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Circle Economy

Fashion for Good

SORTING FOR CIRCULARITY EUROPE

AN EVALUATION AND COMMERCIAL ASSESSMENT OF TEXTILE WASTE ACROSS EUROPE

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Acknowledgements

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At the time of the initial public release of the Sorting for Circularity Europe report (September 2022), the report included a chapter on policy recommendations, which has since been removed. The recent release of Policy Hub's position paper (August 2022) best reflects the perspective of industry players to date and is therefore a guiding document for policy recommendations.

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Please note that the findings of this report do not reflect the opinion nor position of those parties listed as stakeholders to the project. This report represents an analysis of the data gathered during the project timeline and as such represents a position at one point in time as such describes research findings only.

About Us

FASHION FOR GOOD

Fashion for Good is the global platform for innovation.

At its core is the Global and Asia Innovation Programme that supports disruptive innovators on their journey to scale, providing hands-on project management, access to funding and expertise, and collaborations with brands and manufacturers to accelerate supply chain implementation.

To activate individuals and industry alike, Fashion for Good houses the world's first interactive museum dedicated to sustainable fashion and innovation to inform and empower people from across the world and creates open-source resources to action change.

Fashion for Good's programmes are supported by founding partner Laudes Foundation, co-founder William McDonough and corporate partners adidas, BESTSELLER, CandA, CHANEL, Inditex, Kering, Levi Strauss & Co., Otto Group, Patagonia, PVH Corp., Reformation, Stella McCartney, Target and Zalando, and affiliate and regional partners Arvind Limited, Birla Cellulose, Norrøna, Pangaia, Teijin Frontier, Vivobarefoot, Welspun and W. L. Gore and Associates.

CIRCLE ECONOMY

We are a global impact organisation with an international team of passionate experts based in Amsterdam, empowering businesses, cities and nations with practical and scalable solutions to put the circular economy into action.

Our vision is an economic system that ensures the planet and all people can thrive.

The Circle Textiles Programme works to enable the data, technology and infrastructure needed to valorise textile waste at end-of-use and increase apparel brands' capacity to adopt circular strategies and business models. With deep expertise in the areas of textile-to-textile recycling, circular business models, design for cyclability, technology assessments and circular infrastructure developments, our mission is to connect a circular supply chain of producers (manufacturers, retailers and brands) and solution providers (collectors, sorters, recyclers, manufacturers, logistics etc.).

Glossary

Comparability of analysis results amongst sorting facilities is fundamental in order to obtain reliable research outcomes. Therefore, speaking the same language is imperative. Key definitions as used throughout the Project are described below to ensure sorters, researchers and other parties involved in the research, or wishing to conduct further research building on these results, have a clear understanding of the categorisations used.

Bring banks
Unstaffed collection points for recyclable materials, including containers for textiles amongst other waste streams.

Chemical recycling
The processes by which fibres are broken down to the polymer or monomer level. There are diverse recycling technologies encompassed under this archetype, including amongst others pulping processes to recycle cotton and viscose, to solvent-based processes to recycle polyester and polycotton, to processes such as glycolysis, hydrolysis and enzymatic that take polyester and polyamide back to monomers.[1]

Colour
The colour of an item is considered the solid or dominant colour. If it is not possible to define one and the same dominant colour, the article is to be considered multicoloured.

Disruptor
An element present on a textile product (eg. fastener, button, zipper, fabric patch etc.) that may be a disruptor to the recycling process and will need to be removed before the product is suitable as feedstock for recycling.

- Removable disruptors: for the purpose of this Project, it is defined that metal and plastic hardware are suitable to be removed prior to recycling activities
- Non-removable disruptors: for the purpose of this Project, all other hardware found in textiles as well as combinations of different types of hardware are considered as non-removable for the purpose of fibre-to-fibre recycling activities.

Downcycling
Reprocessing discarded textiles to create new consumer or industrial products, in a process that is usually mechanical (cutting, shredding, bonding). Discarded textiles are no longer in their original form, and new products do not re-enter the textile supply chain, resulting in a subsequent use that is of lower value than the original source of the material.[2]

Eco-modulation fees
Differentiated Extended Producer Responsibility (EPR) fees for producers based on certain criteria which strive to support design changes towards environmental sustainability of their products.[3]

Glossary

EU-27
Represents the 27 European Union countries after the UK left the EU from 1 February 2020.

EU Waste Framework Directive
The European Union Directive that sets the basic concepts and definitions related to waste management, including definitions of waste, recycling and recovery, in order to protect the environment and human health. It came into force in December 2008.

Fibre-to-fibre recycling
In the context of this Project, this emcompasses all textile recycling processes where the output is used again in this specific sector, in similar applications for which it was first developed.

Fraction
Categories by which collected used textiles are sorted into for different reuse and recycling purposes, which are sold on different local and global markets.[4] The Fraction excludes footwear.

Low value textiles
For the purpose of this study, non-rewearable and low-value rewearable textiles are referred to as low value textiles. On one hand, this includes non-rewearable textiles going into downcycling, wiping, fibre-to-fibre recycling, energy recovery and ultimate waste. Additionally, this definition includes low-value rewearable textiles, those currently deemed rewearable by sorting facilities and sold in the second-hand market at low prices, but where market demand is expected to stop when volumes collected rise.

Mechanical recycling
The process by which textiles are cut, shredded and opened into fibres that are usable for diverse applications. They may include downcycling applications such as fibres for insulation, filling or non-woven for automotive and other industries as well as fibre-to-fibre applications. For the purpose of this Project, the potential feedstock for mechanical recycling is only presented for fibre-to-fibre recycling.

Mono-layer
Products that are made from one layer or type of textile.[5]

Multi-layer
Products that are made from more than one distinct layer, each of which may be composed of different materials.[6] There are two types of multi material garments:

- Case 1: True multilayer = "Several main layers". Refers to an article consisting of at least a second layer representing more than 1/3 of the surface of the article (eg. jacket lining). The composition of up to two different layers were captured and allocated to the same product using the app.
- Case 2: Monolayer + others = "1 main layer and 1 or more auxiliary or minority layers": article made up of a main layer with the presence of other minority layers representing less than 1/3 of the surface (eg. pocket bottom, badge, yoke, embroidery, lace). This article was captured as 'with a fabric disruptor'.

Glossary

Non-rewearable
Garments and household textiles that cannot be reused in their original form and are made from one or multiple types or layers of textiles. This category is known as "material reuse" among many textile collectors/sorters[7] and includes:

- Materials for downcycling (recycling / garneting): garment textile products which are meant to be shredded or garnetted (opening up the fabric into a fluffy, fibrous condition for reuse),[8] with a purpose of future use of these fibres for recycling into insulation, automotive, mattress filling, yarn or other.
- Materials for wiping: various mainly cotton rags used for cleaning machinery as well as used for hand wiping.[9]
- Materials for fibre-to-fibre recycling: garment textile products which are meant to be shredded or cut into smaller pieces with a purpose of future use of these materials for recycling into outputs used again in this specific sector, in similar applications for which it was first developed.
- Fibres and materials destined to become refuse-derived fuel: fibres and materials from garment textile products that are used to produce Refuse Derived Fuel (RDF) to ultimately produce energy and heat.[10]
- Ultimate waste: wet, damp, damaged garment textile products which are not fit to be sold in reuse or recycling markets.

Post-consumer textiles (PCT)
Textiles that have been disposed of after consumption and use by the citizen or end-users of commercial or industrial institutions, processed by a specialised textile sorter.

Rewearable
Garments that can be reused in their original form, for their original purpose. This category is known as "product reuse" among many textile collectors/sorters.[11] Rewearables are categorised into cascading qualities, with the Cream, or highest quality, and Vintage categories usually being sold domestically, while other qualities categorised from A to C or 1 to 3, mostly being exported abroad.

Image 1: Sorting facility in motion (Source: Wtórpol)

Executive Summary

Fibre-to-fibre textile recycling commitments and policies are continuously increasing, as one of the key strategic components propelling organisations to support the transition towards a circular fashion industry. In turn, these developments are expected to drive an increased demand for post-consumer textiles collection, sorting and recycling infrastructure across the EU. Scaling this infrastructure will require substantial investment. In order to holistically inform any future investments, there is a need to understand both the characteristics of post-consumer textiles available in the European market as well as the business case for monetisation through recycling. The Sorting for Circularity Europe Project was created to address this knowledge gap, exploring these materials in depth. The Project is aimed at analysing types of waste being generated, quantities available as feedstock for recycling, and the ability to channel textile waste as feedstock for those with innovative solutions. This report is key as it is the first to provide powerful information on which informed decisions can be made for further investment, policy developments and next steps towards circularity.

Overall, the Sorting for Circularity Europe study finds that a total of 494,000 tonnes each year —or 74% of low value post-consumer textiles, is readily available and suitable for closing the loop in the clothing and textiles sector across six European countries. These findings culminate in promising opportunities for recapturing value via mechanical and chemical recycling and resultantly diverting textiles away from less circular destinations like downcycling to non-wovens, insulation or filling material, the wipes industry and incineration. This represents a potential value increase of €74 million per year when sorted textiles are reintroduced into the textiles value chain.

The Sorting for Circularity Europe project aims to increase harmonisation between the sorting and recycling industry and stimulate a recycling market for unwanted textiles that can generate new revenue streams for sorters and unlock demand for recyclers and brands. Conducting analyses across Europe, in Belgium, Germany, the Netherlands, Poland, Spain, and the United Kingdom, the project provides the most comprehensive and representative snapshot of post-consumer textiles composition generated in Europe to date.

Sorting for Circularity is a framework conceived by Fashion for Good, with the aim to (re)capture textile waste, expedite the implementation of game changing technologies and drive circularity within the fashion value chain. The framework is based on insights from the Fashion for Good and Aii collaborative report "Unlocking the Trillion Dollar Fashion Decarbonisation Opportunity", which charts a trajectory for the industry to meet its net-zero ambition by 2050, highlighting the potential and significant impact on carbon emissions in the industry through material efficiency, extended and re- use of waste. Created with scalability in mind, the project was first initiated in Europe, and has expanded to include Sorting for Circularity India.

LEAPING FORWARD THROUGH TECHNOLOGY

Using innovative Near Infrared (NIR) technology to determine garment composition, traditionally a task performed manually, the project analysed a total of 21 tonnes of post-consumer garments. On-the-ground examinations were performed over two time periods, autumn/winter 2021 and spring/summer 2022, to account for seasonal changes in the types of garments entering sorting facilities. The project focuses on textiles that cannot be reused in their original form (considered 'non-rewearable') and textiles that can only be resold at low prices ('low value rewearable'). For readability purposes, these two categories are referred to as 'the Fraction' solely.

Cotton was found to be the dominant fibre (42%), albeit elastane might be present in a relevant share of this category. Cotton is followed by a large presence of material blends (32%), almost half of which consisted of polycottons (12%). Based on three characteristics, material composition, presence of disruptors, such as zippers and buttons, and colour, 21% of the materials analysed are deemed suitable as feedstock for mechanical recycling, while 53% are suitable for chemical recycling. However, it needs to be technically and financially viable to remove disruptors for chemical recyclers, otherwise only around one fifth of the total potential feedstock for chemical fibre-to-fibre recycling would be available.

Figure 1 presents an overview of the flow of clothing and household textiles from the moment they are placed on the market, to the volumes being collected in the focus countries of this project, to their eventual destinations. For the Fraction there is an indication of the breakdown by fibre composition and colour where relevant. The potential recyclability of these textiles is shown through the possible use cases for the different fibres, either for mechanical or chemical recycling and its related potential prices per kilo of material.

Executive Summary

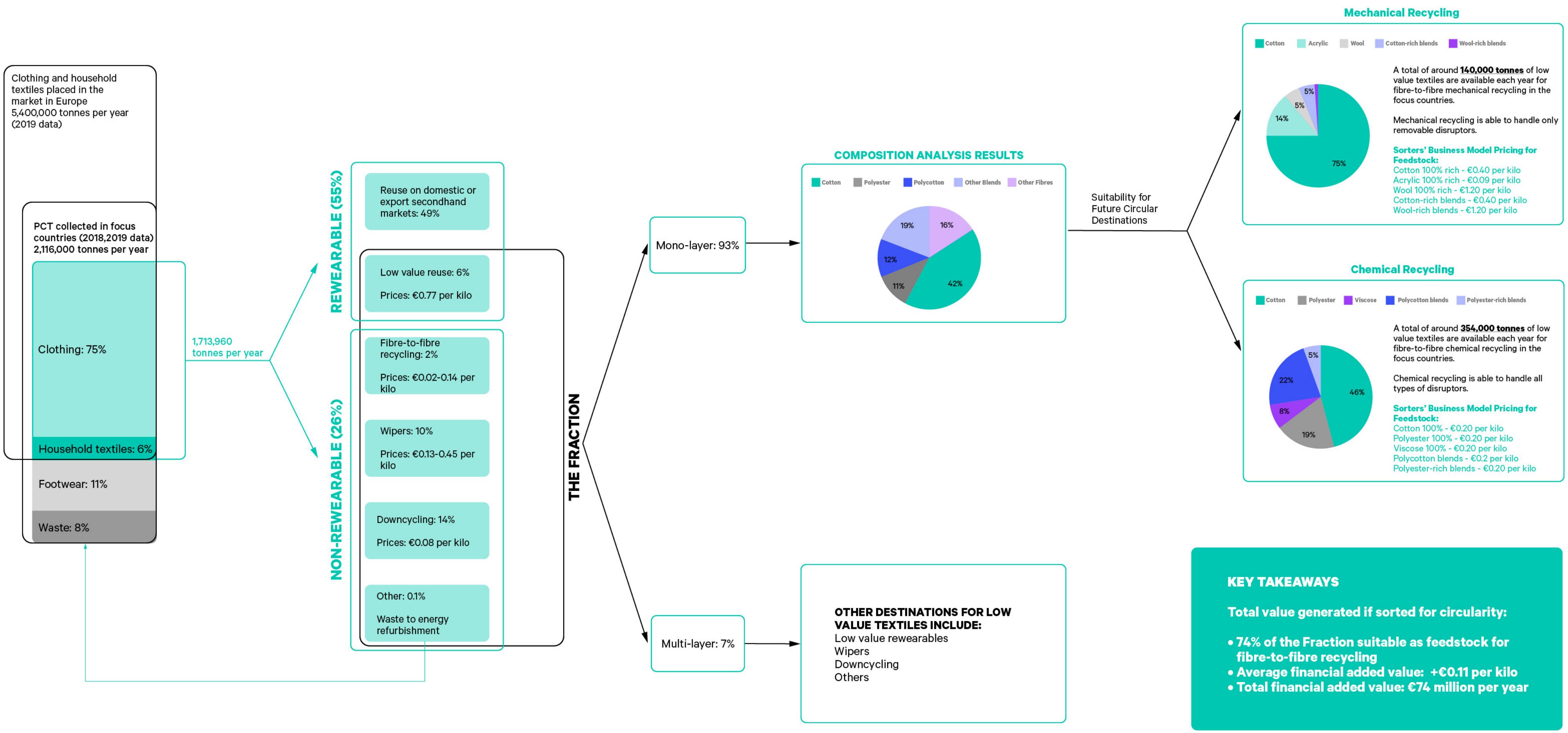

FIGURE 1: FLOW OF END-OF-USE TEXTILES FROM MARKET PLACEMENT TO FINAL DESTINATIONS. SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

BUILDING A ROBUST SORTING AND RECYCLING INFRASTRUCTURE

In addition to this report, two further industry resources are available; Recycler’s Database, a database mapping textile recycler's capabilities, illuminating crucial gaps between the sorting and recycling industry, and an open source Sorters Handbook to guide and support the sorting industry should they wish to do new or further analyses. Building off the project, two open digital platforms, Reverse Resources and Refashion Recycle, have been identified as critical tools to further enable the connections needed to match textile waste from sorters with recyclers, driving greater circularity in the years to come. Following an assessment of suitable digital platforms within and outside of the textile industry, Reverse Resources have 39 active recyclers and 32 active waste handlers/sorters on their platform, while Refashion Recycle have 103 recyclers and 66 sorters onboarded onto their platform. This represents a large portion of the European circularity industry.

