European Commission

Fate and Composition of Textile Waste from Italy, the Czech Republic and Romania

Bakowska, O., Mora, I., Walsh, S., van Duijn, H., Novak, M., Cherubini, G., Joshi, R., Morbiato, A., Visileanu, E., Veselá, A., Ryšavá, E., Holicky, M.

Huygens, D. (editor)

2025

Joint Research Centre

Contact information

Name: Name: European Commission - Joint Research Centre
Email: JRC-WASTE-RESEARCH@ec.europa.eu

EU Science Hub

https://joint-research-centre.ec.europa.eu

JRC141441

PDF   ISBN 978-92-68-25278-9   doi:10.2760/3332076   KJ-01-25-156-EN-N

Luxembourg: Publications Office of the European Union, 2025

How to cite this report: European Commission: Joint Research Centre, Bakowska, O., Mora, I., Walsh, S., van Duijn, H., Novak, M., Cherubini, G., Joshi, R., Morbiato, A., Visileanu, E., Veselá, A., Ryšavá, E. and Holicky, M., *Fate and Composition of Textile Waste from Italy, the Czech Republic and Romania,* Huygens, D. editor(s), Publications Office of the European Union, Luxembourg, 2025, https://data.europa.eu/doi/10.2760/3332076, JRC141441.

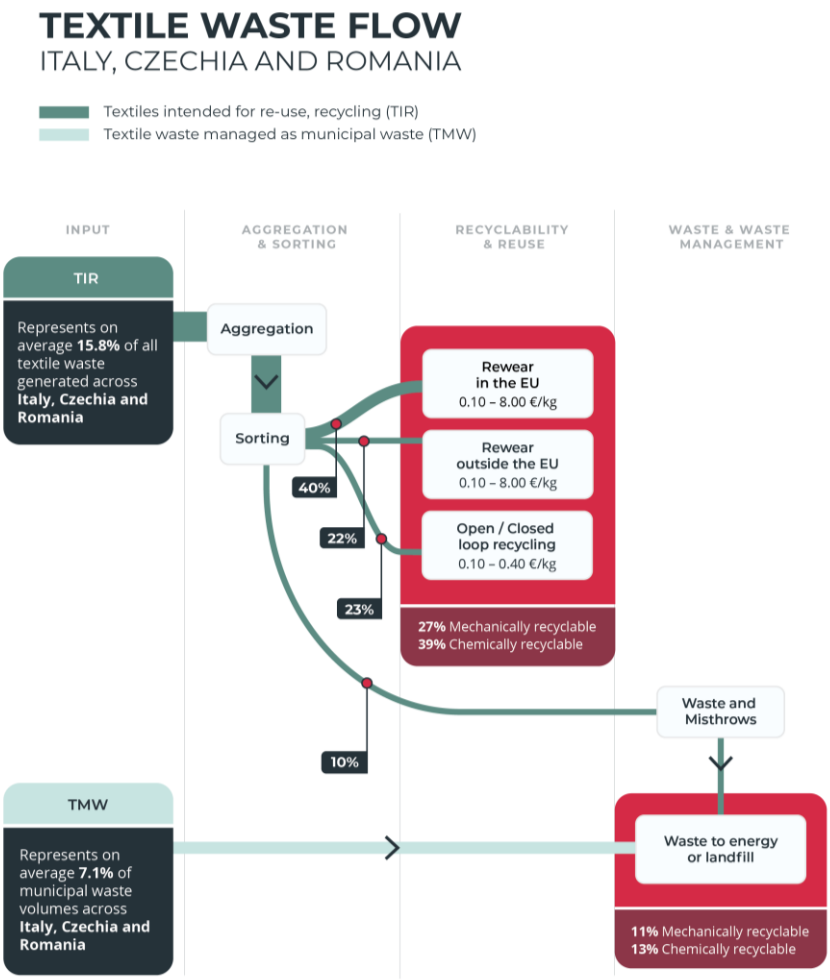
Contents

Abstract

This study investigates the characteristics of post-consumer textile (PCT) waste collected separately as well as disposed of in municipal waste in terms of its reusability and recyclability. The geographic focus of this study is on previously under-researched EU Member States in South and Eastern Europe. An international consortium of partners collected 18 tonnes of waste from three countries: the Czech Republic, Romania, and Italy (with separately collected Italian textile waste being sorted in Bulgaria) between November 2023 and June 2024. Currently, literature provides limited information on the quantities and qualities of textile waste in these areas. However, it is urgently needed due to the increasing volumes of PCT waste being disposed of and separately collected across Europe and the pressing need to enhance sustainable waste management practices.

The study findings show that textiles intended for re-use and recycling are mostly sorted for re-wear in the EU (40%), with further equal shares (22% - 23%) for re-use outside the EU and open/closed loop recycling (Figure A1).

Figure A1: The current fate and recyclability of textiles intended for re-use and recycling (TIR) and textiles ending up in mixed municipal waste (TMW) (input and recyclability data are an average of measured samples collected from waste management and textile sorting facilities in Italy, the Czech Republic and Romania; volumes and prices are interview-based information collected at the same facilities).



Source: Own work.

It was assessed that most (~75%) textiles exported for reuse outside the EU are without noticeable defects. However, a significant portion, approximately 25%, does have noticeable defects. The share of local re-wear in the EU is higher than previously reported, suggesting different sorting standards applied in East-Europe than in other EU regions. On average, >65% of these textiles are mostly fibre blends or cotton-rich materials, and have a composition that would enable mechanical or chemical fibre-to-fibre recycling from a technical perspective.

On average 7.1% of textiles by volume were found in mixed municipal waste samples (TMW), with up to 14% of the mixed municipal waste consisting out of textile waste in Romania. This share that is higher than the commonly assumed 5-6% based on studies in West-European Member States. Hence, local re-use (see above; up to 40% on average) may not necessarily lead to a long-term reduction in textile waste, particularly when involving low-value textiles end up ultimately in mixed waste. These findings suggest that a proper sorting up to acceptable quality standards is an essential element for sustainable textile waste management. The textile waste ending up in mixed waste also represents a limited potential for re-use (below 10%) and recycling (24.5%) (Figure A1), but pre-treatment and the separation of non-textile fractions in the waste may further increase recyclability.

This study concludes that the material composition of PCT makes it a largely recyclable stream. Hence, waste characteristics are not a barrier to enable an environment for the capturing and the processing of the increased volumes of textile waste into recycled fibres for apparel, or other open and closed-loop recycling techniques. However, proper sorting at the household and sorting centre level are paramount for further increase feedstock availability for recycling.

Acknowledgements

Circle Economy Foundation wishes to acknowledge their

Research Partners

- **Fashion for Good** acted as a Methodology development partner, who did quality control & coordination with past and ongoing Sorting for Circularity projects.

  Fashion for Good is a platform that supports disruptive innovators on their journey to scale, providing access to funding and expertise, and collaborations with brands and manufacturers to accelerate supply chain implementation.

- **Matoha Instruments Ltd**. is a NIR technology provider that acted as a data collection partner that provided Matoha Fabritell devices alongside scientific and engineering expertise to support the data collection.

Country Leads

- **INCIEN** is a Circular Economy Institute in the Czech Republic, which acted as a Czech country lead and worked with Czech facilities. The organisation brought invaluable experience in municipal solid waste analysis, as they have conducted over 70 analyses of mixed municipal waste in the Czech Republic.

- **INCDTP**, The National Research and Development Institute for Textiles and Leather in Romania, acted as a Romania country lead who worked with Romanian facilities and created a functional network of local actors. INCDTP brought invaluable experience in textile research and engineering.

- **Humana People to People Italia S.C.a r.l.** acted as Italy's country lead and an industrial partner with a functional network of textile collection and sorting facilities in Italy and Bulgaria.

  With Italy being in the top six global importers of second-hand textiles and Humana People to People being the biggest textile waste collector in Italy, it was essential to expand their team capacity for NIR-enabled sorting.

  Humana collects, sorts and sells second-hand clothes and supports development projects across Africa, Asia and Central and South America.

Industrial Partners

- **Diakonie** - TIR partner in Czech Republic

  Diakonie employs approximately 100 people, processes 25 tonnes of textiles per day and 400 to 500 tonnes per month. According to the requirements of customers and end users, Diakonie sorts into up to 200 grades, both by product type and material.

- **COMPAG Group** - TMW partner in the Czech Republic

  COMPAG group is part of the multinational Austrian concern BRANTNER and has been operating in the Czech market since 1993, handling over 100 different types of municipal waste across 6 companies in Mladá Boleslav, Votice and Mimon. It provides a wide range of services in more than 150 municipalities and for more than 2,000 companies.

