel Llop, Rafel Reixach, Pere Mutjé, and Francesc X. Espinach. 2019. “Recycling Dyed Cotton Textile Byproduct Fibers as Polypropylene Reinforcement.” *Textile Research Journal* 89(11):2113–25. doi:10.1177/0040517518786278.

Statista. 2025. *Annual Textile Waste Managed in Spain from 2010 to 2021 (in Metric Tons)*.

Tang, Kuok Ho Daniel. 2023. “State of the Art in Textile Waste Management: A Review.” *Textiles* 3(4):454–67. doi:10.3390/textiles3040027.

Texlimca. 2025. “Texlimca | Productos Derivados de Residuos Textiles.” https://texlimca.com/servicios.

Todor, M. P., M. Rackov, I. Kiss, and V. G. Cioata. 2022. “Composite Solutions with Recycled Textile Wastes.” *Journal of Physics: Conference Series* 2212(1):012030. doi:10.1088/1742-6596/2212/1/012030.

Uchimaru, Motoko, Teruo Kimura, and Tetsuya Sato. 2013. “Study on Recycling System of Waste Textiles Based on Colour.” *Journal of Textile Engineering* 59(6):159–64. doi:10.4188/jte.59.159.

Valtere, Megija, Tereza Bezrucko, and Dagnija Blumberga. 2023a. “Analysis of Textile Circularity Potential.” *Environmental and Climate Technologies* 27(1):220–32. doi:10.2478/rtuect-2023-0017.

Valtere, Megija, Tereza Bezrucko, and Dagnija Blumberga. 2023b. “Analysis of Textile Circularity Potential.” *Environmental and Climate Technologies* 27(1):220–32. doi:10.2478/rtuect-2023-0017.

Vieira, Pedro E., Andrea Desiderato, David M. Holdich, Pedro Soares, Simon Creer, Gary R. Carvalho, Filipe O. Costa, and Henrique Queiroga. 2019. “Deep Segregation in the Open Ocean: Macaronesia as an Evolutionary Hotspot for Low Dispersal Marine Invertebrates.” *Molecular Ecology* 28(7). doi:10.1111/mec.15052.

Wagaw, Tamene, and K. Murugesh Babu. 2023. “Textile Waste Recycling: A Need for a Stringent Paradigm Shift.” *AATCC Journal of Research* 10(6):376–85. doi:10.1177/24723444231188342.

Wagner, Melissa Monika, and Tincuta Heinzel. 2020. “Human Perceptions of Recycled Textiles and Circular Fashion: A Systematic Literature Review.” *Sustainability* 12(24):10599. doi:10.3390/su122410599.

Watkins, Tyson, Kaylee Moffitt, Robert E. Speight, and Laura Navone. 2024. “Chromogenic Fusion Proteins as Alternative Textiles Dyes.” *Biotechnology and Bioengineering* 121(9):2820–32. doi:10.1002/bit.28772.

Weber, Sabine, Jennifer Lynes, and Steven B. Young. 2017. “Fashion Interest as a Driver for Consumer Textile Waste Management: Reuse, Recycle or Disposal.” *International Journal of Consumer Studies* 41(2):207–15. doi:10.1111/ijcs.12328.

Wikipedia. 2025. “Macaronesia.” https://es.wikipedia.org/wiki/Macaronesia.

Wojnowska-Baryła, Irena, Katarzyna Bernat, Magdalena Zaborowska, and Dorota Kulikowska. 2024. “The Growing Problem of Textile Waste Generation—The Current State of Textile Waste Management.” *Energies* 17(7):1528. doi:10.3390/en17071528.

Wu, Yanfen, Yizhen Che, Xuewei Wei, Qikun Hu, Jun Xu, Baohua Guo, and Zhiqiang Niu. 2024. “Nondestructive Recovery of Cotton from Waste Polycotton Textiles by Catalytic Hydrolysis.” *ACS Sustainable Chemistry & Engineering* 12(28):10446–54. doi:10.1021/acssuschemeng.4c02547.

Zamora-Marín, José M., Antonio A. Herrero-Reyes, Ana Ruiz-Navarro, and Francisco J. Oliva-Paterna. 2023. “Non-Indigenous Aquatic Fauna in Transitional Waters from the Spanish Mediterranean Coast: A Comprehensive Assessment.” *Marine Pollution Bulletin* 191. doi:10.1016/j.marpolbul.2023.114893.

Zandberga, Anda, Silvija Nora Kalnins, and Julija Gusca. 2023. “Decision-Making Algorithm for Waste Recovery Options. Review on Textile Waste Derived Products.” *Environmental and Climate Technologies* 27(1):137–49. doi:10.2478/rtuect-2023-0011.

Zhai, Heng, Zekun Liu, Lulu Xu, Ting Liu, Yangyang Fan, Lu Jin, Ruihan Dong, Yangpeiqi Yi, and Yi Li. 2022. “Waste Textile Reutilization Via a Scalable Dyeing Technology: A Strategy to Enhance Dyestuffs Degradation Efficiency.” *Advanced Fiber Materials* 4(6):1595–1608. doi:10.1007/s42765-022-00192-1.

Table 1. Textile wastes collected in 2019 in Spain (in tons) by region (Moda-RE et al. 2021)

Region	Separated textile collection (t)	Total textile wastes (t)	Collected/produced textile wastes	Textile collection rate (kg/hab/year)
Andalucía	15,886	159,871	9.94%	1.89
Aragón	2,971	25,067	11.85%	2.25
Principado de Asturias	2,881	19,433	14.82%	2.82
Illes Balears	3,148	21,840	14.41%	2.74
Canarias	3,961	40,914	9.68%	1.84
Cantabria	1,289	11,040	11.67%	2.22
Castilla y León	5,600	45,591	12.28%	2.33
Castilla - La Mancha	3,515	38,624	9.10%	1.73
Catalunya	20,288	145,829	13.91%	2.64
Comunitat Valenciana	15,243	95,072	16.03%	3.05
Euskadi	10,457	41,948	24.93%	4.74
Extremadura	566	20,286	2.79%	0.53
Galicia	5,259	51,290	10.25%	1.95
Comunidad de Madrid	11,569	126,604	9.14%	1.74
Región de Murcia	2,759	28,384	9.72%	1.85
Comunidad Foral de Navarra	2,049	12,430	16.48%	3.13
La Rioja	855	6,019	14.20%	2.70

Figure 1. Map on the Macaronesia region (created on ChatGPT 4.0 – free version; adapted from (Wikipedia 2025))

Figure 2. Annual textile waste managed in Spain from 2010 to 2021 (in metric tons) (Statista 2025)

Figure 3. Representative flow chart of the textile waste life cycle applying the waste hierarchy, and main constraints of the different stages for the outermost regions