PATH TOWARDS A CIRCULAR INDUSTRY

The amount of low value textiles collected is likely to increase, due partly to growing consumption and disposal, as well as driven by incoming legislation, for instance the Waste Framework Directive, that mandates the separate collection of textiles across Europe by 2025. However, the current and future potential of these textiles for circularity is complex to capitalise on; feedstock prices for current destinations (e.g. wipers) are at times more economically viable than those offered for fibre-to-fibre recycling. This might change as current recycling technologies are scaled and further investment is made to integrate operations related to automated sorting and removal of disruptors into the sorting process.

Overall, a sound business case for sorting low value textiles is required in order to retain and increase sorting capacity in Europe. This further highlights the need for increased investment into infrastructure that can sort and prepare textiles for reuse and recycling. To support the retention and further development of this sorting capacity in Europe, policy and upcoming legislation will play a key role in ensuring the environmental, social and financial sustainability of these stages of the clothing and textiles value chain. Policy Hub, together with textile industry players, published a position paper in August 2022 outlining key recommendations for policy development that supports the advancement of textile waste circularity. The position paper can be read in full here.

Executive Summary

The outcomes of this project point towards the following recommendations for the wider industry to enact:

- **For collectors, sorters, and recyclers**
    1. Use the Sorters Handbook and the Sorting for Circularity Europe report as a guide to conduct further trials and continue to build a knowledge of fibre composition, sorting and recycling processes. This could be further supported by local governments, industry and civil society engaging with textile or household waste streams.
    2. Provide open-access to trials and data that can support and direct investment into necessary infrastructure.
    3. Update and utilise the Recycler's Database to build knowledge about mechanical and chemical recycling destinations.
    4. Join digital platforms such as Reverse Resources and Refashion Recycle to unlock and connect supply with demand for post-consumer textiles.

- **For brands and manufacturers** - 74% of the low value post-consumer textiles could be used as feedstock for recycling. Whilst this is a considerable share, this still leaves 26% without a circular destination due to their composition, the presence of multiple layers and/or non-removable disruptors.
    1. **Prioritise designing for appropriate lifecycles**. Hence, products that are designed for longevity should have a strong focus on durability and longevity. Ultimately, recycling should be a last resort for textiles, in accordance with the waste hierarchy, and not a goal in itself.
    2. **Further commit to adopting circular design practices prioritising mono materiality, reducing disruptors where possible and incorporating recycled fibres into** product portfolios as mandated by the Ecodesign for Sustainable Products Regulation in the European Union.

- **For policymakers** - Sorting activities in European countries are at risk of being unable to continue their business as usual if the share of these lower value textiles in volumes collected continues to increase. Additionally, current sorting and logistics costs may pose a financial challenge for chemical recyclers to purchase these sorted textiles at scale. Therefore, it is important that policymakers, where required, utilise report findings to inform policy consultations and regulations.

- **For consumers** - take into account that the purchase and disposal choices you make also have an influence on the end of use of these textiles. As far as possible, try to prioritise purchases of mono material products, or blends limited to two compositions, limited aesthetic trims and accessories. As a citizen, follow the instructions from your municipality to correctly dispose of your clothing and home textiles. Try repairing, reselling and swapping as activities to extend the lifetime of your products.

This report outlines the results from Phase 1 of the Project, which includes a comprehensive composition analysis of low value textiles using NIR technology to understand what and how much potential feedstock for fibre-to-fibre recycling is generated across European countries. The report also discusses future business models required for sorters to commercialise low value textiles and reflects upon the upcoming policy landscape in the European Union. Phase 2 of the report looks at understanding and supporting digital platforms that match supply and demand by connecting sorters and recyclers through waste mapping and match-making capabilities. Lastly, the report concludes with recommendations for various stakeholders to progress necessary action in the sorting and recycling industries.

Introduction

Fibre-to-fibre textile recycling commitments and policies are continuously increasing, as one of the key strategic components propelling businesses to support the transition towards a circular fashion industry. Brands and manufacturers have made strong commitments to increase cyclability and use of secondary raw materials, such as the Global Fashion Agenda 2020 Circularity Commitments,[12] Ellen MacArthur's Make Fashion Circular Commitments and the Jeans Redesign Guidelines[13] or WRAPs Textiles 2030.[14] Commitments have been accompanied by substantial increases in the number of facilities certified to operate under recycled content standards, resulting in a nine fold increase between 2014 and 2019 of certified facilities by the Recycled Claim Standard (RCS).[15] The European Commission is also expected to drive further change in the EU policy environment in the coming years, as the EU Textiles Strategy for Sustainable and Circular Textiles unfolds.[16]

In turn, these developments are expected to drive an increased demand for post-consumer textiles collection, sorting and recycling operations across the EU. Whilst there has been a surge in innovation in recycling technologies that can handle a variety of different textile materials, significant investment is still required to enable fibre-to-fibre recycling to operate at scale. A study by McKinsey (2022) estimates that investments in the order of 6 to 7 billion euros may be needed by 2030 to scale the industry to be able to recycle 18 to 26% of gross textile waste in Europe.[17] The investment needs are not only relevant for chemical and mechanical recycling technologies but also across the entire value chain, including sustaining and further developing pre-processing operations such as hardware removal and sorting in Europe.

In order to holistically inform any future investments, there is a need to understand both the characteristics of post-consumer textiles available in the European market as well as the business case for monetisation through recycling. The Sorting for Circularity Europe Project was created to address this knowledge gap, exploring these materials in depth. The Project is aimed at analysing types of waste being generated, quantities available as feedstock for recycling, and the ability to channel textile waste as feedstock for those with innovative solutions. This report is key as it is the first to provide powerful information on which informed decisions can be made for further investment, policy developments and next steps towards circularity.

Introduction

OVERVIEW OF TEXTILE FLOWS ACROSS EUROPE

Between 2005 and 2019 the European textile and apparel market grew by 15%. This means that **each EU citizen consumed on average 12.4 kgs of textiles in 2019** —of which 10.0 kg was clothing.[18] Thus, approximately 5.4 million tonnes of new clothing and household textiles were placed on the market across the EU-27 in 2019[19]. While this growth represents an increase in the amount of textiles consumed, the amount spent by consumers on clothing and household textiles has merely risen 1% since the beginning of the century[20], meaning that we are purchasing more textiles for approximately the same amount of money.

On average, 38% of the textiles placed on the market each year are collected separately when the consumer no longer wants them. This is based on the average of the countries in focus for this Project and in line with the European average[21], with a lower average of 12% for Spain[22] and a higher one of 60% for Germany[23]. Textiles are mostly collected via bring banks, usually complemented with indoor collection systems at first- or second-hand retail stores, except for the UK where the predominant mode of collection is via charity shops. With a few exceptions, separate collection systems are primarily in place for the collection of clothing for reuse on global second-hand markets and the majority of the textiles collected separately is reused. In the focus countries of this Project, 55% is sold as rewearable textiles, with the purpose of reusability, which aligns with other publications in the European landscape.[24]

However, at collection points, citizens also dispose of clothing and textiles that are not rewearable in its current state. This means a significant share of those are diverted into other applications with lower environmental and economic benefits. These post-consumer textiles (PCT) are usually referred to as non-rewearable , either because of their unsuitability for the second-hand market (extensive use or damage, lack of quality, cleanliness) or due to the market saturation that lower quality second-hand clothing currently faces on global markets.[25]

Image 2: Workers sorting in a sorting facility (Source: Soex)

Introduction

Separate collection of textiles across Europe is projected to change and increase significantly after 2025. The 2018 revision of the EU Waste Framework Directive (2008/98/EC) requires all EU Member States to ensure that systems are in place for the separate collection of discarded textiles by January 1st, 2025.[26] For countries where there are well-established and well-used commercial and charitable collection systems, the main change will be an increased collection of the non-rewearable fraction. In countries with less established systems there is likely to be an increase in collection of both rewearable and non-rewearable textiles.

Increasing separate collection quantities will depend on how active Member State governments are in establishing collection systems, the degree to which they set targets for collection and the resources they use for increasing awareness amongst citizens. As a benchmark, the countries and regions that have been most active in increasing textile collection to date - France, Belgium (specifically the province of Flanders) and the Netherlands - observed increases in the order of 180 to 220 grams per capita per year. This has been mainly due to proactive public initiatives to increase collection rates through either Extended Producer Responsibility (EPR), soft target setting and citizen awareness raising campaigns. This could mean for example that in Spain collection rates could go from the 12% mentioned above to roughly 24.6% by 2030.[27] Additionally, not only the quantities for all separate collected textiles is foreseen to increase, but the trend shows that the quality of the textiles collected is also decreasing amongst others. This is due to increasing pollution of collected textiles with household waste, extensive use or damage, decreasing material quality, the market saturation that second-hand clothing is currently facing or even due to the emergence and growth of customer-to-customer (C2C) platforms.[28][29] All of this will lead to an increase in non-rewearables present in PCT.

EUROPEAN UNION UPCOMING LEGISLATION

The **Waste Framework Directive** aims to protect environmental and human health by preventing and reducing waste. It sets basic concepts and definitions related to waste management, recycling, and recovery, and specifically sets a waste hierarchy for the Member States within the European Union. It defines when waste ceases to be waste and when waste can become a secondary raw material.

The Directive's 2023 revision focuses on introducing and implementing:

Extended Producer Responsibility (EPR) makes producers operationally and financially responsible for the end-of-use phase of the products they put on the market, and aims to introduce economic incentives such as eco-modulation fees.

Polluter Pays Principle (PPP) places the responsibility of covering costs related to environmental damages caused by polluter's actions or operations. A recent EU Commission study indicated poor implementation of the PPP within the textiles sector, the revision hopes to improve the implementation and prevent pollution through schemes such as EPR and separate collection.

Separate collection of waste mandates Member States to separately collect waste produced by households by 2025. The upcoming 2023 revision aims to set a mandatory step to prepare textile waste for reuse.

Introduction

The increased volumes of textiles will need to be sorted and prepared for reuse or recycling. The textile sorting system today heavily relies on manual processes that effectively serve the reuse market, which is currently the main financial driver for these activities, and will remain so for the foreseeable future. As such, manual sorting is likely to remain the first step for sorting any PCT with rewearable content. However, manual sorting is not the optimal solution for recycling, especially for high quality mechanical and chemical recycling which requires identification of specific fibre types. To feed such recycling markets, manual sorting is likely to be followed by automated, or semi-automated, sorting of the non-rewearable fraction by fibre type and colour. A better understanding of the typical material composition of non-rewearable textiles is currently needed to guide investments into appropriate recycling facilities that are tailored to the fibre composition and volume of future flows of textile waste.

Image 3: Bags of textiles in sorting facility (Source: Wtórpol)

Introduction

AIM AND OBJECTIVES

The Sorting for Circularity Europe project (the Project) aims to create greater harmonisation between the sorting and the recycling industry to ensure that increasing amounts of collected low value textiles can be diverted away from their less circular destinations, like downcycling, the wipers industry and incineration, to recycling solutions. The Project has two phases; phase one aims to assess low value post-consumer textiles in the following six countries: Belgium, Germany, the Netherlands, Spain, the United Kingdom and Poland (referred to as focus countries). Phase 2 aims to support digital platforms that match supply and demand by connecting sorters and recyclers through waste mapping and match-making capabilities, to ultimately facilitate the recycling of textiles across Europe and Global regions in a transparent and open-source manner. Overall, the research outcomes of this Project can enable and inform investments in the sorting, pre-processing and recycling infrastructure needed to commercialise textiles currently considered of low value in the market.

THE FIBERSORT PROJECT

The Fibersort Project was an Interegg funded project, led by Circle Economy and involved partner organisation Smart FIbersorting B.V., Valvan Baling Systems, Stichting Leger des Heils ReShare, Worn Again Technologies Ltd., and Procotex Corporation S.A. This project addressed two main challenges: 1) the environmental need to reduce the impact of virgin textile materials, and 2) development of new business models and open markets for the growing amounts of recyclable textiles in North-West Europe.

The Fibersort uses Near Infrared (NIR) based technology, which can automatically sort large volumes of mixed post-consumer textiles by fibre type. Once these textiles are sorted, the materials become reliable and consistent input materials for high-value textile to textile recyclers.

NEAR INFRARED TECHNOLOGY

Near Infrared (NIR) spectroscopy is based on molecular absorptions and is measured in the near infrared part of the spectrum. The NIR light is selectively absorbed by fibres, creating a characteristic spectrum that is specific to the fibre. This spectrum is then compared to a predefined database, thereby making it possible to identify the material composition of the textile material.

Some advantages of using NIR technology include:

- Higher accuracy and efficiency than manual sorting as it can sort to countless predefined criteria and classifications
- Does not rely on any additional tagging of the garment
- Relatively inexpensive compared to other spectroscopic technologies

Some disadvantages of NIR technology include:

- Darker colours and some finishes (i.e. dyes or detergents) can hinder fibre identification
- Unable to recognise low content of fibre in blends, especially elastane, which is a significant contaminant for chemical recycling
- Only able to penetrate the outermost layer of the garment

Introduction

This report showcases Phase 1 results and briefly discusses key players operating in Phase 2.

The Project was launched in May 2020 by Fashion for Good together with Circle Economy. Catalytic funding was provided by Laudes Foundation and facilitated by brand partners, adidas, BESTSELLER, and Zalando, Inditex and H&M as an external partner. Fashion for Good partners Arvind Limited, Birla Cellulose, Levi Strauss & Co., Otto and PVH Corp. are participating as part of the wider working group. Circle Economy has led the creation and implementation of the methodology, with support from TERRA, to assess the characteristics of low value textiles. Both organisations build on their extensive experience from similar projects, such as the Interreg Fibersort project[30] and previous textile composition analyses.[31] [32] Refashion created the Refashion textiles materials library, a copy of which was used for the textile composition assessment. Matoha has provided the Near Infrared (NIR) technology, used to assess textiles composition.

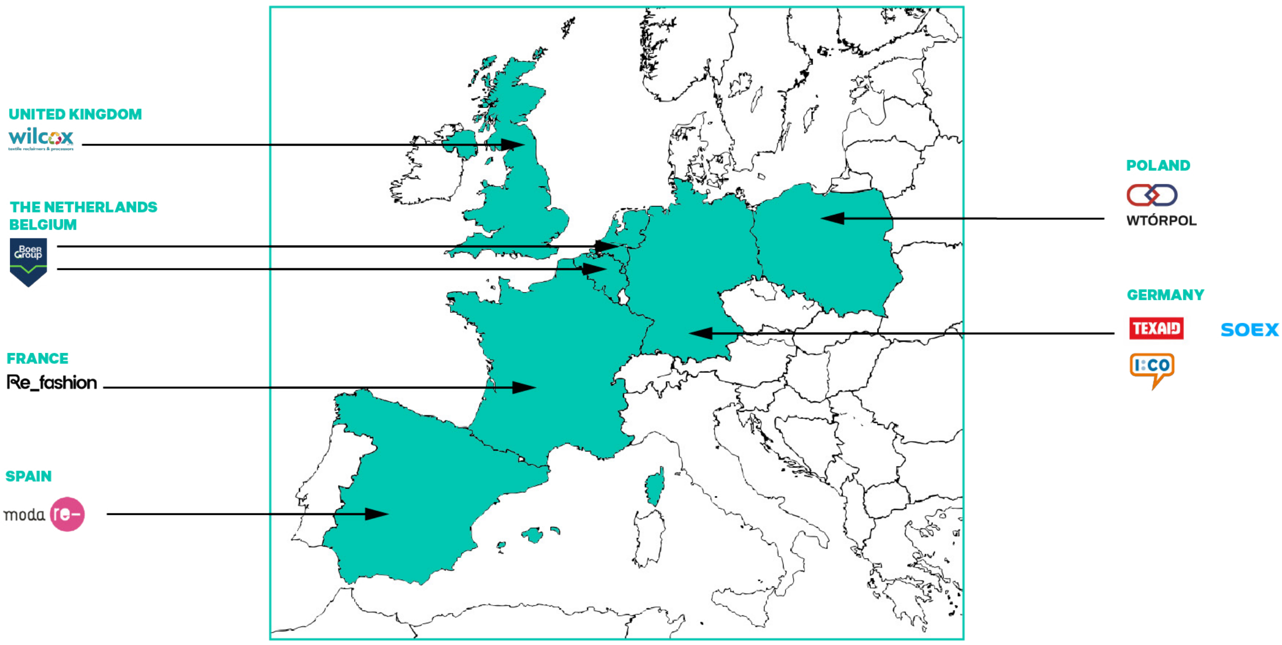

FIGURE 2. MAP OF TEXTILE SORTING FACILITIES INVOLVED IN THE STUDY. SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

Finally, the Project brings together the largest industrial textile sorters in the North-West European region; including the Boer Group, I:CO (a part of SOEX Group), JMP Wilcox (a part of Textile Recycling International), Modare-Cáritas, Wtorpol and TEXAID (referred to as the Sorters), placing key industry players firmly at the heart of the Project and driving the industry towards greater circularity.