- **HUMANA People to People Italy** - TIR partner in Italy

  Humana Italy is a humanitarian organisation supporting international cooperation since 1998 and the biggest textile waste collector in Italy with a network of 5,000 collection containers in 1,200 Italian municipalities. The surplus from the sale of the clothes within 15 stores in Italy goes towards funding international development cooperation and social awareness activities in Italy.

- **HUMANA People to People Bulgaria EOOD** - TIR partner processing Italian textiles in Bulgaria

  Used textiles collected in Italy are sorted in both Italian and Bulgarian Humana facilities. Half of the volumes in the Bulgarian facility are of Italian origin.

- **Iren S.p.A.** - Italian TMW partner

  Iren S.p.A produces energy and offers a variety of energy, water and environmental services with excellent sustainability credentials. Serving 418 municipalities, it manages over 3.7 million tonnes annually in 53 material recovery plants, 3 waste-to-energy plants and 4 landfills. Iren achieved 70% of collected municipal waste collection in Emilia-Romagna, Liguria and Piedmont, above the national average of 64%.

- **SC 3R Green SRL** - TMW partner in Romania

  S.C. 3R Green S.R.L. is a waste management company with full Romanian capital centred around the principles of the circular economy. Hiring over 120 professionals, it carries out collection, transport and sorting of municipal waste from Giurgiu, Ilfov and Bucharest counties. Sorting facilities in Chitila and Popești Leordeni, handle bulky waste, and sort 8,000 to 11,000 tonnes of recyclable waste at source into paper, plastic, glass and WEEE from Giurgiu, Ilfov, Dâmbovița, Mureș and Bucharest.

- **GDSACP Sector 6** - TIR partner in Romania

  The General Directorate of Social Assistance and Child Protection of the Municipality of Bucharest and the General Directorate of Social Assistance and Child Protection of Sector VI-Bucharest led by SocialXChange acted as a TIR analysis partner for the INCDTP team. The GDSACP aims to ensure the application of social assistance policies and strategies in the Municipality of Bucharest, in the field of child and family protection, single and elderly persons, or persons with disabilities.

  One of their activities is the collection of used clothes with over 800 tonnes collected annually, of which 730 tonnes were donated, and the rest are still in storage and will be donated.

Authors

Authors (Circle Economy)

Ola Bakowska, Irlanda Mora, Saoirse Walsh

Contributing Authors

Hilde van Duijn (Circle Economy), Marijana Novak (Circle Economy), Giorgia Cherubini (Circle Economy), Richa Joshi (Circle Economy), Alessandro Morbiato (Humana People to People Italy), Emilia Visileanu (INCDTP Romania), Andrea Veselá (Incien Czechia), Eva Ryšavá (Incien Czechia), Martin Holicky (Matoha Instruments Ltd)

Editor (Joint Research Centre)

Dries Huygens

Executive summary

Policy context

The European Commission is driving changes in the European Union (EU) policy landscape by adopting the EU textile strategy for sustainable and circular textiles[1]. Next to it, voluntary commitments continue to grow as one of the key drivers of the transition to the circular industry.

These developments are expected to increase the demand for post-consumer textile (PCT) collection, sorting and recycling across the EU. Although, there has been a surge of recycling innovation technologies, an investment of €6-7 billion is estimated to still be required by 2030 to scale the industry's ability to recycle 18-26% of gross textile waste in Europe[2]. The investment needs include further developing chemical and mechanical recycling as well as pretreatment activities.

To help unpack the waste flow challenge and to increase our understanding of its impact on the EU this technical study was undertaken. Furthermore, it can inform future investments by providing in-depth information on the post-consumer European market, available textiles and their characteristics.

Key conclusions

The main technical consequences arising from this report circle around the characterisation of post-consumer textile waste in terms of quantities and composition. This information may be useful to create an enabling environment for capturing and processing increased volumes of textile waste for the manufacturing of recycled fibres or other open and closed-loop applications.

The study lists essential and recommended preparation for re-use steps (Sorting for Re-use) and preparation for recycling steps (Sorting for Recycling). These include (i) removing all foreign materials and all significantly soiled and polluted textiles including textiles visibly wet, or otherwise significantly mutilated, and (ii) sorting used and waste textiles into main categories and quality grades considering the cultural fit and other market criteria. Sorting for recycling ought to be focused on items that represent limited value on the second-hand market, are made of one layer of material, or multiple layers of the same material, are not covered in waterproof treatment, coating or excessive accessories. Such process should focus on classifying materials aligned to material and fibre composition and colour.

Separate textile collection

With existing policy measures requesting separate collection of textiles, we can effectively expect an increase in textiles intended for re-use and recycling collected. The comparison of municipal waste samples in regions with and without the separate collection in place analysed, suggests that even after setting up separate collection, a non-negligible share of textiles is found in the mixed municipal waste stream. On average 7.1% of textiles by volume were found in mixed municipal

[1] EUR-LEX (2022). EU strategy for sustainable and circular textiles. Retrieved from [European Union website]

[2] McKinsey, 2022. Scaling textile recycling in Europe-turning waste into value. Available at: https://www.mckinsey.com/industries/retail/our-insights/scaling-textile-recycling-in-europe-turning-waste-into-value.

waste samples analysed. Specifically, on average 6.4% of textile waste was found in regions with separate collection systems and 14.5% without. The highest amounts of textile waste were found in samples from Romania. The organisations located Italy, The Czech Republic and Romania participating in this study struggle with increasing textile waste collection rates as without subsidies, the business case for upscaling the collection of used textiles is limited and relies on the volumes that can be sold on domestic and international second-hand markets.

Sorting for recycling

The main revenue streams for sorters are the rewearable textiles sold on second-hand markets in Europe. The non-rewearable textiles represent a gross cost, and currently, there are no incentives to establish at scale fibre sorting and disruptors-removal solutions to transform non-rewearable textiles into feedstock for closed-loop recycling. While this study shows that post-consumer textiles represent a highly recyclable waste stream, the business case for sorting for recycling and processing used textiles to become feedstock for recycling is negative for multiple reasons.

Hence, the overview of feedstock sources that recyclers rely on today is mainly post-industrial and pre-consumer textile waste, which are more homogeneous in composition and require less pre-processing than PCT. To increase the circularity of the industry and enable economies of scale for re-use and recycling all stakeholders need to move beyond that.

Main findings

A clear conclusion that emerges is that the material composition of PCT makes it a largely recyclable stream but there is a noticeable gap between its theoretical recyclability and practical implementation (Figure 1).

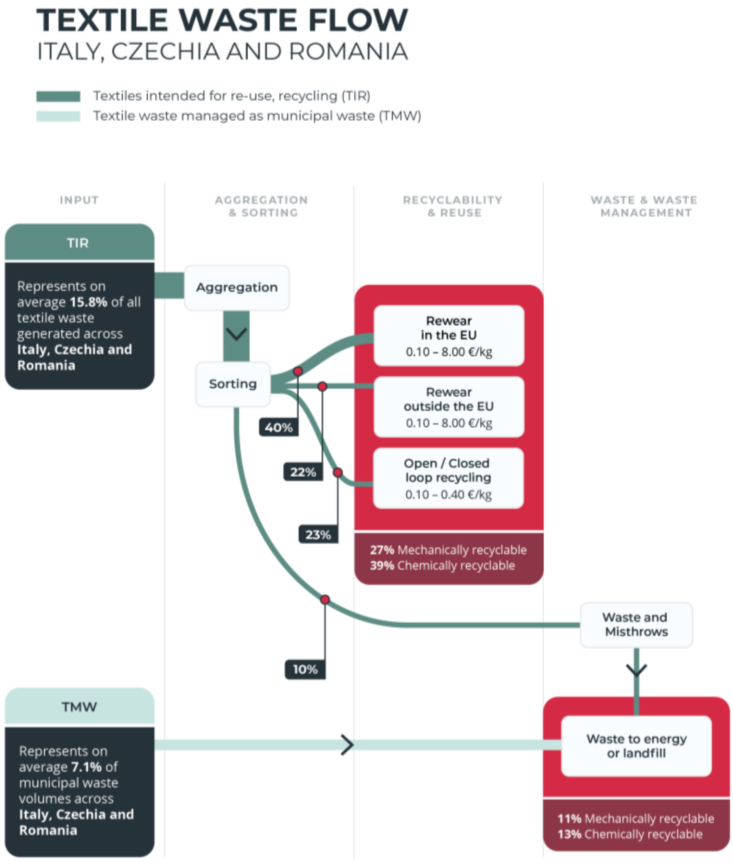
In terms of material composition, in general, the compositions are similar across re-wearable and non-re-wearable fractions with other blends and 100% cotton garments representing the biggest share in all the samples, followed by polyester and polyester-rich blends and cotton-rich blends. Pure (100%) cotton garments represent up to 26% of the fraction sorted for recycling and is below 20% in all other fractions, going down to as little as 12% by volume of the fraction for energy recovery and disposal. More than 95% Polyester garments represent on average 23% of the fraction for energy recovery and disposal but only 9% of the fraction sent to recycling today. Other blends make up an important share of the reusable fraction destined for non-EU countries (33%).