Sorting for Circularity is a framework conceived by Fashion for Good together with Circle Economy, with the aim to (re)capture textile waste, expedite the implementation of game changing technologies and drive circularity within the fashion value chain. The framework is based on insights from the Fashion for Good and Aii collaborative report "Unlocking the Trillion Dollar Fashion Decarbonisation Opportunity", which charts a trajectory for the industry to meet its net-zero ambition by 2050, highlighting the potential and significant impact on carbon emissions in the industry through material efficiency, extended and re-use of waste. Created with scalability in mind, the project was first initiated in Europe, and has expanded to include Sorting for Circularity India.

PHASE 1 SCOPE AND APPROACH

The project focuses on textiles that cannot be reused in their original form (considered 'non-rewearable') and textiles that can only be resold at low prices ('low value rewearable'). For readability purposes, these two categories are referred to as '**the Fraction**' solely.[33] The Fraction excludes mattresses, footwear and other non-textile accessories arriving at the sorting facility. Phase 1 aimed to achieve the following objectives:

- Conduct a comprehensive composition analysis of the Fraction using NIR technology, to understand exactly what (e.g. material composition) and how much (e.g. volumes) potential feedstock for fibre-to-fibre recycling is generated across European countries.
- Create a methodology that can be replicated by sorters globally and publish a handbook for sorters to implement this methodology on-the-ground.
- Map the textile recycler's capabilities to understand how well-aligned current supply of potential feedstock is with recyclers' processes - also illuminating potential gaps whereby greater investment and innovation must occur. This has been collected through a database of fibre-to-fibre recyclers that will be made available on the Fashion for Good website.
- Understand the future business models required for sorters to commercialise the Fraction as feedstock for fibre-to-fibre recycling.
- Reflect upon the implications of these results for the current and upcoming policy landscape in the EU.

Phase 1 followed a three-stepped approach including Preparation, Implementation and Analysis, and Reporting. A total of 21.8 tonnes of PCT have been analysed in two time periods: the first during autumn/winter 2021, the second during spring/summer 2022, to account for seasonal changes in the types of garments entering sorting facilities. This data has been collected and analysed in a way that is comparable to the data that will be available for France through the characterisation study conducted by Refashion, commissioned to TERRA, to be released in 2023.

Introduction

The following steps have been taken to analyse the sample items and form conclusions at country level:

1. Sorters participating in the on-the-ground composition analysis were trained in the use of the NIR device and how to track information according to the studies' pre-defined categories (product type, presence of disruptors, etc). Training materials developed are explained in depth in the Sorters Handbook.
2. Items were scanned by the Sorters using a Matoha hand-held NIR scanner which has been improved with the textiles materials library developed by Refashion to recognise fibre composition. For multi-layered items, the two main layers of the garment were scanned.
3. If the result of the scan was unknown, the fibre composition was manually entered using the item's label.
4. Mono vs. multi-layers, colour, presence of disruptors, product type and age group were tracked by the Sorters in a tablet device after scanning. The process of scanning the item and tracking the additional information has been conducted at an average speed of 41 seconds per item.
5. The sample data was collected in .csv format.
6. The sample data was extrapolated to obtain indications of volumes available in the focus countries per fibre type, using volumes from textiles collected in the focus countries available through prior literature.

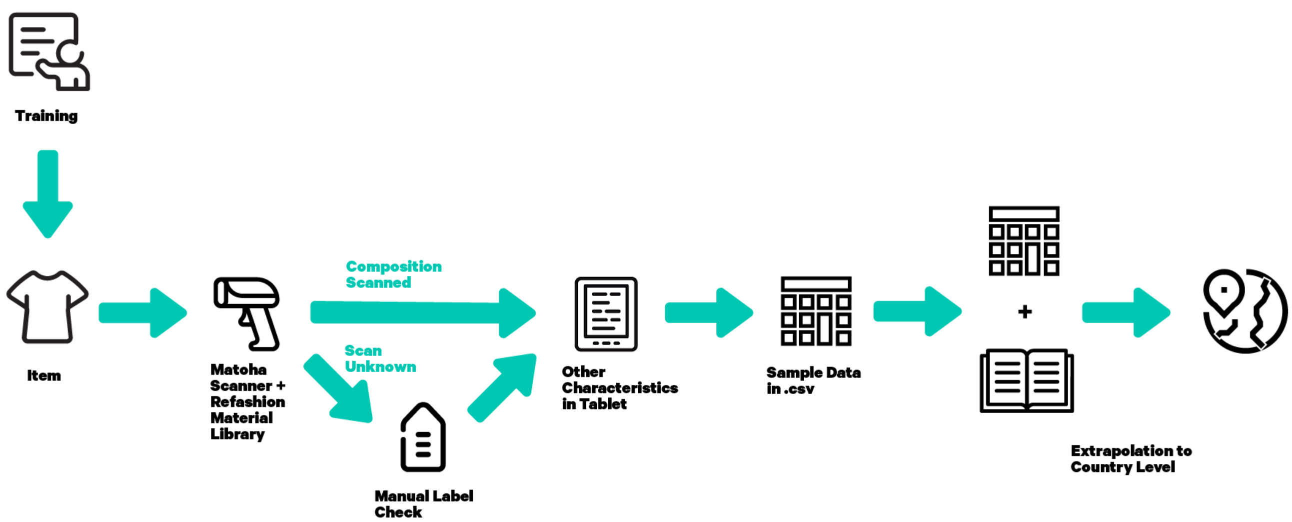

FIGURE 3: STEP BY STEP APPROACH FOR THE IMPLEMENTATION OF THE DEVELOPED METHODOLOGY ON-THE-GROUND. SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

A detailed description of the activities conducted under each step of the process can be found in Annex at the end of this report.

PHASE 1: UNPACKING THE POTENTIAL OF LOW VALUE TEXTILES ACROSS EUROPE

Textile Flows in Focus Countries

Once clothing and household textiles are disposed of by citizens or end-users of commercial or industrial institutions within Europe, they enter the end-of-use value chain for PCT. They are mostly collected via bring banks, reaching percentages as high as 78%[34] and 88%[35] of all textiles separately collected for France and Germany respectively. This collection method is usually complemented with indoor collection, either across the counter or with small bring banks placed in second-hand shops or first-hand retail stores. In the UK, the situation differs, as the predominant mode of collection is via charity shops (48%), whilst bring banks are the second most common method of collection.[36] A smaller percentage is also collected via kerbside collection across these countries, although this method is usually more rare. Each method presents both advantages as well as challenges. For example, bring banks usually generate high collection volumes, however, present more risks of polluting the collected textiles with household waste than indoor collection.[37] Kerbside collection on the other hand, usually presents higher costs and also higher theft risks.[38]

Image 4: Collection bin (Source: Koopera)

Textile Flows in Focus Countries

From the point of collection, textiles go into sorting facilities either locally or abroad. The aim of textile sorting activities is to ensure that textiles are used at their highest potential, both from an environmental and an economic perspective. These processes are widespread across European facilities and the sorting capacity of focus countries range from around 40,000 tonnes per year in Spain, to 200,000 tonnes in Poland, and 234,000 tonnes in the Netherlands, according to 2020 estimates[39, 40], as shown in Figure 4. Sorting capacity is not always fully utilised for textiles collected domestically. For instance, in the Netherlands, 55% of collected textiles are sorted abroad, and most of the local sorting capacity is used to sort textiles from Germany.[41] These current intra-EU trade dynamics may be explained due to lower costs of purchasing collected textiles from other countries as a result of differences in the fees paid for collecting textiles in each geography. Hence, for sorting facilities in countries where collected textiles are more expensive to buy, collected textiles from neighbouring countries are attractive feedstock for their operations.[42]

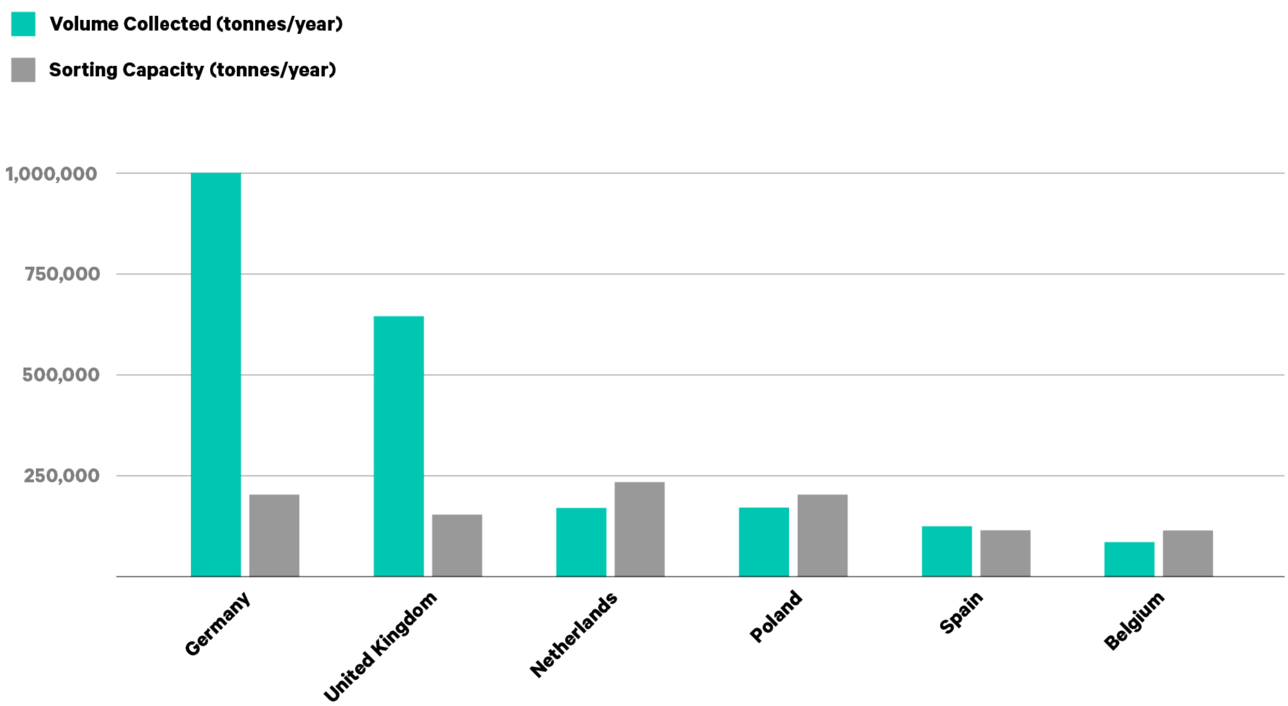

FIGURE 4: TEXTILES COLLECTION VOLUMES AND SORTING CAPACITY IN FOCUS COUNTRIES. SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

Textile Flows in Focus Countries

Manual sorting operations are conducted in a step by step approach focussing on 1) the removal of non-textile items (like household waste and footwear), 2) the identification of articles with a value on the second-hand market ('rewearables'), as well as separating those articles which have other end-markets, such as for fibre-to-fibre recycling, wiping or downcycling ('non-rewearables'). The destinations of collected volumes in the focus countries is illustrated in Figure 5 below.

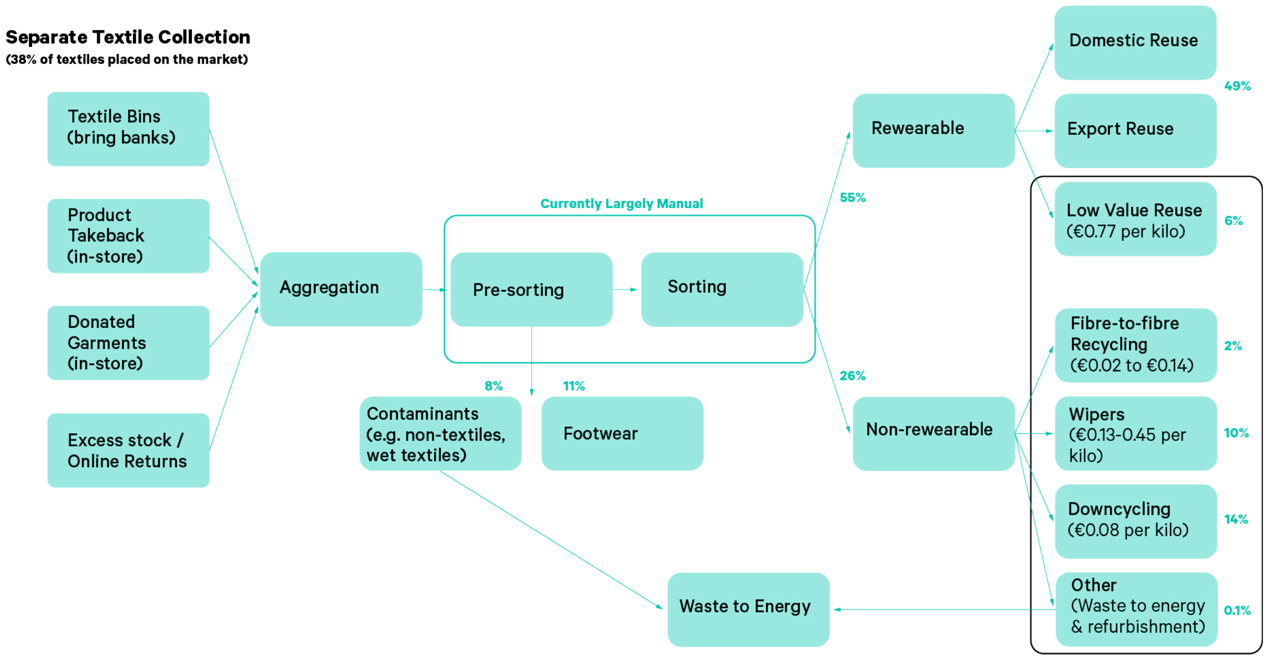

FIGURE 5: SHARES OF TEXTILE COLLECTION AND SORTING BY DESTINATION IN FOCUS COUNTRIES, INCLUDING PRICE RANGES. SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

REWEARABLE TEXTILES

Typically, 55% of the input arriving at the sorting facilities can be deemed as fit for the second-hand textiles market.[43] The share of rewearable garments is extremely important for the sorting system today, as the revenue is primarily derived from approximately 30% of the highest quality textiles from the reuse categories.[44] This means that the top quality rewearable textiles, for example from well-known brands or those that still have a price tag on them (also known as Cream), is estimated to account for 50% of the revenue, and that all of the rewearable fractions together may account for up to 90% of a businesses' revenue.[45]

A minor part of these high quality rewearable items are re-sold locally (±10% of volumes collected). Yet, the European sorting industry serves mostly global second-hand markets. In 2020, the EU-28 exported around 1.2 million tonnes of used textiles and worn clothing, mainly to Pakistan, UAE, Tunisia, Cameroon, Ukraine and Turkey.[46] The average price for these textiles to other regions was €0.76 euro per kilo in 2019.[47] Germany, the UK, Poland, Belgium, and the Netherlands fall within the largest ten exporters of used textiles and worn clothing (in weight) globally.[48]

For countries such as Germany, although the amount of locally collected textiles is extremely high (over 1,000,000 tonnes each year), the sorting capacity estimates of the country are quite low in comparison (190,500 tonnes). This difference means that a large amount of collected textiles are exported and sorted abroad. Concerning the import of used textiles and worn clothing, the Netherlands is also the fifth major importer in weight globally; while Poland ranks tenth. This indicates the presence of an established sorting capacity that can handle not only locally used textiles, but also input from abroad, mostly from other European countries.[49]

NON-REWEARABLE TEXTILES

After an item is classified as non-rewearable, it is sorted for specific destinations, separately from the rewearables. Non-rewearables sorting is focused on identifying textiles fit for downcycling, wiping, refurbishment, and fibre-to-fibre recycling or to be used for energy recovery. These end-markets usually have lower prices than the rewearable textiles, and from the Sorters involved in the study, they may represent on average around 26% of the sorted textiles, whilst only accounting for 10% or less of a facilities' revenue.[50] These sorted goods may also serve local or global markets. Additionally, the non-rewearable share of sorted textiles is foreseen to rise in the coming years, as Sorters participating in this project indicate that approximately 6% of the sorted volume is now considered low-value rewearable items that European sorters already struggle to find financially viable end-markets for. This is due to a combination of diverse reasons, yet mostly related to market saturation of global second-hand textile trade and lowering quality of textiles reaching the facilities.[51] As collection rates are expected to increase across European countries in the near future, the market for low value rewearable textiles will be saturated leaving these textiles as potential feedstock for fibre-to-fibre recycling. Hence, these recycling technologies need to be ready to handle these textiles as well. Although that is the case for mechanical recycling technologies today, certain chemical recycling technologies are yet to achieve the necessary readiness level to handle the expected volumes of low value post-consumer textiles collected.

Figure 5 shows the different destinations of the sorted textiles included in the sample of this Project and the share they represent from the total sample. Wipers are the destination for 10% of sorted textiles whilst prices are between € 0.13 and 0.45 per kilo. Downcycling to applications such as fibres for insulation, filling or non-woven for automotive and other industries represents the destination for 14% of the textiles and prices are € 0.08 per kilo for feedstock. Low-value rewearables represent 6% of the sorted textiles and prices per kilo are € 0.77 per kilo. Finally, feedstock for fibre-to-fibre recycling represents 2% of sorted textiles and prices are currently between € 0.02 and € 0.14 per kilo.[52] Sorters currently sell cotton, wool and acrylic textiles as feedstock for fibre-to-fibre recycling to mechanical recyclers, and increasing volumes of cotton textiles are being sold to chemical recyclers.

Both the non-rewearable and the low-value rewearable fractions are the focal point of this composition analysis. For readability purposes, throughout the next chapters we will refer to these two categories as 'the Fraction' solely.

Fibre Types In The Fraction

The outcomes outlined in this report are based on the analysis of a sample of 90,777 items of PCT from categories included in the Fraction, originating from collection schemes in the six focus countries. Based on average product weights per garment type and age group, the total volume of the sample is estimated at 20,523 kilos. [53]

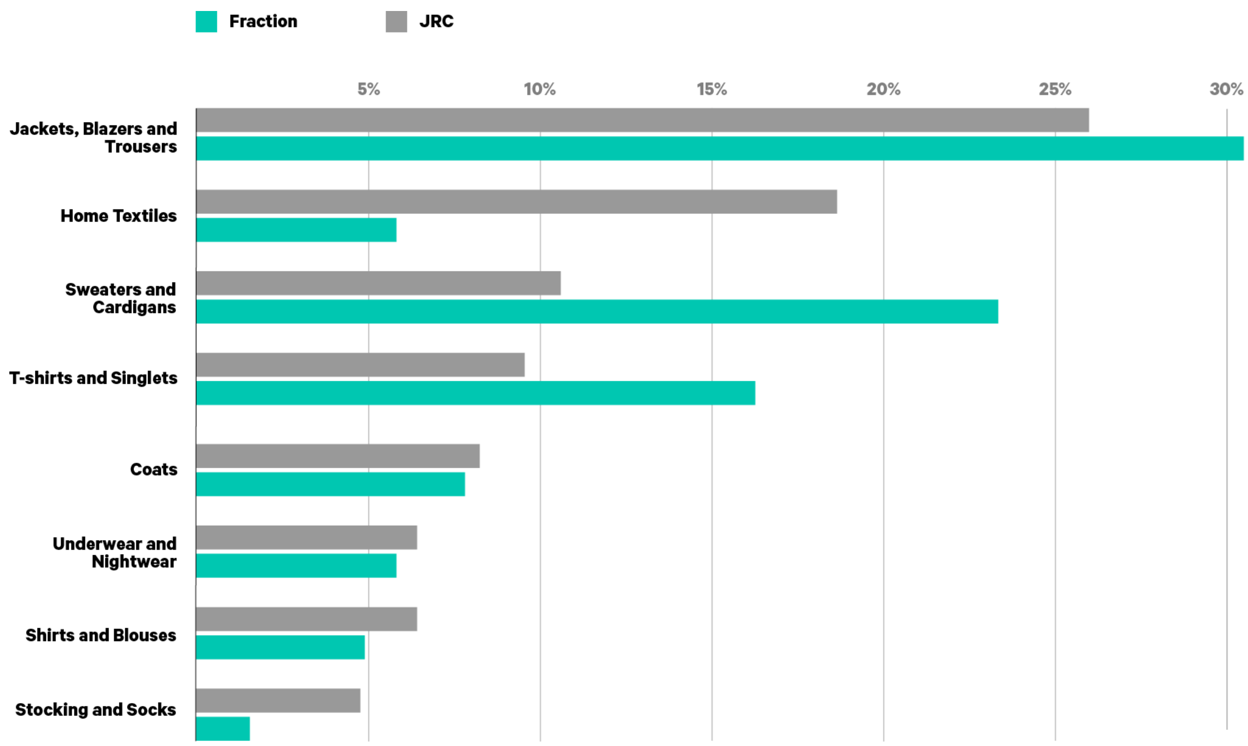

FIGURE 6: COMPARISON OF THE PRODUCT CATEGORY BREAKDOWN OF THE FRACTION TO THE GARMENT PRODUCT TYPES PLACED ON THE EUROPEAN MARKET. SOURCE: JRC (2021), CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

In the Project, tops like sweaters and t-shirts are over-represented in the Fraction compared to garment types sold on the European market, while home textiles are underrepresented. The overrepresentation of these product categories, illustrated in Figure 6, most likely reflects the current most prevalent destinations for non-rewearable textiles as feedstock for mechanical recycling (with preference for wool- and cotton-rich items) and the wipers industry (with preference for garments that allow for cutting out large pieces of fabric, like tops). Another explanation could be that bottoms, like trousers, tend to either be too worn out at time of disposal. In this case these garments are more likely to end up in household waste than in textile collection bins, or are not worn that often and sold for reuse on second-hand markets. Home textiles are underrepresented in this Project, accounting for only 5% of the research sample whilst representing 19% of the volume consumed in the EU each year.[54] This difference is due to the fact that home textiles can often be resold on the global second-hand markets.[55]

Fibre Types In The Fraction

Besides, the Sorters participating in this study were mostly keen on exploring the composition of garments due to the very large variety of product types found in this product group. The overrepresentation of garments should be taken into account in the interpretation of this Project's results.

The findings of the on-the-ground research at the Sorters' facilities were extrapolated to obtain indications of volumes available in the focus countries per fibre type, shown in Figure 7 below. Considering the wide range of characteristics of textile products on the European market, extrapolating sample data to country level only provides an estimate of what the total volume might look like. However, presence of fibre types cannot be translated directly into feedstock for recycling, as 31% of fibres in the Fraction occur in blends.[56] Most fibre-to-fibre recycling technologies currently at scale only accept textiles consisting of pure materials. The suitability of the Fraction as feedstock for recycling is further described in the next chapter.

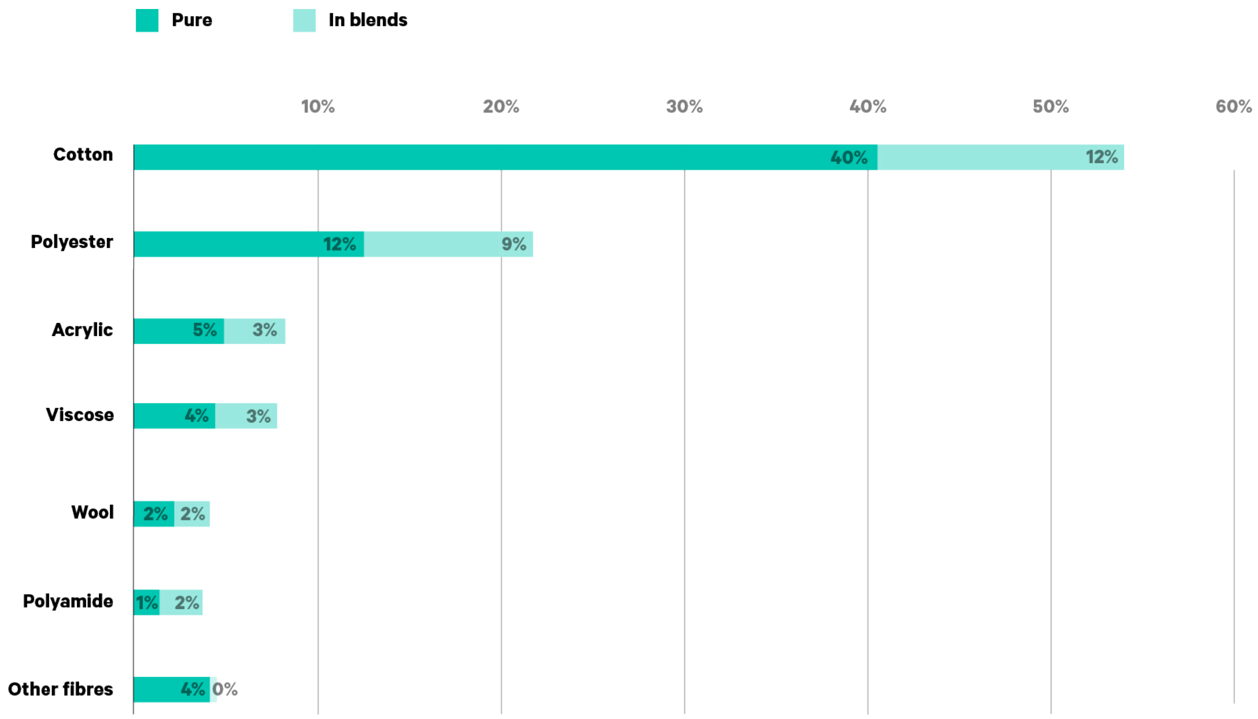

FIGURE 7: PRESENCE OF FIBRE TYPES IN THE FRACTION, OCCURRENCE AS PURE MATERIALS VS. IN BLENDS. SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

Fibre Types In The Fraction

Pure cotton is the most prevalent fibre type in the Fraction in the focus countries, but it is likely that a large share of this feedstock is actually contaminated with elastane. The sample was analysed using NIR technology. Whilst the use of this technology allows for efficient analysis of the composition of large amounts of textiles, there are limitations to its accuracy, as described in Annex II. One major limitation of the use of NIR is its limited ability to recognise the presence of elastane. Elastane is often added in cotton garments to optimise comfort and fit.[57, 58] Elastane was detected in only 2% of this Project's cotton sample, suggesting that a considerable share of the study's feedstock claimed as pure cotton in Figure 7 may contain small amounts of elastane.

Whilst cotton is the dominant fibre type found in the Fraction, polyester is the world's most produced fibre type. According to Textile Exchange's 2021 Preferred Fiber and Materials Market Report, polyester accounted for 52% of world fibre production in 2020 and cotton for only 24%.[59] There are a few possible explanations for this significant difference between the world's fibre production and fibre types found in the Fraction:

- The world's fibre production does not cater for the fibre need of producers of consumer textiles only. A considerable share of fibres produced are destined for workwear or technical textiles. For example, it is estimated that industrial textiles represent almost 20% of global fibre demand.[60] Workwear and technical textiles are polyester-rich materials, hence a large proportion of the world's polyester production most probably does not end up solely in consumer textiles and therefore contributes to the Fraction's share of polyester being smaller than expected.

- The difference in fibre composition found could also reflect a preference from consumers in the focus countries for cotton products over polyester, or could be an effect of consumer disposal behaviour as they might regard polyester products as lower value and therefore, choose to dispose of them in household waste rather than giving it to charity for reuse. In this case, increasing collection rates of textiles from household waste to the collection bins would lead to an increased share of polyester found in the Fraction.

- The characteristics of today's non-rewearable textiles are a direct effect of the market demand for second-hand textiles, feedstock for recycling, wipers and downcycling. As polyester is a more durable material than cotton, collected textiles with high polyester content might be more likely to be sold on domestic or global second-hand markets than products consisting of natural fibres, like cotton, that tend to wear out over time. On the other hand, demand for polyester-rich textiles as feedstock for recycling is currently limited because recycling technologies at scale are mostly mechanical and in search of natural fibres like cotton and wool. The same applies to the wipers industry, which has a strong preference for cotton-rich fabrics.

One of the common explanations for differences between world fibre production and the fibre types found in PCT is the delay between production and disposal. Assuming consumers use textile products for approximately four years implies that volumes collected today reflect the fibre production of 2017 when polyester accounted for 51% of world fibre production.[61][62] The delay between production and disposal hence does not explain the significant gap between world fibre production and the share of polyester found in the Fraction.

Unpacking The Fraction: Its Potential For Recycling

The suitability of textiles as feedstock for recycling is determined by the following characteristics: 1) composition of the product's fabric, 2) presence of disruptors, 3) colour. Data was captured on these characteristics during the on-the-ground analysis. Sample data was extrapolated to country volumes to illustrate the potential feedstock availability in this Project's focus countries. The following section describes the potential feedstock availability for recycling based on the Fraction's composition and the presence of disruptors. A detailed description on the prevalence of colours is included in section 3 of this chapter, where the potential for mechanical recycling is introduced.

1. FABRIC COMPOSITION

An estimated 7% of the Fraction volume consists of multi-layered items like jackets and coats. Multi-layered items can be disassembled manually or automatically before being sorted based on their composition, for instance using NIR sorting technology. The multi-layered items found in the Fraction are currently used for downcycling (63% of the volume of multi-layers), wipers (12%) or have a destination as low value rewearable textiles (19%). The fabric types used in multi-layered items mostly consist of polyester (33%), blends (31%) or cotton (11%).

Since there is no business case for manual disassembly in Europe and technologies for automated disassembly are not available at scale, multi-layered items have been excluded from the Fraction for now. While the disassembly of multi-layered items is not financially viable today, the potential for PCT as feedstock for recycling illustrated in this Project might further spur innovations for automated disassembly of multi-layered items in the future.

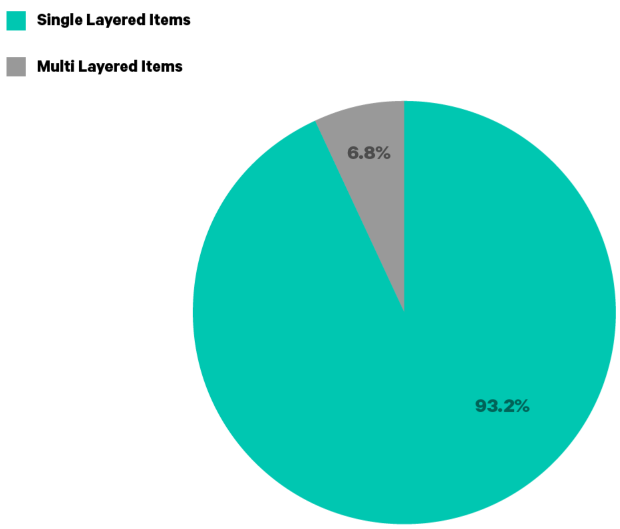

FIGURE 8: SINGLE VS. MULTI-LAYERED ITEMS IN THE FRACTION. SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

Unpacking The Fraction: Its Potential For Recycling

The removal of multi-layered items has led to the following potential volumes of feedstock in the focus countries, as visualised in Figure 9. These estimates do not exclude textiles that contain non-removable disruptors and therefore might not be suitable for recycling after all. Details on the presence of disruptors are further discussed in the material breakdowns in this chapter, where the potential of these materials for different recycling technologies is explored.