Textiles present in the mixed municipal waste represent an extremely limited potential for re-use (below 10%) and certain potential for recycling (24%) (Figure 1). Nonetheless, in line with previous research, 66% of the TIR sample was classified as recyclable upon pre-processing.

The average prices for sorted textiles identified across researched countries are between 0.1 – 8.0 €/kg and between 0,1 - 0,4 €/kg for recyclable feedstock (Figure 1). With respect to the financial value of these textiles, it must be recognised that both the second hand and recycling are characterised by high volatility and fluctuations in prices and markets. Textiles sorted as not suitable for re-use are sent towards open and closed-loop recycling or end-of-life processing, but the ultimate factor determining the management route remains the selling price.

While these are substantial quantities sorted and characterised, the conclusions of this study should be interpreted with caution. Local differences in citizen’s engagement in sustainable waste management and sorting standards may be evident across multiple seasons, sampling locations, and over an increased period of time that could not be captured in this study.

Figure 1. Schematic overview of the proposal distribution and fate of textiles intended for re-use and recycling (TIR) and textiles in mixed municipal waste (TMW), averaged over the samples collected in Italy, the Czech Republic and Italy. Recyclability results from all the TIR and TMW samples are based on observed and measured characteristics, while the estimated volumes and prices are interview-based information collected from waste management and textile sorting facilities in the Czech Republic, Romania and Italy.



Source: Own work.

Related and future JRC work

This work further complements JRC studies on textile waste[3,4].

Quick guide

This study applied an empirical and validated methodology through a scalable train-the-trainer approach to quantify textile waste characteristics in strategic and under-researched EU Member States in South and Eastern Europe. The research collected data in sorting and municipal waste facilities that was further classified and contextualised by the Circle Economy team to bring new findings about textile waste recyclability and management in the EU.

[3] https://publications.jrc.ec.europa.eu/repository/handle/JRC134586

[4] https://publications.jrc.ec.europa.eu/repository/handle/JRC125110

1. Introduction

1.1. Used and waste textile management in the EU

According to EEA data, the European Union generated around 6.9 million tonnes of textile waste in 2020 – around 16 kg per person.[5] Only 4.4 kg of this is collected separately and has the potential to be repurposed via re-use or recycling, with around 11.6 kg per person ending up in mixed household waste.[6] Hence, a majority (73%-87%)[7,8] of the used and waste textiles is incinerated or landfilled.

The disposal of textiles is ultimately driven by an escalation in production and overconsumption: while the average consumer buys 60% more items today than 15 years ago, these are kept for half as long on average.[9] Moreover, the socio-environmental impacts of the industry are vast. The industry accounts for 2 – 8 % of global carbon emissions, and textiles account for approximately 9% of annual microplastic transfer to the ocean[10].

Currently, textile re-use rates in Europe remain low with the average citizen mostly consuming new textiles per year[11]. Research suggests that Danish citizens are most likely to buy second-hand, but still 83% of them buy new textiles without considering second-hand clothing as an option.[12] Even so, the market demand for re-use is growing significantly, with a 22% estimated annual growth rate[13] and the re-commerce market, valued at 16 billion euros in 2021 was expected to double between 2017 and 2025.[14] However, existing consumer behaviour research suggests that it is unlikely that the increased consumption of second-hand clothing is replacing new textiles; rather these two consumption streams may operate in parallel.[15]

Addressing these complex and interrelated issues demands a range of proactive and creative solutions. While it is crucial to curb overproduction, there is also a fundamental need to shape innovative, economically viable solutions for textile re-use and recycling.

---

[5] European Environmental Agency. (2024, May 21st). Management of used and waste textiles in Europe's circular economy . EEA. Retrieved from: EEA website.

[6] European Environmental Agency. (2024, May 21st). Management of used and waste textiles in Europe's circular economy . EEA. Retrieved from: EEA website.

[7] Huygens, D., Foschi, J., Caro, D., Patinha Caldeira, C., Faraca, G., Foster, G., Solis, M., Marschinski, R., Napolano, L., Fruergaard Astrup, T. and Tonini, D., Techno-scientific assessment of the management options for used and waste textiles in the European Union, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/6292, JRC134586.

[8] European Parliament. (2020, December 29th). The impact of textile production and waste on the environment. European Parliament. Retrieved From: EP website.

[9] UNEP. (2019, March 14th). UN Alliance For Sustainable Fashion addresses damage of 'fast fashion'. United Nations Environment Programme. Retrieved from: UNEP website.

[10] UNEP (2022, February 17th) Inside the clean seas campaign against microplastics (no date) UNEP. Retrieved from: UNEP website.

[11] Gray, S. (2017) Mapping clothing impacts in Europe: the environmental cost. WRAP & ECAP. Retrieved from: WRAP website.

[12] Gray, S. (2017) Mapping clothing impacts in Europe: the environmental cost. WRAP & ECAP. Retrieved from: WRAP website.

[13] Consultancy.eu. (2024, April 5th). Europe's booming second-hand market to reach €86 billion by 2028. Retrieved from: Consultancy.EU website

[14] Statista. (n.d.). Value of the second-hand fashion market in the European Union (EU) from 2017 to 2025. Retrieved from: Statista website.

[15] Sandin, G. and Peters, G.M. (2018). Environmental impact of textile re-use and recycling – A Review. Journal of Cleaner Production. Retrieved from: ScienceDirect.

Based on data mostly collected from Northern and Western EU Member States, textiles intended for re-use[16] and recycling (TIR) are largely being exported to global second-hand markets. The volume of reusable textiles being exported from the EU has tripled over the last two decades, from slightly over 550 000 tonnes in 2000 to almost 1.7 million tonnes in 2019.[17] This reusable fraction accounts for around 54% of separately collected textiles, while 32% are recycled through open-loop recycling processes, i.e. being transformed into lower-value products for different industry applications, such as wipers, or insulation.[18] Only between 1 and 2% of separately collected textiles are currently recycled into new clothes.[19,20] Several barriers hinder the large-scale implementation of textile re-use and recycling, including desirability, economic viability, quality concerns, and performance requirements.[21]

1.2. A need for composition data on used and waste textiles

There are several knowledge gaps regarding the quantity and composition of European discarded textiles. Data on textile waste volumes, flows, and re-use and recycling rates across the EU-27 countries varies across studies and can be unreliable and incomplete. Importantly, there is a significant gap in textile waste reported by municipalities and textile waste estimates based on data from apparent textile consumption[22].

Composition studies in mixed municipal waste, particularly in East- and South-European countries for which no or limited data is available, are required. Gathering this information will be crucial for developing a supportive policy environment to drive textile re-use and recycling in the transition to a circular economy. With most data about textile waste generation, treatment and composition being collected in Western and Northern Europe, this project brings together insights from Eastern and Southern Europe to support adequate policy changes and to respond to the current knowledge gaps.

Composition assessments conducted will help frame the textile waste flow challenges, better estimate the feedstocks available for closed-loop recycling and determine feasible solutions. Furthermore, these assessments will inform future investment by providing in-depth information on the post-consumer European market, and the available textiles, as well as enable building feasible business opportunities via recycling strategies. These assessments must be not only conducted in silos by individual European member states, or regions since only close cross-country collaboration makes visible the challenges and opportunities for building European circular value chains.

[16] In this document, re-use also includes "preparation for re-use" in case the material was classified as waste upon collection (only products can be re-used). "Preparation for re-use" operations involve a quality check to classify the garment as suitable for re-use, which happens during manual sorting.
[17] EEA. (2023). EU exports of used textiles in Europe's circular economy. European Environmental Agency. Retrieved from EEA website.
[18] CBI. (2024). The European market potential for recycled fashion. Netherlands Ministry of Foreign Affairs. Retrieved from: CBI website.
[19] European Parliament. (2020). The impact of textile production and waste on the environment. European Parliament. Retrieved From: EP website.
[20] CBI. (2024). The European market potential for recycled fashion. Netherlands Ministry of Foreign Affairs. Retrieved from: CBI website.
[21] Candido, R.G., 2021. Recycling of textiles and its economic aspects. In Fundamentals of natural fibres and textiles (pp. 599-624). Woodhead Publishing.
[22] Huygens, D., Foschi, J., Caro, D., Patinha Caldeira, C., Faraca, G., Foster, G., Solis, M., Marschinski, R., Napolano, L., Fruergaard Astrup, T. and Tonini, D., Techno-scientific assessment of the management options for used and waste textiles in the European Union, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/6292, JRC134586.

1.3. Research objectives

This study applied a scalable and replicable train-the-trainer approach aiming to expand the validated methodology to geographies that are strategic to the global trade of textile waste and that happen to be currently under-researched (e.g. central and eastern European regions).

Through strategic partnerships established during this study, the methodology was deepened to outline the most prevalent selection criteria for the categorisation of PCT for re-use and closed-loop recycling. The study assessed current management routes of textiles collected separately for re-use and recycling (TIR) and textiles disposed of with mixed waste (TMW) in Italy, the Czech Republic and Romania - three countries that collect and/or process considerable amounts of PCT but remain without public and extensive quantification analyses of waste flows and composition to date.

Potential destinations of TIR as feedstock for closed-loop recycling were identified with an estimation of the volumes that could be redirected from current destinations to more circular ones.

Through this study, local organisations, or country leads were empowered to lead on the ground activities of quantification and characterisation of TIR and TMW. Through a train-the-trainer approach, these organisations became equipped to perform similar analyses beyond the timeframe and budget of this assignment.

2. The management of used and waste textiles in Italy, the Czech Republic and Romania

2.1. Mass flows – literature data and interviews

2.1.1. General overview

This study is conducted with collaborating organisations from the three focus countries. The national counterparts of Circle Economy in this study are Humana People to People in Italy and Bulgaria[23] (a sorter of Italian textiles), INCIEN in the Czech Republic and the National Research and Development Institute for Textiles and Leather in Romania. From the project start and through interaction with local stakeholders, these national counterparts have gathered country-specific data on textile volumes, sorting capacity and any research findings from previous relevant analyses in the TIR and TMW context.

Table 1 presents an overview of TIR textile flows and destinations for the three countries. In total, estimations suggest that 842 ktonne of textile waste are generated in selected countries, primarily in Italy, followed by Romania and the Czech Republic. All countries have collection rates of around 15% for apparel, home textiles and footwear, which is significantly below the European average of 38%[24]. The information obtained from TIR partners represents different dynamics of respective TIR and second-hand markets. The extremely low domestic re-use rates in the Czech Republic (2%) come in stark contrast to Italy (~25%) (Table1), which could be attributed to multiple factors such as the nature of the TIR partner organisation. The documented presence of textile waste within mixed waste (TMW) was at about 5-6% (Table 1).

The information in Table 1 originates from publicly available reports and interviews with industrial TIR partners and makes visible the challenge of mapping current TIR flows in detail and understanding the market dynamics they operate. With four industrial partners interviewed in Romania, this study did not succeed in obtaining the data on prices or exports.

Table 1. Textile waste collection and management routes in focus countries.

	Population	Textile waste generated annually	Textile waste collected separately (TIR, %)	% of textile waste within mixed municipal waste (TMW)	Current management routes (interview-based)	Current prices (interview-based and aggregated)
Czech Republic	10,8 mln[25] (2023)	78 k tonnes (JRC, 2021)	15% (14k tonnes) (JRC, 2021)	6.2%[26] (average between 2016-2021)	re-use in the Czech Republic 2%, re-use outside the EU 25-30%,	Re-use price for different textile grades across the

[23] The Humana facility in Bulgaria sorts textiles collected in Italy and therefore while we will conduct analysis there, Bulgaria is not a focus country of this study.
[24] Köhler et al (2021). EU-27 2020. Excludes the UK
[25] Czech Statistical Office. (2024) Population. Retrieved From: CZSO website
[26] Jonasova S.K., Zoumpalova T., Moldan B. (2022) Analysis of the amount of textile waste in mixed municipal waste in the Czech Republic between 2016 and 2021. Waste Forum, 4, pp. 271-283.

					50% wipers and insulation 5-10%, Charity donation 10%; incineration	focus countries 0,10 - 8,00 €/kg Average price for open loop recycling (wipers) 0,40 €/kg Average price for closed-loop recycling 0,10 €/kg
Italy	58,8 mln[27] (2022)	615 k tonnes (JRC, 2021)	15-20% (277 k tonnes) (McKinsey, 2022)	5%[28] (average between 2014-2019)	Sorted in Bulgaria re-use in the EU 26%, re-use outside the EU 44 %, wipers 11%, closed-loop 12%, incineration 7% Sorted in Italy re-use in the EU 25%; re-use outside EU 40%; wipers 15%, knitwear recycling 10% incineration 5%, RDF 5%	
Romania	19,4 mln[29] (2019)	149 k tonnes (JRC, 2021) and up to 180 k tonnes (McKinsey, 2022)	15% (27 k tonnes) (McKinsey, 2022) - no formal textile waste collection system	no capture rates could be calculated because information on the composition of residual waste is not available[30]	Re-use in Romania 90% Disposal 10%[31]	

Source: Own work, complemented with publically available data as cited in the Table.

Existing analysis indicates that 18% to 26%[32] of textile waste may be suitable for closed-loop recycling by 2030 in the EU, particularly when collection rates of textiles increase to 50 or 80%. Within the TIR fraction analysed in six European countries, consisting of non-rewearables and low-value re-wearables, up to 75%[33] were suitable for closed-loop recycling, upon undergoing a relevant preparation for recycling steps. Currently, recyclers have high feedstock quality standards, as they rely on sorted and clean post-industrial and pre-consumer waste most of the time, rather than TIR and no tests of TMW suitability for recycling are known.

---

[27] Instituto Nazionale do Statistica (2024) Experimental statistic: Municipal demographic projections. Retrieved from: istat.it

[28] EEA (2022). Early warning assessment related to the 2025 targets for municipal waste and packaging waste. Retrieved from: EEA website

[29] Eurostat (2019) Demographic change in Europe — Country factsheets: Romania. Retrieved from: Eurostat

[30] EEA (2022) Early warning assessment related to the 2025 targets for municipal waste and packaging waste. Retrieved from: EEA website

[31] Rates obtained from a small charity collection and sorting partner - DGASPC Sector 6

[32] McKinsey (2022). Scaling textile recycling in Europe—turning waste into value. Retrieved from McKinsey website

[33] van Duijn, H., Papú Carrone, N., Bakowska, O., Qianjing, H., Akerboom, M., Rademan, K., Vellanki, D. (2022) Sorting for Circularity Europe. Retrieved from: Fashion for Good website

2.1.2. The Czech Republic

Czechia generates mixed municipal waste (MMW) above the EU average, and waste prevention measures did not lead to a decrease in volumes following the adoption of the national Waste Prevention Plan that entered into force in 2014. Textile waste generation it is estimated at 78 ktonnes annually of which 15% is separately collected (TIR). At the same time, textile waste in mixed waste (TMW) represents between 3% to 6%, depending on sources. Looking at the exports of used textiles, under the trading code HS6309, they are steadily increasing from 2020, totalling 30 430 tonnes in 2023, while imports were reported at 22 829 tonnes in the same year (mainly from Germany, United Kingdom and Slovakia).

From interviews conducted with the TIR partner in this study, approximately 10-20% of the collected material goes to landfills or incineration, 5-10% is donated to local charity organisations and the rest is sold either as re-wearable clothing or as secondary raw material for further processing. Domestic re-wear was estimated to represent only 2% of the total collection, 25-30% is exported for re-wear to African markets and 20-50% is downcycled and repurposed into wipers, carpets, dusters, or insulation materials. According to the TMW partner, they hand the textile waste over to an authorised textile processing plant. At the same time, it was shared that the cost difference between incinerating textile waste versus mixed waste is minimal (103 €/tonne and 76 €/tonne for textile waste and mixed municipal waste, respectively); therefore, no incentive is indicated for extracting textiles from the MMW.