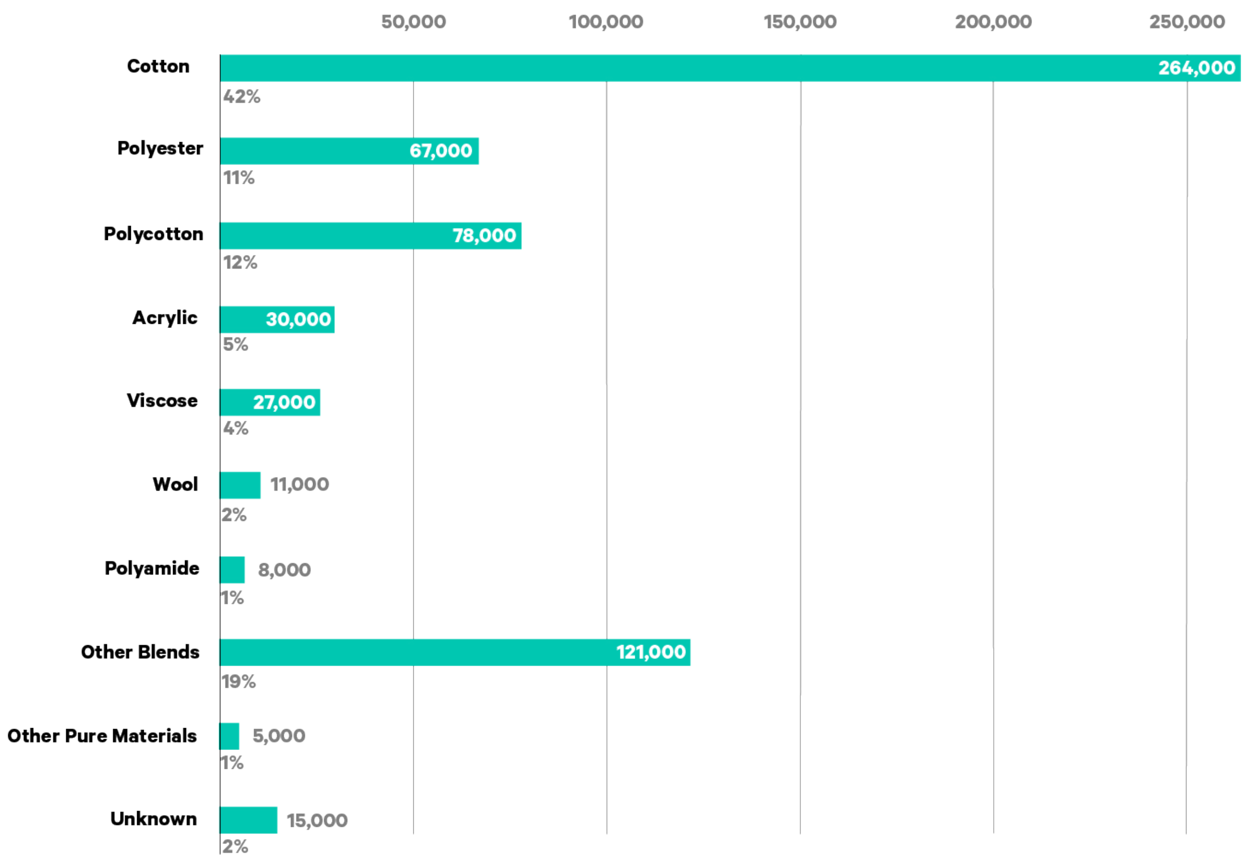

FIGURE 9: POTENTIAL FEEDSTOCK AVAILABILITY FROM THE FRACTION IN FOCUS COUNTRIES BY MATERIAL COMPOSITION (IN TONNES/YEAR). SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

Unpacking The Fraction: Its Potential For Recycling

Pure cotton is the most prevalent fibre type in the Fraction in the focus countries[63], followed by polycotton (12%) and polyester (11%).

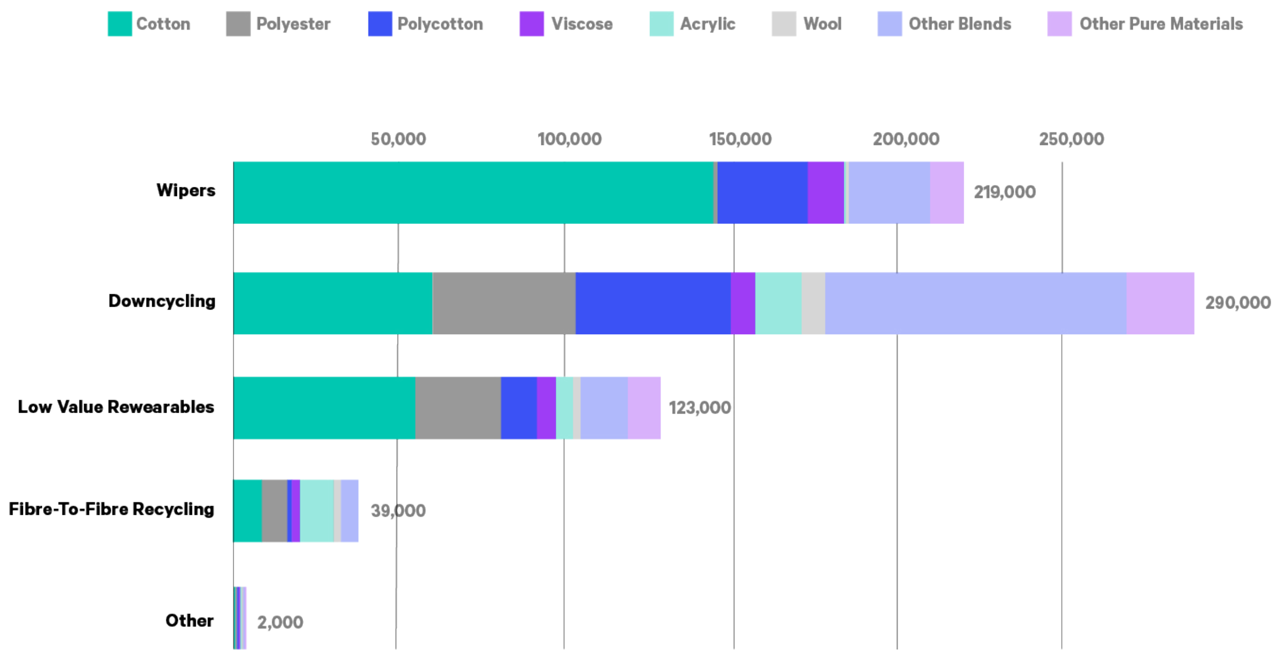

FIGURE 10: BREAKDOWN OF THE FRACTION PER CURRENT DESTINATION AND FIBRE COMPOSITION (IN TONNES/ YEAR). SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

Textile sorters categorise textiles to meet the specific requirements of their clients. This means all sorters have different product categories and therefore comparisons between countries are highly influenced by the differences in client requirements of participating sorters in each country. However, trends can be identified in the composition of products currently used as wipers, for downcycling, as low-value rewearable, as feedstock for fibre-to-fibre recycling (predominantly with mechanical recycling technologies), or for refurbishment or incineration (classified as "other destinations" in Figure 10). The fibre composition for each current destination is illustrated in Figure 10, whereas cotton and poly cottons are mostly sold for wipers and for example polyester and multiple blends are most commonly sold today for downcycled applications. Considering the low volumes of wool and acrylic found in sorted textiles in comparison to other fibres, these compositions have a high relevance when it comes to destinations for fibre-to-fibre recycling for wool and wool-rich blends and for acrylic when it comes to downcycling applications.

Unpacking The Fraction: Its Potential For Recycling

While cotton is the most prevalent fibre in most product categories, it is most commonly found in t-shirts and (denim) trousers. Sweaters have a high degree of diverse types of blends, for example wool-acrylic blends or blends containing viscose. Additionally, polyester can be seen mostly present in light jackets as well as in trousers.

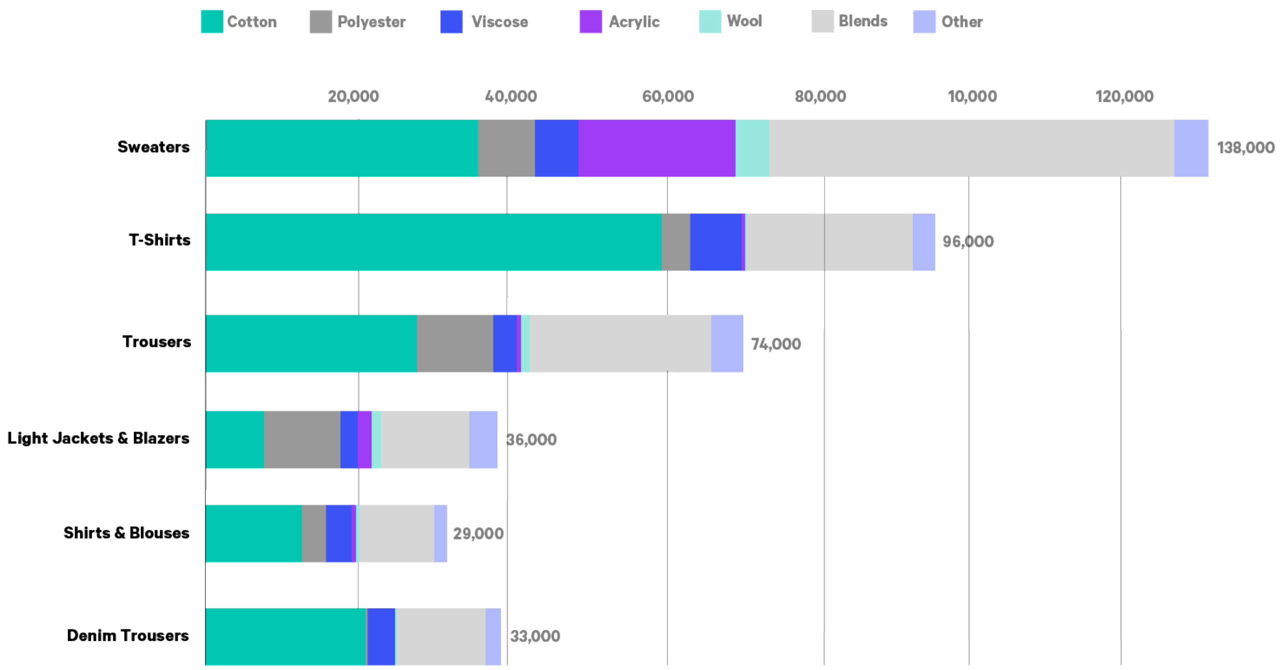

FIGURE 11: BREAKDOWN OF THE FIBRE COMPOSITION OF THE MOST COMMON PRODUCT TYPES IN THE FRACTION. SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

Image 5: Shredded fibres in facility (Source: Wtórpol)

2. PRESENCE OF DISRUPTORS

The presence of elements such as buttons, fasteners and zippers may create a disruption for certain recycling processes. This is also the case for certain aesthetic applications such as sequins. Slightly over one third of the single-layered items in the Fraction (32%) do not contain any disruptors and can be considered as feedstock for recycling.

On the other hand, slightly over two thirds of the single-layered items in the Fraction (68%) contain disruptive elements for the recycling process. However, there is an important distinction between removable and non-removable disruptors. For the purpose of this Project, metal and plastic hardware have been regarded as removable disruptors, meaning that they can be removed either manually or automatically in preparation for recycling.[64] All other hardware found in textiles as well as combinations of different types of hardware are considered as non-removable disruptors for the purpose of fibre-to-fibre recycling activities. Additional to the physical possibility of removing these elements, is the consideration of whether it is financially viable to do so. This is further discussed in chapter five on the business case for sorting for circularity.

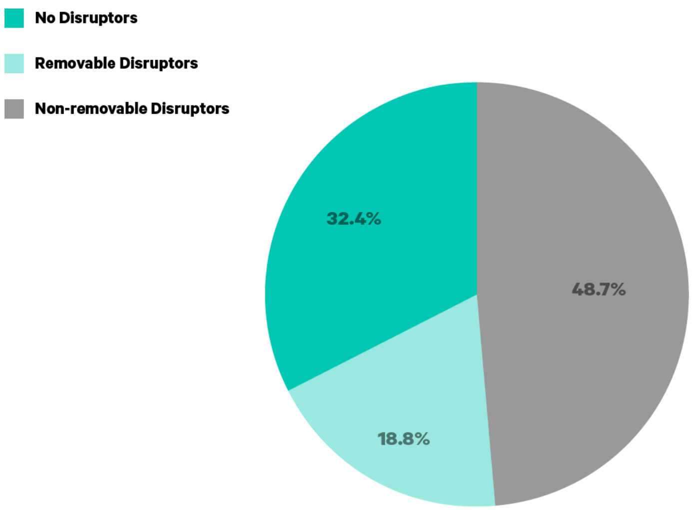

FIGURE 12: PRESENCE OF DISRUPTORS ON SINGLE LAYERED ITEMS IN THE FRACTION. SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

3. RECYCLABILITY OF THE FRACTION

The potential availability of feedstock for fibre-to-fibre recycling is described below for mechanical and chemical recycling separately. For each recycling archetype the volumes available of different material compositions are shown, alongside relevant information on the presence of disruptors and colours found. The assumptions of the feedstock suitable for each recycling archetype are also explained in the relevant section.

MECHANICAL RECYCLING

Mechanical recycling is the process by which textiles are cut, shredded and opened into fibres that are usable for diverse applications. Some of the most common applications for this process are as fibres for insulation, filling or non-woven for industries such as the automotive. These applications are considered downcycling and the feedstock availability for these is not discussed in this section.

Nonetheless, the fibre-to-fibre mechanical recycling market is a mature one, with energy- and cost-efficient technologies at scale. Feedstock such as knitted textiles and denim are currently in high demand from sorters to feed into fibre-to-fibre recycling. Although fibres are shortened during the recycling process, these are usually compensated by being blended together with virgin fibres in order to obtain final yarns that are suitable to be woven or knitted back into textiles.

Assumptions made to estimate the volumes of feedstock available for mechanical recycling in the Fraction

- Composition: Pure cotton, pure wool, pure acrylic, cotton-rich and wool-rich blends (>80%).[65]
- Disruptors: None or removable.
- Colour: Multi-colour excluded.
- Only destinations for fibre-to-fibre recycling are taken into account

A total amount of around **140,000 tonnes of low value textiles** is available in focus countries each year for fibre-to-fibre mechanical recycling processes. This volume represents 21% of low value textiles collected in the focus countries. This includes 1) 105,000 tonnes of pure cotton[66] and 7,000 tonnes of cotton-rich blends with more than 80% cotton content (polycotton blends excluded), 2) 20,000 tonnes of pure acrylic, and 3) 7,000 tonnes of pure wool and 700 tonnes wool-rich blends with more than 80% wool content. The research found 47% of cotton-rich blends (polycotton excluded) were contaminated with nylon, 35% with elastane. However, cross-checks with composition claims on care labels hint that most of the contamination claimed as 'polyamide' actually consisted of elastane (further explained in Annex II). Contrastingly, the majority of wool-rich textiles are blended with polyamide (72%), followed by cotton (14%) and polyester (11%). Only monocoloured textiles that have no disruptors or removable ones are included in these volumes.