While the infrastructure for the collection of used textiles has improved significantly over the past few years, with nearly 10 000 textile containers located in the country (~1 container per 1100 habitants). One of the oldest organisations in the field of collection and re-distribution of used textiles is Diakonie Broumov, belonging to the Aretex association, with 972 textile waste containers in all regions of the Czech Republic except for western and southern Bohemia. This facility has partnered in data collection in the TIR analysis in this study. Another successful collector of used textiles is Potex with a network of several hundreds of containers located in the Czech capital and its neighbourhood. Dimatex is also an important player whose main activities are textile collection and redistribution for re-use with over 2,000 containers in the Czech Republic, textile to composite recycling and production of cleaning cloths. Aided z.s. is an independent charitable ecological association that thanks to the donated used textiles, serves people in areas affected by natural disasters in the country and also abroad. The Czech Red Cross and the Salvation Army are also active in the redistribution of used clothing through the TextilEco project. Most of these collection companies are associated with the ARETEX association (Romanian Association of Recycling of Used Textiles). Collection of textiles is additionally provided by companies providing comprehensive waste management services, such as SAKO Brno, a.s. or FCC Czech Republic, s.r.o. There are no textile sorters located in the Czech Republic that are currently a member of EuRic.

On another hand, there are social initiatives like the FOREWEAR project that organise a collection of unwanted clothing from partner company employees to donate them to charity organisations and obtain recycled material that is being turned into textile products, like bags or notebooks, printed with companies' branding.

The Czech Environment Ministry recently announced plans to enforce compulsory textile waste collection from 2025 and that Producers will assist municipalities in bearing the collection costs. Previously, the Czech Republic Waste Management Plan was approved by the Government in May 2022, including the production of textile waste as one of 49 complementary national indicators. Most of the measures stipulated in the programme are in line with the requirements of Article 9 of the Waste Framework Directive and focus on activities supporting and promoting the reduction of waste generation in several sectors, including through effective dissemination of information and awareness programmes.

2.1.3. Italy

The fashion and textile industry is one of the most important industrial sectors for the Italian economy, with about 50 000 active companies and 400 000 people employed. Post-consumer textile waste from the circuit of municipal collections is classified with waste codes EER 20.01.10 for clothes and EER 20.01.11 for textiles, both being classed as “Absolute Non-hazardous”. They are collected through dedicated roadside containers together with clothing representing the preponderant portion.

The total volume of textile waste generated in 2021 is between 615 000[34] to 800 000 tonnes[35] depending on sources, with 154 200 tonnes[36] collected separately. This represents an increase of 7.6% from 2020 and is comparable with the approximately 157 700 tonnes collected in 2019. In 2021, the largest quantities were collected in Northern Italy (77 200 tonnes), followed by the South (42 100 tonnes) and then the Center (34 900 tonnes).

Estimates[37] indicate that the annual per capita consumer input ranges from 12.7 to 16.0 kg/yr, while separate collection of textiles reaches 2.6 kg/yr, which corresponds to 16-20% of textiles entering the market. The same sources report second-hand textiles imports of 56 000 tonnes in 2019 (mainly from Germany, Switzerland and Austria) and exports of 48 500 tonnes (mainly to Tunisia, Austria and Hungary). In 2023 imports were at 45 816 tonnes (mainly from Germany, Austria and the Czech Republic) and exports at 181 494 tonnes[38] (mainly to Tunisia, Pakistan and Guinea). This reflects the post-Covid drop in exports, which is slowly building back up to pre-Covid rates.

Textile waste separately collected (TIR) undergoes preparation for re-use at dedicated facilities, that on average based on interviews, process 65% of products for re-use (including 25% for re-use in Europe), 25% for open and closed loop recycling (including 15% wipers and 10% yarn recycling) and 10% of scrap towards energy recovery (5%) or incineration (5%). Of the total textile waste coming from separate collections, about 100 000 tonnes are sent to sorting and recovery plants located within the country; the remaining 60 000 tonnes are sent to sorting plants located abroad, including in Bulgaria where the TIR analysis was also carried out.

The National Strategy for the Circular Economy[39] issued in June 2022 in Italy, calls for the inclusion of textiles within the reformed Extended Producer Responsibility system and an update of the End of Waste regulations for textiles. In 2023, the Minister of the Environment issued[40] a draft decree to

[34] JRC, 2021
[35] ISPRA (2022) Rapporto Rifiuti Urbani. Retrieved from: ISPRA website
[36] ISPRA (2022) Rapporto Rifiuti Urbani. Retrieved from: ISPRA website
[37] Fondazione per lo Sviluppo Sostenibile. (2022) Il riciclo in Italia. Retrieved from: Fondazione website
[38] UN Comtrade Database, reporting country Italy, looking at volumes HS6309
[39] Ministero della Transizione Ecologica (2022) Strategia Nazionale per l’Economia Circolare. Retrieved from: mase.gov website
[40] Ministero della Transizione Ecologica (2023) Tessile/Moda: MASE, per sostenibilità e minore impatto su ambiente arriva la responsabilità estesa del produttore. Retrieved from: mase.gov website

introduce an EPR for apparel, footwear, accessories, leather goods and home textiles. By the end of 2023, a consultation of key stakeholders had been carried out. However, the measure has not been officially published yet, presumably due to waiting for harmonisation developments at the European level. While waiting for a policy mechanism at the national level, the entrepreneurial system is already actively forming consortia that aim to tackle the issue of post-consumer textile collection and management, including:

- Cobat textile[41], which includes manufacturers, craft associations, industrialists and recycling companies in Tuscany ;
- Corertex[42] promoted by Prato textile district;
- Ecotessili and Ecoremat[43] for mattresses, promoted by Federdistribuzione;
- Erion Textiles[44], whose founding members are Amazon, Artsana, Essenza, Miroglio Fashion, Rimoda Lab and Save The Duck;
- RE.CREA[45] coordinated by the National Chamber of Italian Fashion;
- Retex.Green[46] created by Sistema Moda Italia.

2.1.4. Romania

Annually, Romania generates about 160 000 tonnes of textile waste and of this, depending on the sources between 15% and 30% is separately collected, with a collection rate of ~ 0.5 kg/person per year . These are slightly more optimistic assessments than the most current one from 2024, from EEA indicating that up to ~75-80% of textile waste generated ends up in MMW. However, interviewees indicated that only 8-16% is separately collected. This indicates a pressing need to invest in collection container infrastructure, which requires around 15 000 units to perform, but also in advanced sorting and recycling technologies.

In 2021, ~302 kg of municipal waste per capita was generated in Romania, of which ~11.3% was recycled and ~7.3 kg/capita/year represents textile waste (2.4%). According to Eurostat 2020, the percentage of textile waste directed to incineration is ~3.6%, and this number corresponds with insights from industrial partners interviewed.

At the moment, all the TMW waste is declared as incinerated or stored at authorised warehouses according to the Emergency Order 92/21, but there aren't national waste composition study results available and numerous non-authorised landfills operate in the country.

Based on data from ARETEX, a member of EuRIC, around 20 companies are operating in Romania in the field of sorting and preparing textiles for re-use and recycling. Of these, 10 are ARETEX members with a turnover of more than 50 million euros. Still, their capacity needs to be increased to be able to provide textile waste sorted by composition and fabric type.

Looking at the imported second-hand textiles, their amount has been fluctuating with 69 321 tonnes in 2021 and 47 857 tonnes in 2023 (mainly from Germany, Austria and Hungary) with

[41] Renewable Matter. (2023). Cobat Tessile, a Cross-cutting Approach to EPR Retrieved from: Renewable Matter
[42] Corertex (2024) Retrieved from: Corertex.it
[43] EcoTessili (2024) About Us. Retrieved from: Ecotessili
[44] ErionTextiles (2024) Retrieved from: Erion Textiles website
[45] Prada Group (2022) The RE.CREA Consortium is born. Retrieved from: Prada Group website
[46] Retex.Green (2024) Retrieved from: Retex website

exports at 3 938 tonnes (mainly to the United Arab Emirates, Hungary and Pakistan) in the same year.

The National Research and Development Institute for Textiles and Leather warns that there is a high probability that the majority of imported textiles are being dumped or landfilled, due to low collection rates. Humana Romania runs 41 stores throughout the country, involving over 300 staff members and reports ca. 6 million pieces sold in 2023. Second-hand shops in Romania sell imported clothes for approximately 2.4 EUR/kg. With the lowest recycling rates in the EU, Romania also faces social and environmental consequences of breaking the waste management laws. This includes burning, abandoning or illegal storage of waste, improper separate collection, as well as, illegal imports, which have been identified as disguised shipments of second-hand goods. In 2023, the Border Police stopped more than 6 000 tonnes of garbage at the border, mostly textile and clothing waste, brought in by "waste brokers" (Harta Reciclării, 2024)

Interviewees indicated that about 23% of TIR is exported as re-wearable, the rest is directed towards local charities for re-wear or incineration at a low value (up to 150 €/t). The Red Cross, CARITAS and smaller organisations operate the domestic charity re-use systems. Next to the free distribution of worn or used clothing, the Cross Rosie is obliged to carry out cleaning, disinfection and disinfestation operations accompanied by a separate document for each batch of clothes. As indicated on the website of ZARA, being one of the collectors for the Red Cross, other clothes are marketed within the charity channels of non-profit organisations, to finance their social projects - this would indicate that some of them are potentially being exported from Romania.

From a policy perspective, in Romania, the Government Emergency Ordinance (GEO) no. 92/2021 (modified by GEO125/2022) regarding the waste regime regulates refers in art. 12 to the EPR scheme and separate collection of textile waste in art. 17 (3). The targeted companies may choose to implement EPR obligations either individually or through an organisation that implements EPR obligations (OIEPR) authorised by law. In Romania, OIEPR collect the tax from producers, directing the funds to collection, sorting and recycling operations, to ensure that national recycling targets are met.

In June 2024, the Recycling Factories Program was opened, funded by European Funds, which aims to build recycling facilities for selectively collected waste to reduce the impact of waste on the environment and the population and to reduce consumption.

2.2. The economic value of textile waste for recycling

Textiles sorted as not suitable for re-use are often directed towards wipers manufacturing and open or closed loop recycling. Currently, the factor determining the management route of that fraction remains the selling price, so the highest bidder gets the sorted feedstock. Some of the feedstocks that are of the highest value and could be applied to multiple management routes are cotton-rich white knitted and woven materials and cotton-rich denim. Sorters need to obtain revenue from textiles sent to recycling, since identifying and sorting that feedstock is a significant labour intensive effort.

There is a common misconception that textiles that cannot be sold on second-hand markets are 'valueless' and could be obtained as feedstock for closed-loop recycling at little to no cost[47]. Sorters obtain revenues from textiles sent to recycling. Hence, redirecting textiles towards recycling feedstocks for closed-loop recycling faces strong competition from their use in manufacturing wipers. As closed-loop recycling is not yet a mature industry at scale, its prices need to be defined. In addition to the lack of unified criteria, the price and prevalent current business model that slow down the scaling of closed-loop solutions.

The price estimates for recyclable feedstocks presented in Table 2 below were obtained from textile recyclers in 2021[48]. As illustrated, these prices are not competitive with current prices declared by sorters interviewed in this study, who declared that the lowest export price is at 0.10 eur/kg, which is the same as for closed-loop recycling and significantly lower than prices offered by wiper manufacturers (0.40 eur/kg). The prices for domestic re-wearable textiles were declared to be starting from 2 euros/kg, although this data was obtained from one country lead and may thus not be necessarily representative. This means that technically available feedstocks for closed-loop recycling may continue to be sent to existing destinations, like the wipers industry, for business reasons, unless there is a legislative or economic incentive in place to do otherwise.

[47] van Duijn, H., Papú Carrone, N., Bakowska, O., Qianjing, H., Akerboom, M., Rademan, K., Vellanki, D. (2022) Sorting for Circularity Europe. Retrieved from: Fashion for Good website
[48] van Duijn, H., Papú Carrone, N., Bakowska, O., Qianjing, H., Akerboom, M., Rademan, K., Vellanki, D. (2022) Sorting for Circularity Europe. Retrieved from: Fashion for Good website

Table 2. Closed-loop recycling solutions feedstock specifications overview (based on interviews with recyclers)

	price	input
Chemical	0.20 eur/kg	≥95 polyester, <5% other
	0.20 eur/kg	≥60% polyester, <40% cotton, < 10% others
	0.20 eur/kg	Mainly: ≥95% cotton, <5% others, no protein-based fibres Also possible: ≥88% cotton, <12% others (lower cotton content is also possible, but this decreases the profitability of the process)[49]
Mechanical	0.40 eur/kg	≥80% cotton
	0.09 eur/kg	≥95% acrylic
	1.20 eur/kg	≥80% wool

Source: Own work.

2.3. The re-usability of textile waste

2.3.1. Textiles in mixed waste (TMW)

2.3.1.1. Methods

The TMW sampling strategy and methodology were developed based on the tested procedure for the waste analysis of mixed municipal waste conducted by INCIEN in the Czech Republic so that the analyses performed are repeatable and the results are based on clearly defined processes. The methodology is based on the Methodology for Determining the Composition of Mixed Municipal Waste from Municipalities and Municipal Waste (Result V4), which was developed by the Brno University of Technology for the Czech Ministry of the Environment as part of the project Forecasting Waste Production and Determining the Composition of Municipal Waste.

To meet the planned sample, each TMW facility provided waste weighing 1000 kg, which consisted of two samples as indicated below (except for Italy where it was not possible to sample in regions without textile collection bins). These are normal samples from different types of areas (urban, suburban, rural, houses and flats) and it is necessary to ensure that they are identifiable for analysis.

The target TMW sample consisted of two samples:

- One originating from the designated area/region/district where there are dedicated textile bins - volume 500 kg per facility

[49] Based on specifications of the BASF recycler in the T Rex project. Retrieved from: T Rex website

- One originating from the area/region/district where there are no dedicated textile bins - volume 500 kg per facility
- Unsorted textiles were hand-picked out of the total 1000 kg sample of mixed waste, excluding mattresses, footwear, or toys.

The full overview of the sampling methodology can be found in Annex 1.

The textiles were classified according to re-usability grades as indicated in Table 3.

Table 3. Reusability grade definitions applied in this study.

Reusability Grade 1	Not usable	Multiple stains, multiple holes, missing buttonnes and/or broken zippers, including clothes impossible to identify (mutilated)
Reusability Grade 2	Barely usable	Multiple stains and holes, missing buttonnes and/or zippers but the garment is possible to identify, however, the garment would require significant interventions to be reusable.
Reusability Grade 3	Noticeable defects	Few and small stains or holes and/or some discolouration and/or pilled or thinned to a major extent.
Reusability Grade 4	Minor defects	An item is visibly worn with perhaps minor hole(s) or stain(s) or fabric being to a minor extent thinned or pilled.
Reusability Grade 5	Perfect condition	New items with tags, without tags, or like new. No visible damages.

Source: Own work.

2.3.1.2. Analysis results

The sampled mixed municipal waste (MMW) stream contained significant percentage of textile waste (7.1% on average). The highest percentages observed for Romania (13.9%, averaged over sites and collection rounds), and much lower percentages (4.6% - 1.2% in samples collected in the Czech Republic and Italy) (Table 3).

Table 4. Share of textile waste in 500 kg mixed municipal waste, sampled at regions with and without separate collection of textile waste in operation

Country		Separate collection of textiles in operation	No separate collection of textiles
Italy	Round 1	1.4%	NA
	Round 2	1.2%	NA
Czechia	Round 1	4.6%	2.4%
	Round 2	3.9%	2.2%
Romania	Round 1	5.2%	14.9%

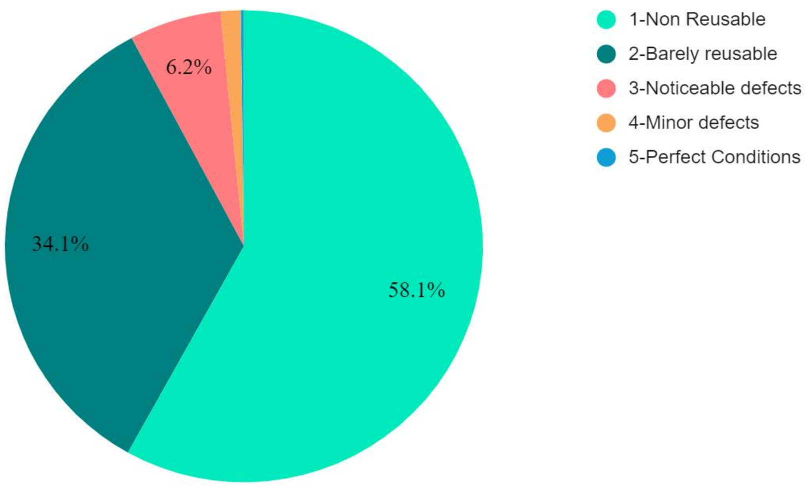
	Round 2	16.5%	19%
Average	All	7.1%	

Source: Own work.