Unpacking The Fraction: Its Potential For Recycling

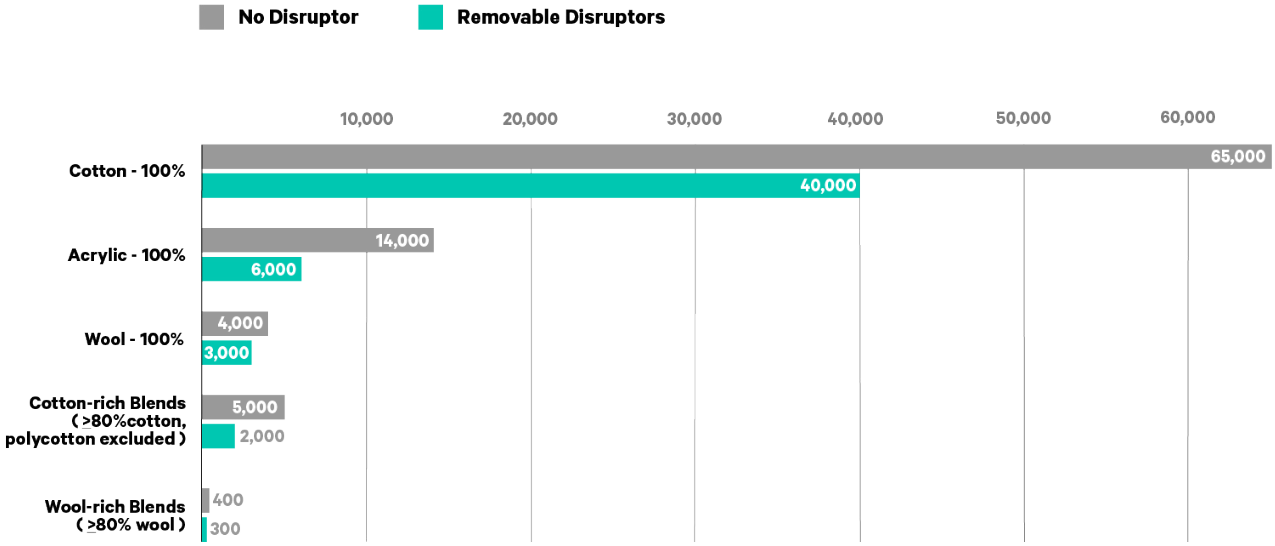

FIGURE 13: AVAILABILITY OF FEEDSTOCK FOR MECHANICAL RECYCLING IN FOCUS COUNTRIES BY FABRIC COMPOSITION (TONNES/YEAR). SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

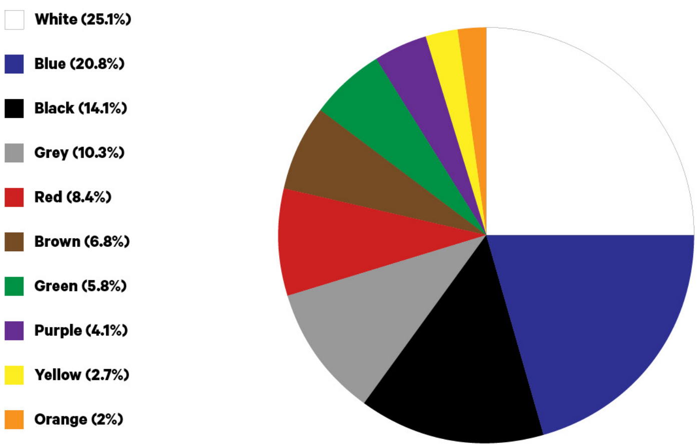

FIGURE 14: BREAKDOWN OF MOST PREVALENT COLOURS IN AVAILABLE FEEDSTOCK FOR MECHANICAL RECYCLING IN FOCUS COUNTRIES. SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

In terms of colour, the majority of the feedstock available is white (24%), while considerable amounts of blue (20%), black (15%), and grey (11%) are also available. The colour palette found in the Fraction has been visualised in Figure 14.[67] Although white is the most common colour overall, on average, black is the most prevalent colour for wool and grey for wool-rich blends.

Additionally, multi-coloured textiles have been excluded from these figures. This is due to the fact that one of the key aspects of the efficiency and low environmental impact of mechanical recycling processes is related to avoiding the re-dyeing and minimising over-dyeing of recycled fibres. Having multi-coloured textiles as input to this process would eventually create multi-coloured fibres as an output, which would not be marketable at scale under current requirements. Hence, these textiles are considered more suitable for a different recycling process. The presence of multi-coloured textiles for these fabric compositions with none or removable disruptors in the Fraction has been estimated to be 21%.

CHEMICAL RECYCLING

Chemical recycling are the processes by which fibres are broken down to its basic building blocks, either to polymer or monomer level. There are diverse recycling technologies encompassed under this archetype, including amongst others pulping processes to recycle cotton and viscose, to solvent-based processes to recycle polyester and polycotton, to processes such as glycolysis, hydrolysis and enzymatic that take polyester and polyamide back to monomers.[68]

Assumptions made to estimate the volumes of feedstock available for chemical recycling in the Fraction

- Composition: Pure polyester, poly cottons, polyester-rich blends other than with cotton (>40% polyester content), pure viscose and pure cotton that is not suitable for mechanical recycling.
- Disruptors: None, removable and non-removable disruptors.
- Colour: All colours and multi-coloured.

A total amount of **354,000 tonnes of low value textiles** is available in focus countries each year for fibre-to-fibre chemical recycling processes. This volume represents 53% of low value textiles collected in the focus countries. This includes:

1. 163,000 tonnes of pure cotton[69], which considers only the volume that is not suitable for mechanical recycling —all multicoloured pure cotton items, and pure cotton items with non-removable disruptors.

2. 78,000 tonnes of poly cotton blends, The majority of polycotton blends (61%) consists of cotton-rich materials, with cotton content of 50% or above. The remaining 39% is considered polyester-rich, with polyester content of 50% or above.

3. 67,000 tonnes of pure polyester,

Certain technologies can further extract polyester from polyester-rich blends if the average polyester content is at least 40%. This is a relevant consideration, as 63% of all blends contain polyester:[70]

4. 19,000 tonnes of other polyester rich blends —that contain at least 40% of polyester and exclude those blended only with cotton. The main contaminants included in these blends are viscose (48%), wool (19%), elastane (11%), acrylic (11%) and polyamide (10%).

Unpacking The Fraction: Its Potential For Recycling

Finally, considering the small quantities of other types of man-made cellulosic fibres found in the Fraction, all man-made cellulosics have been aggregated under the term 'viscose' in this Project:

5. 27,000 tonnes of pure viscose.

PCT containing all types of disruptors (both removable and non-removable) have been considered as potential feedstock for chemical recycling. In the case that non-removable disruptors cannot be processed by recyclers, only 19% of the total potential feedstock for chemical fibre-to-fibre recycling would be available.

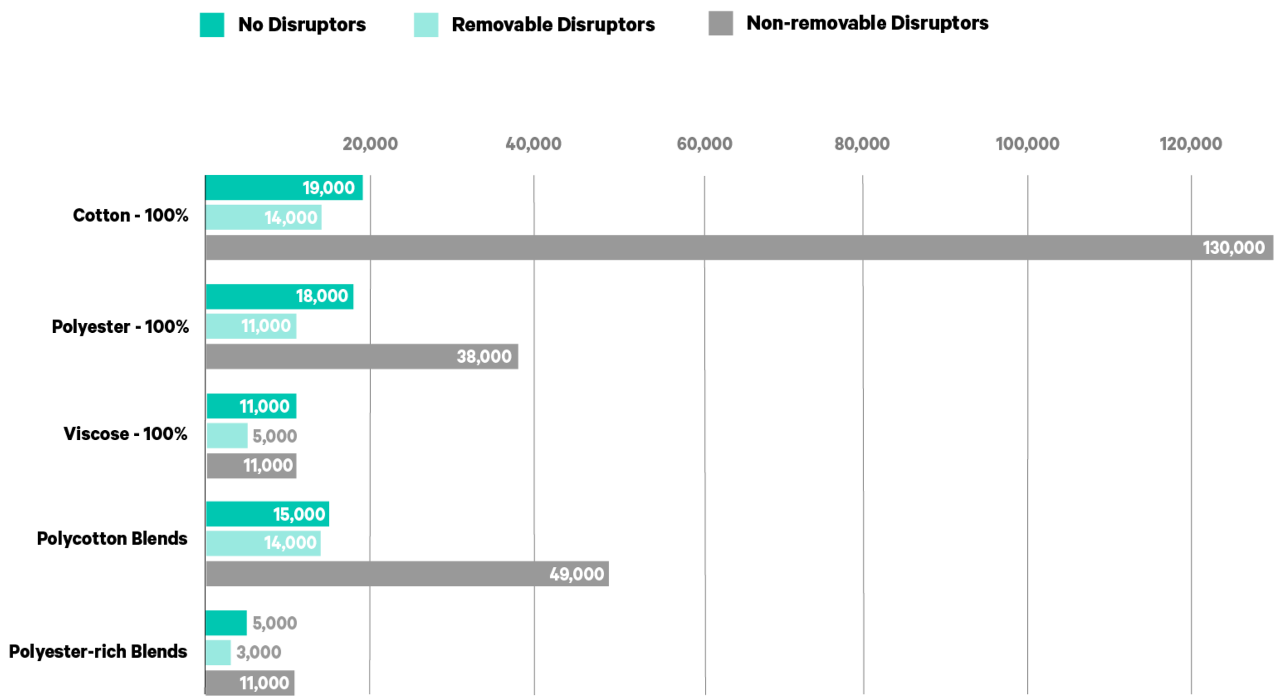

FIGURE 15: AVAILABILITY OF FEEDSTOCK FOR CHEMICAL RECYCLING IN FOCUS COUNTRIES BY FABRIC COMPOSITION (TONNES/YEAR). SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

For chemical recycling technologies, all colours have been considered as potential feedstock for recycling, including multi-coloured textiles. Although colour is not usually a hindrance for selecting feedstock for these types of processes, it is worth pointing out that multi-coloured textiles are the most prevalent colour in polyester (23% of available feedstock volume), viscose (26%) and polycottons that contain more than 50% of polyester (22%). For polycottons that contain more than 50% of cotton the most prevalent colour is blue (24%) of available feedstock volume), and for polyester-rich blends it is grey (19%).

OTHER RECYCLING TECHNOLOGIES

It is noteworthy to mention that pure synthetic textiles (eg. 100% polyester) could also be suitable in the future as feedstock for emerging thermomechanical processes - which use heat and pressure to melt synthetic textiles. However, at present, the purity requirements are extremely high for the technology to work and this presents a challenge for PCT.

The Business Case For Sorting For Circularity

There is a common misconception that textiles that cannot be sold on second-hand markets are 'valueless' and could be obtained as feedstock for fibre-to-fibre recycling at little to no cost. The weighted average additional revenue generated with the Fraction (€ 0.11 per kilo) does not outweigh the costs of sorting, as illustrated in Figure 16. The negative business case for sorting these low-value materials is currently compensated by the revenue generated through rewearable textiles (as described in chapter 1). This balance will most probably no longer apply in the near future as the share of low-value textiles is projected to rise considerably as collection rates increase.[71]

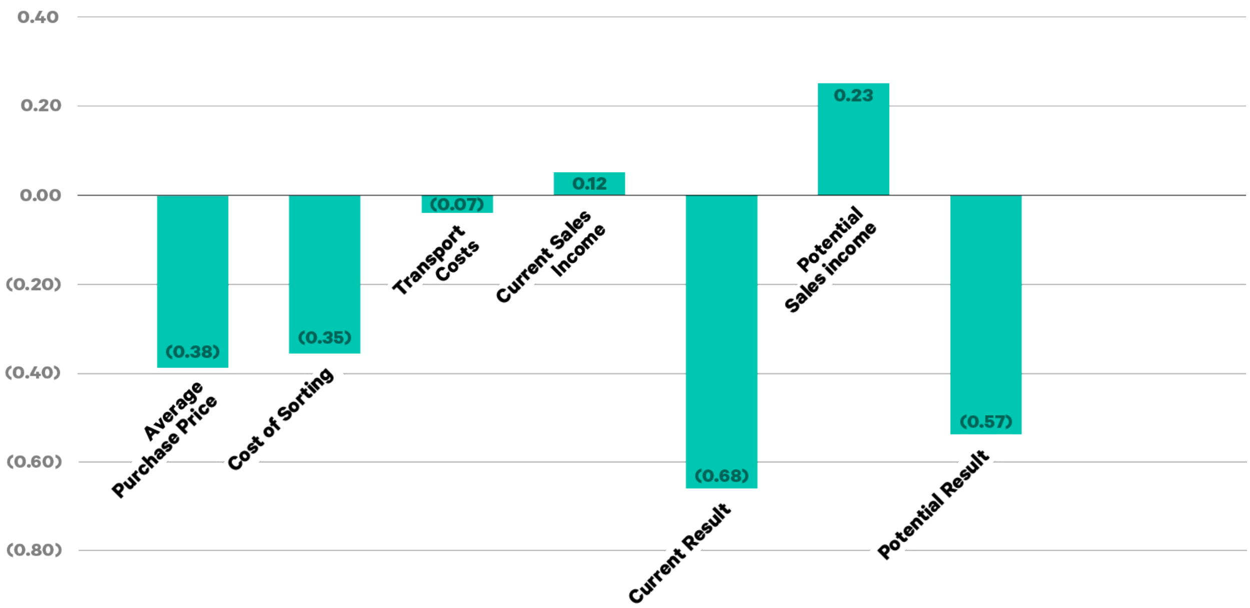

FIGURE 16: CURRENT BUSINESS CASE FOR SORTING LOW VALUE PCT - ILLUSTRATIVE[72] (PRICES IN € / KILO). SOURCE: EIGEN DRAADS AND FASHION FOR GOOD (2022)

Prices paid for feedstock for fibre-to-fibre recycling will need to compete with the average sales income of sorters for these materials in order to redirect textiles from current destinations. As fibre-to-fibre recycling is not yet a mature industry at scale, prices are not yet predefined. Therefore, estimates obtained from textile sorters and recyclers were used to illustrate what the business case for sorting for circularity could potentially look like. As illustrated in Table 1, not all projected feedstock prices are competitive with current prices received (shown in Figure 5). This means parts of the volume that might technically be available as feedstock for fibre-to-fibre recycling will continue to be sent to existing destinations, like the wipers industry, in the future.

The Business Case For Sorting For Circularity

	Price in model[72]	Feedstock input	Ability to handle disruptors	Colours
Chemical Recycling - Polyester	€ 0.20 /kg	≥95 polyester, <5% others	Yes	All
Chemical Recycling - Polycotton	€ 0.20 /kg	≥60% polyester, <40% cotton, < 10% others	Yes	All
Chemical Recycling - Cotton	€ 0.20 /kg	≥95% cotton, <5% others, no protein based fibres	Yes	All
Mechanical Recycling	€ 0.40 /kg	≥80% cotton	Removable disruptors only	All monocolours
Mechanical Recycling	€ 0.09 /kg	≥95% acrylic	Removable disruptors only	All monocolours
Mechanical Recycling	€ 1.20 /kg	≥80% wool	Removable disruptors only	All monocolours

TABLE 1: BUSINESS MODEL PRICING FOR FEEDSTOCK FOR DIFFERENT RECYCLING TECHNOLOGIES AND ITS KEY REQUIREMENTS. SOURCE: EIGENDRAADS AND FASHION FOR GOOD (2022)

The diversion of PCT to fibre-to-fibre recycling increases the average sales income from € 0.12 per kilo in the current market to at least € 0.23 per kilo in a closed loop scenario, a net increase of € 0.11 per kilo. The total volume that could be utilised as feedstock for fibre-to-fibre recycling based on material characteristics and market value (i.e. feedstock goes to the highest bidder) in the focus countries is estimated at 494,000 tonnes per year, assuming mechanical and chemical recycling technologies are available at scale. This means that 74% of the total volume of the Fraction currently available in the focus countries could be redirected to fibre-to-fibre recycling in the future. This potential feedstock for fibre-to-fibre recycling represents 23% of the total volume of textiles collected in the focus countries. In this scenario the total value created for textile sorters through sorting for circularity is € 74 million per year, for all six focus countries combined. As a result, sorting the Fraction would no longer cost € 0.68 per kilo but € 0.57 per kilo, illustrated in Figure 16.