On average across all countries, we have found 5.5% of textiles present in the sample in regions where separate textile collection is in operation and 10% of textiles present in the sample in regions where separate textile collection is not available (Table 3). This suggests that the presence of textile bins indeed helps limit the amount of textile waste disposed of with the MMW stream but in our study, this result was largely driven by the higher presence of textiles in samples analysed in Romania.

The quality analysis of the TMW sample indicates a low potential for re-use, with only 1.6% of these textiles having minor or no defects (Figure 2). Most of the textiles ending up in mixed municipal waste were either wet or contained disruptors that limit their potential for recycling without pre-treatment (Figure 3). At the same time, most of them (89.2%) were further damaged and stained which sorters classified as non-reusable (grade 1) or barely reusable (grade 2) (Figure 2) so it was not the moisture content that diminished their value, but their quality at the moment of disposal. In CZ, a somewhat significant amount of dry textiles without disruptors was found (15.9% - 22.3%). The country leader for the Czech Republic reported these were often old cotton clothes re-used as cloth wipes for cleaning and baby clothes.

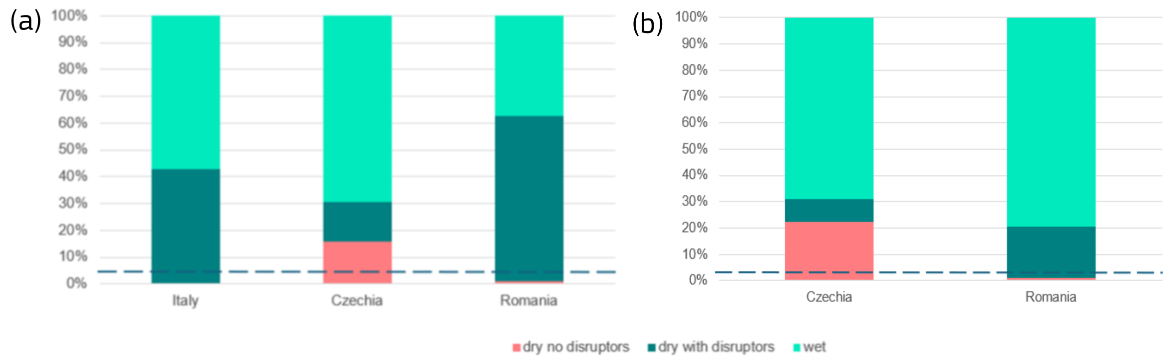
Figure 2. Quality grades found in the aggregated TMW sample of textiles managed from all the sampling regions without separate textile collection. The variability of samples can be found in Annex 6.



Source: Own work.

Some dry textile waste without disruptors was found in the MMW sample, which could be considered recyclable depending on the material composition. It represented 4.6% of the total waste stream analysed in the sample from an area where there were textile bins and 3.6% in a sample where no textile bins were available. The average percentage of dry textiles with no disruptors found across the three samples is indicated with a dotted line in Figures 2 and 3 below and stays below 5%.

Figure 3. Textiles found in the aggregated mixed waste textile sample from the region (a) with an established separate textile collection system, and (b) without separate textile collection system in place.



Source: Own work.

2.3.2. Textiles intended for re-use and recycling (TIR)

2.3.2.1. Methods

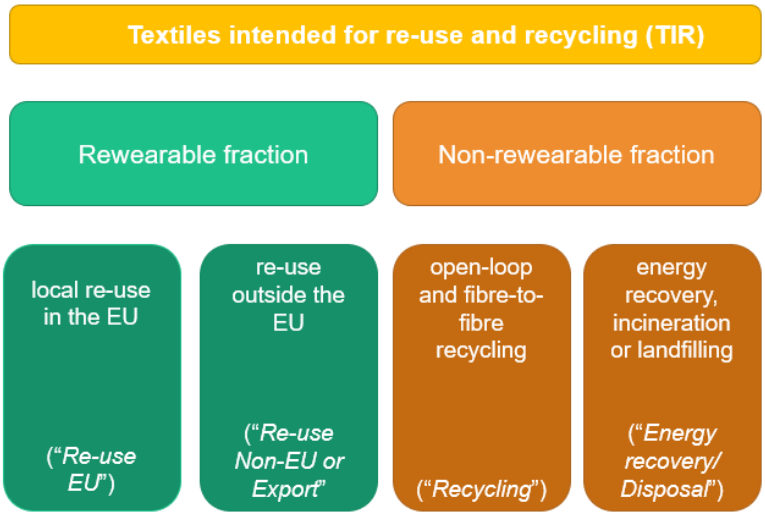
The TIR sample analysed at sorting facilities was extracted from textiles already after the so-called 'main sort' and consisted of the fractions listed in Figure 4:

- Rewearable textiles sorted for re-use in the EU - volume 350 kg per facility (this will be referred to as Re-use EU fraction)
- Rewearable textiles sorted for re-use outside the EU[50] - volume 350 kg per facility (this will be referred to as Re-use Non-EU or Export fraction)
- Non Rewearable textiles going towards wipers, downcycling and fibre-to-fibre recycling[51] - volume 350 kg per facility (this will be referred to as Recycling fraction)
- Non Rewearable - textiles going towards energy recovery, incineration or landfilling - volume 350 kg per facility (this will be referred to as Energy recovery/Disposal fraction)

[50] Romania TIR facilities do not offer this fraction, only domestic re-use and Non-Rewearable. The total fraction analysed for Romania was the same volume as in other countries

[51] as above

Figure 4. The classification of textiles intended for re-use and recycling (TIR) samples, as referred to in this study.



Source: Own work.

Fractions refer to categories of collected used textiles sorted for various re-use and recycling purposes. These fractions are sold in different local and global markets and are specific to each facility, regularly updated based on market demand, resale prices, waste shipment regulations, and other factors. During interviews with country partners, participating sorters nominated facility-specific fractions to be included in the sample, corresponding to the general categories listed above, to represent the re-wearable and non-re-wearable textiles they process. Textiles were selected from non-consecutive bales to diversify the sample. All nominated and selected fractions will be of the same volume to maximize the sample's representativeness. This means the sample size does not represent the relative share of materials being sorted at the facility.

For each sorted fraction, default and equal volumes were selected. However, as shown in Table 1, TIR is not equally divided between management routes and varies across the focus countries. Existing research indicates that TIR is predominantly directed towards re-use in local and global second-hand markets, with 40-89%[52] of TIR directed towards re-use and an average of 64%[53] in North-West Europe. In the focus countries of this study, interviews with TIR partners revealed that an average of 40% was directed towards European re-use (largely driven by Romania, as without it, the average would be 20%), 22% was exported for re-use (lowered by the Romanian facility, as without Romania, it would be 35%). Additionally, an average of 20% was directed towards open loop recycling, 3% towards closed loop recycling, and 10% towards incineration.

It is important to understand that there is no fixed criteria list defining whether a garment is fit for re-use. Common business practice involves facilities having sorting manuals or guidelines and training staff diligently to recognise these criteria efficiently. Staff are often rewarded for excellent productivity or particular skill in identifying high-value products. This means that reusability and

[52] van Duijn, H., Papú Carrone, N., Bakowska, O., Qianjing, H., Akerboom, M., Rademan, K., Vellanki, D. (2022) Sorting for Circularity Europe. Retrieved from: [Fashion for Good website]
[53] van Duijn, H., Papú Carrone, N., Bakowska, O., Qianjing, H., Akerboom, M., Rademan, K., Vellanki, D. (2022) Sorting for Circularity Europe. Retrieved from: [Fashion for Good website]

market fit, which ultimately dictate the price, are based on the subjective decisions of the sorter. They must consider the facility manual, usability, trend, color, brand, and visible damages. These factors are not weighted equally; for example, usability might be compromised if the trend and brand are highly suitable and in demand for a specific market.

The full overview of the sampling methodology can be found in Annex 1.

The textiles were classified according to re-usability grades as indicated in Table 3.