The Business Case For Sorting For Circularity

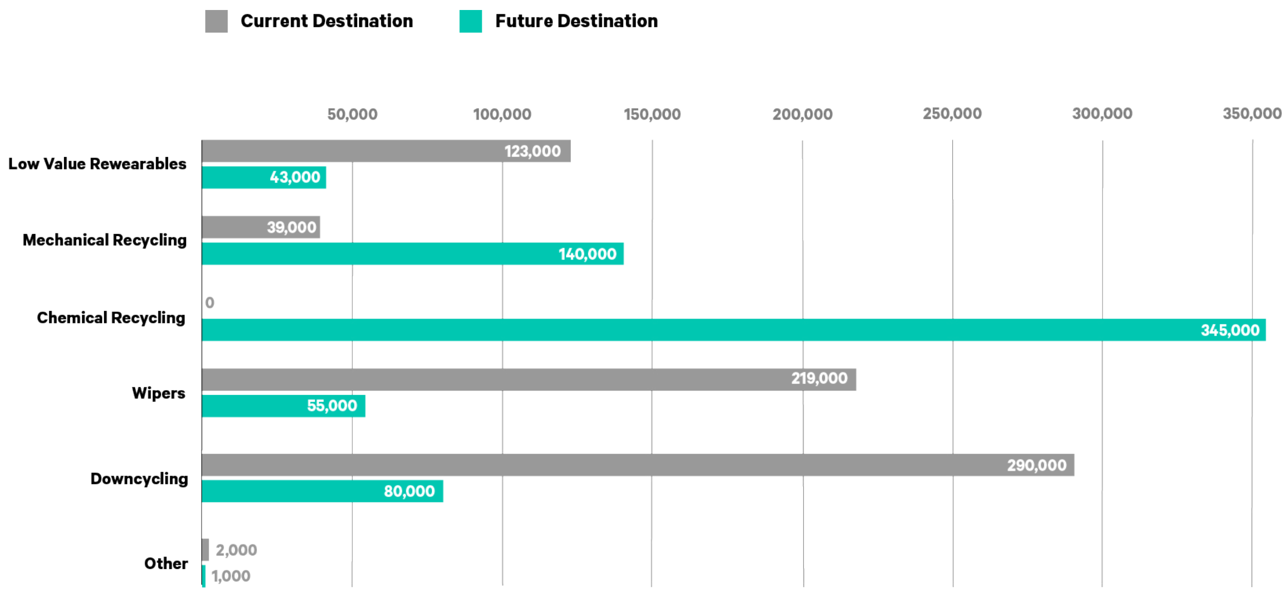

FIGURE 17: CURRENT AND FUTURE DESTINATIONS FOR THE FRACTION IN FOCUS COUNTRIES (TONNES/YEAR). SOURCE: EIGENDRAADS AND FASHION FOR GOOD (2022)

There is an important side note to this conclusion. For textiles to be suitable as feedstock for fibre-to-fibre recycling, they need to be sorted based on their composition, and disruptors need to be removed before entering mechanical recycling. In case these activities need to take place in European countries (for instance at sorters' facilities), investments are required in technologies for automated sorting and hardware removal. This Project did not assess the business case for automated sorting of textiles nor hardware removal. A previous analysis by EigenDraads concluded that setting up a pre-processing facility with a capacity of 20,000 tonnes per year, including NIR-based automated sorting and equipment for removal of plastic and metal disruptors, would require an investment of € 5.3 million. Average costs for automated sorting and removal of disruptors are estimated at € 0.12 per kilo for the pre-processing to be financially viable. The EigenDraads study shows that the financial added value of directing PCT from their current destinations to fibre-to-fibre recyclers results in a return of investment of around 8 years, which is not realistic for private investors. A return of investment of 5 years can be realised in case a subsidy is available for the CAPEX investments of € 1.8 million. The financial added value of sorting for circularity of € 0.11 per kilo (illustrated in Figure 16) does not cover the costs for automated sorting and removal of disruptors of € 0.12 per kilo. Financial compensation through an EPR scheme is required to cover the costs associated with sorting for circularity.[73] Automated sorting technologies are an addition to the current manual process in which rewearable items are separated from non-rewearable ones. There are no technologies available that could replace the categorisation of textiles based on their value for reuse on domestic and global second-hand markets. Therefore, adding automated sorting to the process will most likely not reduce the overall costs of sorting considerably.

The Business Case For Sorting For Circularity

Current global capacity of fibre-to-fibre recycling technologies is limited compared to the world's fibre production.[74] As a consequence, there is little competition between recyclers looking for feedstock. Competition amongst recyclers will increase as global recycling capacity is expected to grow considerably towards 2030.[75] Considering Europe's high collection rates, established sorting infrastructure and circular ambitions, it is well positioned to become a key feedstock supplier for fibre-to-fibre recyclers. An increased demand for feedstock for recycling will most likely drive up prices paid for sorted PCT that meet recyclers' specifications in the future.

Textiles with a low to no value on second-hand markets have a strong negative impact on the business case for textile sorters in Europe, as illustrated in Figure 16. In a future with a surplus of textiles unsuitable for second-hand markets, the business case for textile sorting in European countries will become even less profitable. The majority of textiles collected in the European focus countries of this Project is already sorted abroad, as the sorting capacity in these countries only accounts for 43% of the volumes of textiles collected. Increasing shares of low-value textiles in combination with current shortage on the labour market (and consequent pressure on minimal wages in European countries) might incentivise textile sorters to move (a part of) their activities to lower income countries in the near future. The introduction of Extended Producer Responsibility (EPR) regulation, discussed in more detail in the next chapter, could alleviate the burden caused by decreasing value of textiles sorted and high labour costs in European countries, if the financial support provided to sorters covers the future costs of sorting textiles. An exploratory study in the Netherlands concludes the financial support projected to be available for sorters through the upcoming EPR scheme as € 0.20 per kilo. This unfortunately will not cover the future additional costs of sorting, estimated at € 0.27 per kilo.[76] Therefore, the increase in prices paid for feedstock for recycling, due to increased demand, will be essential in combination with legislation such as mandatory EPR schemes, to sustain the business case for sorting in Europe.

Image 6: Garment on the Fibersort belt (Source: Fibersort)

PHASE 2:
MATCHING SUPPLY AND DEMAND OF TEXTILES

Linking Supply And Demand Through Digital Platforms

Currently, there is no widely adopted tool that can match the supply, the sorters, to the demand, the textile recyclers and material reprocessors. Hence, creating a transparent system where stakeholders in the industry can connect to supply of textile flows that can feed into recycling is required. To enable the link between sorters and recyclers, there is a need for a platform that is open-source and accessible, while providing transparency on the location and flow of PCT across the value chain. This visibility is crucial in order to not only understand current end-of-use infrastructure and its gaps, but also to envision a new circular system for textile sorting and recycling infrastructure.

Phase 2 of the Sorting for Circularity Europe project, started by conducting a landscape analysis of existing platforms within and outside the fashion industry. Within the fashion and textiles industry, some existing platforms include Reverse Resources, Refashion Recycle, Circular.fashion, and Excess Materials Exchange. From this landscape analysis, two types of platforms emerged:

First, an **information-based digital platform** that provides visibility into volumes and locations of waste flows, along with key contacts from sorting and recycling organisations. This type of platform addresses the fundamental challenge around the lack of transparency in the industry and presents a low entry barrier for users, as there is no obligation to share confidential information. However, this type of platform leads to a potential duplication of efforts as this model is seen in various iterations in the market. Moreover, it requires additional effort to facilitate business models outside of the platform, instead of a fully digitised process.

Second, a **transaction-based digital platform**, which is an end-to-end marketplace that matches supply of PCT from sorting partners to the recycler's demand. It provides capabilities and information required for complete business-to-business (B2B) transactions. This type of platform addresses challenges around post-consumer textiles flow data transparency between business partners and standardisation, accelerates the flow of waste into the appropriate end-of-use scenario, and simplifies the implementation of circular business models for sorters and recyclers. However, a transaction-based digital platform requires buy-in from users for commercial and confidential data. Also, due to the infancy of digital platforms in the PCT space, scaling such platforms requires multiple partnerships and additional financing.

Linking Supply And Demand Through Digital Platforms

To evaluate the product-market fit of these two types of platforms, sorters were interviewed to understand potential benefits and challenges in using digital platforms, and functionalities required to efficiently operate and use the platform. The interviews concluded that in the short-term, onboarding sorters and collectors to an information-based platform is more realistic, in the hope that it will transition to a transaction-based system once demand for recycling feedstock increases. The sorters highlighted that an information-based platform is attractive as it enables them to access new markets and customers for feedstock that was previously not valorised. The sorters identified specific needs for the platform such as 1) filtering capabilities (i.e. per location, volume, or composition), 2) accurate contact information for offline transactions, 3) recycler's to include clear description of their operations, and type and quantity of product required, 4) multilingual systems, and 5) low administrative efforts and ease of use. Barriers that sorters face in implementing digital platforms relate to the lack of standardisation in the sorting process that influences output requirements, undefined business case for the recycling fractions (addressed in Section 1.4), low demand from recyclers as the industry relies on long-term business contracts, and confidentiality of pricing and customer information.

Based on the landscape analysis and interviews with sorters, this project aims to amplify two platforms: Reverse Resources and Refashion Recycle. Reverse Resources is an open-access matchmaking, supply chain management and traceability platform for textiles. The platform allows a large network of collectors, sorters as well as textile manufacturers and service providers to securely collaborate in making joint offers of textiles by type and composition to the emerging large textile-to-textile recyclers, verify where, how and whose waste is getting recycled, and provide real-time data and market insight for the industry to support scaling up fibre circulation.

Image 6: Reverse Resources digital platform (Source: Reverse Resources)

Linking Supply And Demand Through Digital Platforms

Refashion, the French accredited Extended Producer Responsibility eco-organisation, has developed the Recycle platform, a digital waste mapping and matchmaking tool focusing on post-consumer household textile waste. It provides detailed overviews on non-reusable textiles and footwear feedstock, recycling solutions and key stakeholder profiles throughout the European textiles recycling value chain. With its cross-industrial approach opening up end markets beyond textile-to-textile recycling, Recycle by Refashion provides a stepping stone to accelerate the industrialisation of recycling solutions in Europe. This project facilitated the introduction between Reverse Resources and Refashion Recycle to the six European sorters involved. Reverse Resources have 39 active recyclers and 32 active waste handlers/sorters on their platform, while Refashion Recycle have 103 recyclers and 66 sorters onboarded onto their platform. This represents a large portion of the European circularity industry.

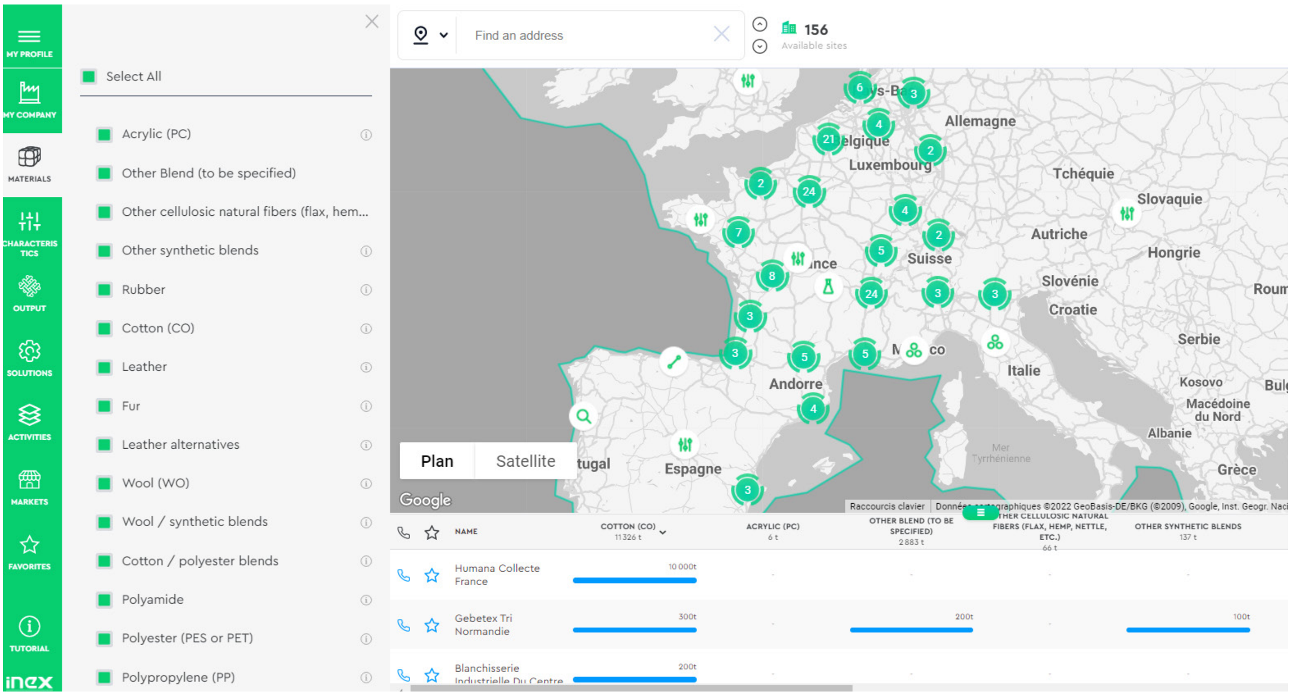

Image 7: Refashion Recycle digital platform (Source: Refashion)

Conclusion and Recommendations

2,116,000 tonnes of PCT are collected each year in Belgium, Germany, the Netherlands, Poland, Spain, and the United Kingdom, the focus countries of this Project. Clothing and household textiles represent 81% (1,713,960 tonnes) of the total volume collected by textile collectors in the focus countries, as the remaining 11% is footwear and 8% are waste textiles and other contaminants. The availability of PCT is expected to continue growing in the coming years, with the updated legislative directives on separate textile collection across the EU.

Sorters participating in this Project indicated 49% of collected PCT are considered fit for the domestic or global second-hand market ('rewearables'), 6% rewearables with low market value, 26% non-rewearable, 11% footwear and the remaining 8% is waste. Currently, the most common destinations for their non-rewearable textiles are as wipers (10% of the total volume sorted), for downcycling (14%), for fibre-to-fibre recycling (2%) and the remaining to other minor destinations like refurbishment or incineration (0.1%). 7% of the Fraction not suitable to be redirected to fibre-to-fibre recycling as they are multilayered items.

From the remaining amount, the most prevalent composition found is cotton (42%), albeit elastane might be present in a relevant share of this category. Cotton is followed by a large presence of material blends (29%) of which a considerable share is made up by polycottons (11%). The breakdown by composition of this analysis differs quite significantly from the global share of fibres put on the market for some materials, such as polyester. This may be attributed to numerous reasons, namely the fact that no workwear or technical textiles are usually found in collected PCT from households, that there is a considerable timespan between consumption of textile items and their disposal, as well as diverging consumption preferences and disposal behaviours depending on fibre types.

74% of the PCT in the Fraction have been found suitable for recycling and fitting current specifications of mechanical and chemical recyclers. This means that 494,000 tonnes of textiles, 23% of the 2,116,000 tonnes of PCT collected each year in the focus countries, has the potential to be redirected to fibre-to-fibre recycling.

However, this potential is currently complex to capitalise on; feedstock prices for current destinations (e.g. wipers) are more economically viable than those offered for fibre-to-fibre recycling . However, this might change as current recycling technologies are scaled and further investment is made in order to integrate operations related to automated sorting and removal of disruptors to the sorting process. Overall, a sound business case is required in order to retain sorting capacity in Europe.

To support the retention and further development of this sorting capacity in Europe, policy and upcoming legislation will play a key role in ensuring the environmental, social and financial sustainability of these stages of the clothing and textiles value chain.

The following recommendations build on the outcomes of this Project and seek to inform sectoral and governmental stakeholders on the implications of these results in the road towards circularity:

- **As the industry intends to transition to a closed loop system, increased attention should be given to design products for recyclability.** This Project finds that 74% of the Fraction could be used as feedstock for recycling. Whilst this is a considerable share, this still leaves 26% without a circular destination due to their composition, the presence of multiple layers and/or non-removable disruptors. This issue could be tackled both from the perspective of individual businesses, including design and product departments, but also through the development of mandatory ecodesign requirements and criteria under the Ecodesign for Sustainable Products Regulation that consequently inform eco-modulation fees for EPR systems.

- **While considering designing for recyclability on the one hand, brands and manufacturers should not forget to prioritise designing for appropriate lifecycles**. Hence, products that are designed for longevity should have a strong focus on durability and longevity. Products designed for cyclability and shorter life cycles should prioritise design choices that help prepare these products for effective reuse and recycling. Ultimately, recycling should be a last resort for textiles, in accordance with the waste hierarchy, and not a goal in itself.

- **The handling costs of non-rewearable and low-value rewearable textiles currently puts pressure on the business case of textiles sorters.** The uptake of these textiles as feedstock for fibre-to-fibre recycling is essential to increase prices offered for these textiles and improve the sorters' business cases, given prices paid for feedstock are at least equivalent to the sales income currently generated with PCT. Textile collection and sorting is a labour intensive process, and costs connected to these activities need to be taken into account in the determination of prices for feedstock for recycling. The business case for sorting PCT to become feedstock for recycling does not (yet) allow for a return on investment in technologies required for automated sorting and hardware removal. Therefore, the creation of this infrastructure to sort for circularity requires collaborative investments of public and private value chain actors.

- **Sorting activities in European countries are at risk of being unable to continue their business as usual if the share of these lower value textiles in volumes collected continues to increase.** An increased dependence will be created on sorters abroad to handle textiles collected if the business case for textile sorting in Europe cannot be sustained (55% of textiles collected in focus countries are already sorted abroad). The introduction of EPR could alleviate pressure on the business case for sorters to handle future volumes of collected textiles, yet financial support now considered in some of the focus countries does not make up for future losses for sorters caused by the declining value of textiles collected. The true business case for sorting for circularity, or the lack thereof, should be considered in the design and implementation of upcoming EPR schemes across Europe.

- **Whilst a considerable amount of PCT was analysed in this Project, it will need to be replicated in focus countries and beyond to create even more reliable insights into the characteristics of post-consumer textiles and their suitability for recycling**. Extending the analysis to rewearable textiles as well as those found in household waste will further increase understanding of consumer behaviour and material flows. The use of NIR enables the efficient analysis of textile composition but has its limitations. Further improvement of the reliability of NIR and the addition of cross-checks with care labels and lab tests could enhance the robustness of findings of future similar analyses. Moreover, the Horizon Europe Programme has recently funded a Textile Recycling Excellence (T-REX) project including key stakeholders in the European textile sector, such as brands, waste collectors, sorters, and recyclers. This project aims to create a blueprint in Europe for creating new business opportunities based on closed loop textile recycling using post-consumer household textile waste as new feedstock and harmonise quality criteria for the various stakeholders, such as sorters and recyclers.

- **Finally, as a consumer, take into account that the purchase and disposal choices you make also have an influence on the end of life of these textiles.** As far as possible, try to prioritise purchases of mono material products, or blends limited to two compositions. Remember that aesthetic trims and accessories such as sequins or strass do pose a challenge for multiple recycling technologies. As a citizen, follow the instructions from your municipality to correctly dispose of your clothing and home textiles. Try repairing, reselling and swapping as activities to extend the lifetime of your products. When you are ready to dispose of them at the end-of-use, do it according to the provided local guidance —whether through bring banks, in-store or kerbside collection.

Annex I - Sorting Analysis Methodology

The composition analysis for the Sorting for Circularity Europe project was conducted in three phases: Preparation, Implementation and Reporting. An overview of the approach and methodology involved in each phase can be found below.

PREPARATION

Image 8: Matoha NIR handheld scanner (Source: Matoha)

Co-creation of research methodology for on the ground analysis
The methodology for the on-the-ground research builds on the process used in a previous study by TERRA to map textiles in France, within their research commissioned by Refashion.[77] In close collaboration with TERRA, this methodology was adapted and fine-tuned to the analysis scope of the Sorting for Circularity Project, relying on the participation of sorting facilities for its implementation.

Translation of methodology to operational protocols per sorting facility
Based on in-depth interviews with each of the participating sorting facilities, an operational protocol has been established for each of them. This protocol is a specification of the overall methodology that reflects the internal configurations of the sorting facility. As all sorting facilities categorise textiles into different fractions, the protocol describes on an individual basis which fractions will be used for the analysis.

Annex I - Sorting Analysis Methodology

Preparation of the data collection templates
Circle Economy and TERRA, in collaboration with Fashion for Good and participating sorters, have created the data collection template that was used in all on the ground analyses. Data was collected using an NIR scanner and an app on an electronic device (ie. tablet). Together with the supplier of the NIR scanners and app, the correct configuration for the analysis equipment was determined and developed.

Testing and refining the methodology and schedule through a process dry-run
The process for the on the ground analysis has been tested at small scale with one of the participating sorters to assess whether the process is clear and the app used allows for accurate and complete data to be captured. Besides, this dry-run has informed sorting facilities on the capacity required to analyse items, since the use of the NIR scanner and app will reduce the volume a sorter can process per hour. Learnings from the dry-run have been shared with all participating sorters, and the methodology has been adapted where needed.

Training sorters (and/or students) for NIR device use
Sorters and/or students that will participate in the on-the-ground composition analysis during the Implementation Phase were trained in the use of the NIR device and the input of information to the app. This entailed up to one hour training at each participating facility (or warehouse) where the analysis took place, at the start of the first composition analysis round.

IMPLEMENTATION

Image 9: Composition scan using Matoha NIR handheld scanner (Source: Matoha)

Annex I - Sorting Analysis Methodology

Once the preparatory phase was completed, the on-the-ground analysis at sorting facilities started. The analysis followed the following standardised process:

Workplace preparation

The sorters (and/or students) conducting the analysis needed to be able to scan garments using an NIR hand scanner, and log additional information using an electronic device like a tablet or smartphone provided by Fashion for Good. The workplace had to allow sorters to use this equipment. It was crucial that textiles were only analysed once, so there had to be a clear workspace distinction between not yet analysed and analysed textiles to avoid double-counting.

Provision of materials

Each sorting facility identified the fractions in scope for analysis with origin in the focus country from representative collection sources prior to the start. This selection was predefined bilaterally and agreed upon by the sorter and Circle Economy, in coordination with TERRA. This was a representative sample of the fractions in scope, however, the exact distribution of the tonnage over the different categories each sorting facility sorts into, as well as the baling volumes and structure of operations at each facility were the key parameters for this definition. In case multiple bales from one fraction were selected from storage for this analysis, non-subsequent bales had to be selected to maximise their representativeness.

Capture of garment characteristics

The on the ground analysis consisted of two main activities:

- The garment was scanned by a sorter/student using the NIR handheld device, to assess its composition. In case the garment consisted of different fabric types or layers, these components were scanned separately.
- Other characteristics of the garment like product type, age group, colour and presence of disruptors were captured in the app on the electronic device through a short predefined multiple choice survey.

The first hour of the analysis was used to calibrate the NIR scanners, train sorters to use the App correctly and get up to speed. Throughout the first hour the process and workplace were adjusted to maximise the process efficiency and output capacity. Once things were going smoothly, the process was repeated for the available time.

Quality control

Throughout the on-the-ground analysis, a representative from TERRA and/or Circle Economy verified that the implementation of the process was in line with the predefined methodology. These external representatives executed labels-based checks in case the NIR scanners did not capture the fibre composition. Cross-checks were executed in case the composition indicated by the scanner was questioned by the sorter, in which case the label information was mostly used for the analysis. Materials that were often not well recognised are described in Annex II of this report.

Student participation

If needed, sorting facilities could invite students to participate in the on the ground analysis to complement the sorters and increase capacity. Students were selected in close collaboration with Circle Economy, and received the same training as the sorters staffed on the analysis to ensure they have the competences to provide reliable, comparable data.

Annex I - Sorting Analysis Methodology

DATA EXTRAPOLATION

Conversion from data points into weight equivalents

The sample data was collected in .csv format and anonymised (sorting facility and fraction name) before further use. The feedback from the on-the-ground team on data points to remove or modify was incorporated into the database. The on-the-ground analysis gathered data per item, whilst this Project explores potential volume available for fibre-to-fibre recycling. Data points were converted into weight equivalents using average weight estimates per product type and product age group (listed in Annex III). Data points without a product type or product age group were removed from the data set as they could not be translated into weight equivalents.

Extrapolation to country level volumes

The sample data was extrapolated to country level volume estimates, using weight data from textiles collected in the focus countries available through prior literature.[78] Since a similar amount of items was analysed for each of the product categories, whilst in reality the categories can differ considerably in size, a multiplier was determined per country, per product category to generate a dataset that is representative of a sorter's reality. A multiplier indicates the amount of times the characteristics of one item were used to generate an estimate on the composition of country level volumes. For instance: an item weighing 0.250 kilo with a multiplier of 33,000 would account for 8,250 kilo in the country level volume. The table below lists the average multiplier per country and the range of multipliers used for underlying product categories.

Focus Country	Volume Collected (tonnes/year)	Average Multiplier (-)	Multiplier range (-)
Germany	1,000,000	43,193	3,015 - 173,400
United Kingdom	650,000	26,258	10,655 - 47,602
Netherlands	136,000	26,626	2,553 - 70,710
Poland	131,985	10,034	588 - 18,251
Spain	108,300	8,757	757 - 35,641
Belgium	90,000	7,158	152 - 15,691

TABLE 2: DATA EXTRAPOLATED TO COUNTRY LEVEL VOLUMES. SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

Annex II - Study Limitations

Whilst NIR scanners allow for the automated recognition of the composition of textiles, the outcomes of this Project have been prone to human error. Data from the scanners were complemented with information of other characteristics of the textile product using an app. In the first round of the on-the-ground analysis, data inserted into the app had to be cleared after saving which was forgotten at times leading to characteristics of one item (like fraction, product type, presence of disruptors, and colour) being copied to a next one. On-the-ground quality controllers were available to ensure data was inserted adequately or corrected afterwards, but human errors certainly occurred throughout the data collection.

The conversion from data per item to a volume equivalent was based on average weight per product type, instead of each item's actual weight. To maximise the volume that could be scanned in the time available for this Project, scanned items were not weighed individually. The product type and age group was captured per item using the App. The composition and characteristics were translated to a volume estimated based on average weight per product type, per age group. The average weights used were based on estimates received from textile retailers and data from Refashion93, resulting in the average weight per product type shown in Annex III. The overall gap between the weight actually scanned and the estimated weight used is +6%. Saved items without a product type or age group were deleted from the sample as no reliable weight could be associated with the product. The weight of multi-layered items was equally attributed to both layers. As multi-layered items were excluded from the sample used to calculate feedstock availability this limitation does not affect the study outcomes.

NIR-based technologies enable efficient recognition of the composition of textiles, but there are limits to their accuracy. The thickness and colour of fabric scanned as well as presence of coatings and finishes can reduce the accuracy of the composition analysis of NIR scanners94. In this analysis blends were only recognised upto combinations of two fibre types, and fabrics consisting of natural or synthetic leather, linen and PU coated fabrics were not detected by the NIR scanners used. The lack of ability to recognise the presence of elastane is a major limitation of NIR technologies considering the abundant presence of elastane in textiles sold on the market.95 Another limitation is its inability to detect composition when textiles are dyed with carbon black ink.

Feedstock estimates were created by extrapolating the research sample to country volumes: an average extrapolation factor of 33,000 times. This means every item scanned was counted 33,000 times on average to constitute an estimate on the characteristics of PCT in the focus countries. Analysing 21,800 kilos of textiles is a vast endeavour, and whilst this is a considerable research sample its representativity for the total volume of the Fraction (estimated at 673,000 tonnes per year in our focus countries) is limited. Estimates on feedstock volumes per material type can therefore only be considered estimates and should be refined by expanding the sample volume in the future.

Data on the fabric structure (knitted or woven) was not captured in this study. As mechanical recyclers mostly process knitted textiles and denim trousers, feedstock estimates for mechanical recycling in this report are higher than the actual volumes available. Based on product categories, around 14% the volume in the estimated volume of feedstock for mechanical recycling consists of products with woven fabric structures like trousers (non-denim), jackets and coats.

Annex III - Estimates On Average Weights Per Product Type

Product Age Group	Product Name	Average weight (kg)
Adults	Bra-lingerie	0.09
Adults	Coat	1.06
Adults	Costume	0.43
Adults	Demin-jacket	0.71
Adults	Demin-overall	0.67
Adults	Demin-shorts	0.32
Adults	Demin-skirts	0.34
Adults	Demin-trousers	0.51
Adults	Dress	0.18
Adults	Heavy-jacket	0.75
Adults	Home-wear	0.31
Adults	Jumpsuit-overall	0.36
Adults	Light-jacket	0.31
Adults	Polo-shirt	0.25
Adults	Waterproof-rainwear	0.8
Adults	Reflective-Safety	0.58
Adults	Shirt-blouse	0.16
Adults	Shorts	0.2
Adults	Skirts	0.24
Adults	Socks-hosiery	0.03
Adults	Sport-trousers	0.21
Adults	Sweaters-hoodie	0.31
Adults	Swimwear	0.12
Adults	Trousers	0.36
Adults	T-shirt	0.16
Adults	Underwear-bottoms	0.09
Babies	Baby-clothes	0.16
Babies	Baby-underwear	0.16
Children	Bra-lingerie	0.03

Annex III - Estimates On Average Weights Per Product Type

Children	Coat	0.59
Children	Costume	0.26
Children	Denim-jacket	0.45
Children	Denim-overall	0.19
Children	Denim-shorts	0.23
Children	Denim-skirts	0.22
Children	Denim-trousers	0.28
Children	Dress	0.22
Children	Heavy-jacket	0.45
Children	Home-wear	0.34
Children	Jumpsuit-overall	0.21
Children	Light-jacket	0.35
Children	Polo-shirt	0.01
Children	Waterproof-rainwear	0.53
Children	Reflective-Safety	0.35
Children	Shirt-blouse	0.01
Children	Shorts	0.15
Children	Skirts	0.18
Children	Socks-hosiery	0.02
Children	Sport-trousers	0.22
Children	Sweaters-hoodie	0.17
Children	Swimwear	0.06
Children	Trousers	0.22
Children	T-shirt	0.1
Children	Underwear-bottoms	0.03
Other	Fabrics	0.25
Other	Gloves	0.04
Other	Headwear	0.1
Other	Household-linen	0.35
Other	Medium-accessory	0.07
Other	Other	0.35
Other	Small-accessory	0.03

TABLE 3: ESTIMATES ON AVERAGE WEIGHTS PER PRODUCT TYPE. SOURCE: CIRCLE ECONOMY AND FASHION FOR GOOD (2022)

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23 JRC (2021).
24 JRC (2021). In line with Fibersort (2020) RECYCLED POST-CONSUMER TEXTILES: an industry perspective (40-89% European average, 64% North-West Europe average).
25 Fibersort (2020) RECYCLED POST-CONSUMER TEXTILES: an industry perspective. Available here.
26 EUR-lex (2008). Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. Available here.
27 Calculation derived from current per capita collection figures in both Spain and Germany and taking into account expected increase of 220 grams per capita/year, as estimated in JRC (2021) from 2025 onwards. Germany could go from 15.3 kg/capita in 2018 to 17.94 kg/capita in 2030, considering a linear progression of 220 grams per capita/year in a slightly more conservative approach than the German Federal Association for Secondary Raw Materials and Waste Management (bvse e.V.) that proposes 300 grams per capita/year, albeit very much in line with it. Spain could go from 2.3 kg/capita

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in 2019 to 4.72 kg/capita in 2030, considering a linear progression of 220 grams/year.
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31 EcoTLC/Refashion, (2014). Caractérisation des TLC usagés entrant en centres de tri ainsi que des déchets résultant du tri. Available online here.
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54 JRC (2021). Apparent consumption figures.
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60 PCI Wood Mackenzie (2016). In: UN Environment Programme (2020). Sustainability and Circularity in the Textile Value Chain - Global Stocktaking. Nairobi, Kenya.
61 Average garment use based on: Sustainability (2020). Clothing lifespans: what should be measured and how. Available here.
62 Estimate share of polyester in world fibre production in 2017 based on Textile Exchange Preferred Fibers and Materials Report (2018). Available here.
63 Due to the limited ability of NIR-scanners to detect elastane, a large share of the volume classified as pure cotton in this Project most likely contains elastane.
64 Items containing sequin and lurex threats were classified as containing "metal disruptors". These disruptors are not removable. Therefore the share of non-removable textiles is in reality slightly higher than the 49% represented here.
65 Mechanical recyclers mostly process knitted fabric structures. This study did not capture data on fabric structures. Based on product categories, 14% of the feedstock for mechanical recycling most likely consists of textiles with woven fabric structures.
66 Due to the limited ability of NIR-scanners to detect elastane, a large share of the volume classified as pure cotton in this Project most likely contains elastane.
67 The colour pink was omitted in the research and traced as 'red'.
68 McKinsey (2022). Scaling textile recycling in Europe—turning waste into value. Available online here.
69 Due to the limited ability of NIR-scanners to detect elastane, a large share of the volume classified as pure cotton in this Project most likely contains elastane.
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71 JRC (2021).
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77 EcoTLC/Refashion, (2014). Caractérisation des TLC usagés entrant en centres de tri ainsi que des déchets résultant du tri. Available online here.
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