2.3.2.2. Analysis results

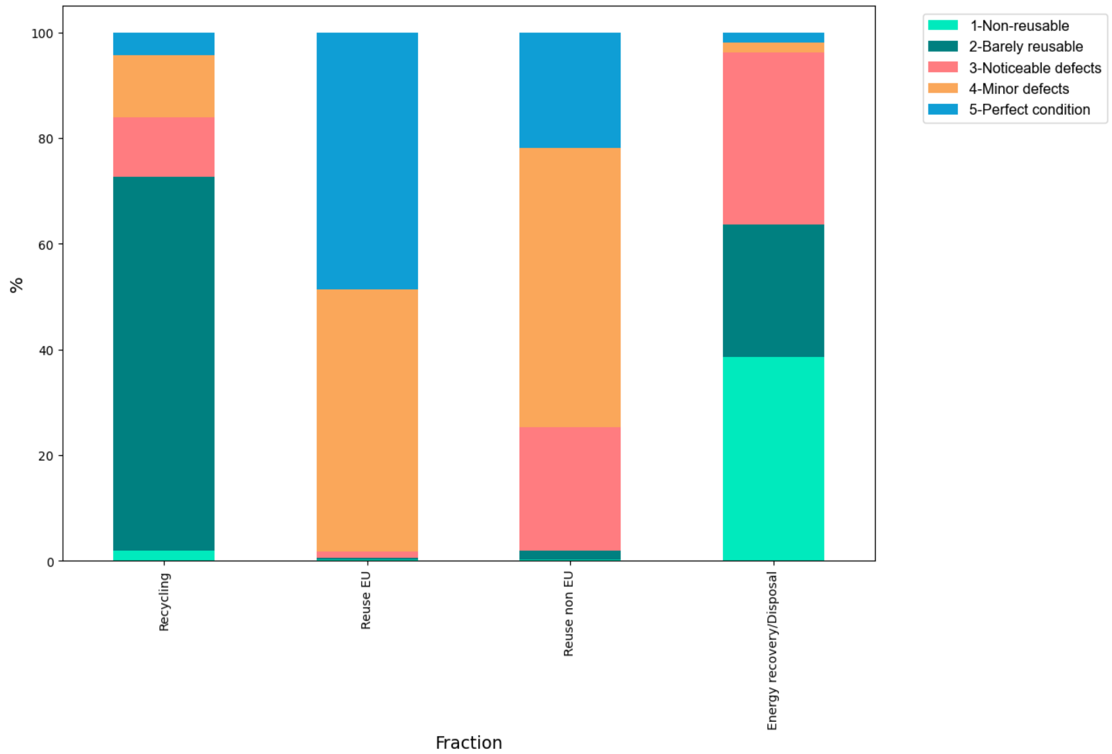
As expected, amongst all countries, the textiles analysed in the TIR fraction are usually dry. In the domestic re-use fraction only 0.03% of the sample was wet, in the Export and Recycling fraction, it was 0.1% and slightly more (1.7%) in the Non-rewearable Fraction.

Similarly, the reusability grades reflect the quality of each fraction. Re-use fractions for the EU and non-EU are represented by higher grades (4 and 5) (Figure 5). For textiles to be re-used in the EU about half are in perfect condition (grade 5) and about half with minor defects (grade 4) with negligible amounts of lower quality (grades 3 and 4) (Figure 5). Textiles exported for re-use mainly have minor defects (~50%, grade 4), followed by textiles with noticeable defects (~20%, grade 3) and ca 20% in perfect condition (grade 5). It is concluded that TIR exported for re-use outside Europe is mostly (ca 75%) without noticeable defects.

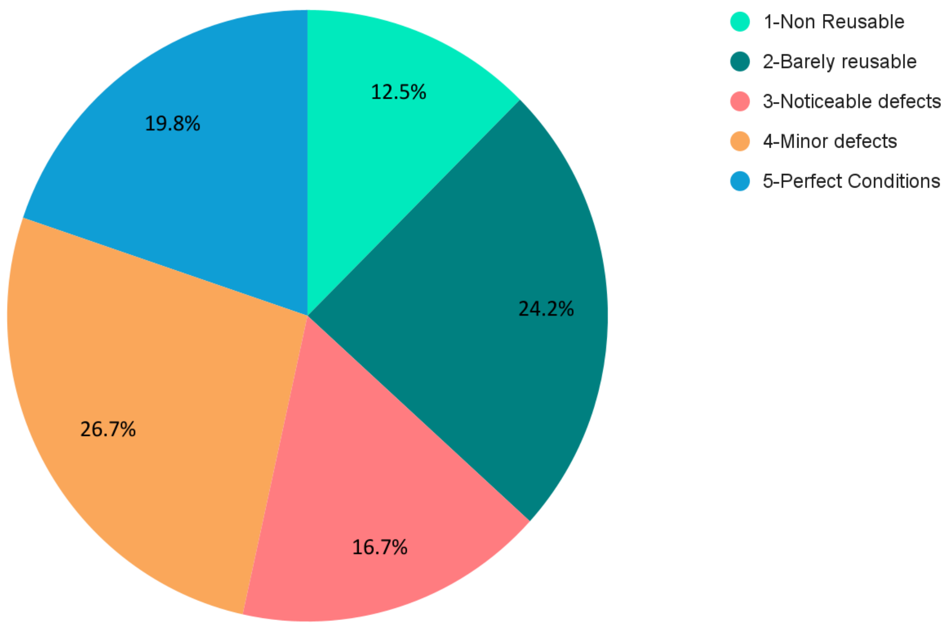
The Non-re-wearable fractions are indicative of lower grades (Figure 5). The Recycling fraction predominantly consists of grade 2 textiles, which are barely reusable (approximately 70%), followed by grades 3 and 4 (around 10% each). The Energy recovery/disposal fraction is primarily composed of grade 1 textiles (about 40%), with grade 3 making up 25% and grade 2 around 20%. This highlights the complex nature of grade 3 textiles, which often have noticeable defects and can be classified as either reusable or non-reusable. Grade 3 textiles account for 20% in exports, 10% in recycling, and 25% in the energy recovery/disposal fraction.

If we were to look at the total TIR sample across all fractions, we see the largest share are clothed with minor defects (grade 4, 27%), followed by of barely reusable textiles (grade 2, 24%) and clothes in perfect condition (20%) (Figure 5). Items with noticeable defects and non-reusable items only make up a total of 29% of the total textile volumes collected (Figure 5). For further insights into variability between samples and countries, it is referred to Annex 6.

Figure 5. Results of the classification on re-usability: (a) reusability grades (1-5) for the different fractions following a sorting process (Re-use EU, Re-use non-EU, Recycling, Energy recovery/Disposal fraction), and (b) weighted average of all fractions considering the allocation of the total textile waste collected to the different fractions by the sorter.



(b)



Source: Own work.

2.4. Fibre composition and recyclability of textiles intended for re-use and recycling

2.4.1. Methods

Textile composition was analysed using Near Infrared Spectroscopy. It is referred to Annex 2 for details on this technology to classify textiles based on their fibre composition. The recyclability of the materials for closed-loop recycling was assessed by the determination of (i) the material composition of the product, (ii) the presence of disruptors, (iii) colour, (iv) layers and (v) structure (knitted and woven).

2.4.1.1. The material composition of the product

The suitability of the textile waste for fibre-to-fibre recycling was primarily assessed based on the fibre composition, and the current feedstock requirements that are presently set by recycling facilities engaging into fibre-to-fibre recycling. Specifically, the Recyclers Database (WRAP)[54] was used a reference point for material composition requirements for closed-loop recycling (Table 5). This database merges information from 64 mechanical and 38 chemical recyclers. When technically feasible, mechanical recycling was assumed to prevail over chemical recycling. Textiles consisting out of 100% cotton and ≥80% cotton rich compositions are suitable for both mechanical and chemical recycling. The ultimate factor determining the decision will be the colour (mono-colour versus multi-colour). Each data point suitable for both recycling pathways will be assigned to the mechanically recyclable fraction and not double counted for chemical recycling. Note that feedstock requirements may change in a future and that this classification should thus be seen as a 2024 snapshot, rather than a fixed classification.

Table 5. The minimum requirements for mechanical and chemical fibre-to-fibre recycling based on the data collected from the WRAP recyclers' database.

For mechanical recycling	***For chemical recycling***
a. 100% Cotton	a. 100% Cotton
b. ≥95% cotton	b. 100% viscose
c. ≥80% cotton	c. ≥95 polyester
d. ≥95% acrylic	d. ≥40% polyester, 0% cotton
e. ≥80% wool	e. ≥50% polyester, cotton following
	f. ≥50% cotton, polyester following[55]

Source: Own work, based on the WRAP Textiles Sorting and Recycling Database.

[54] https://www.wrap.ngo/resources/tool/textiles-sorting-and-recycling-database

[55] 100% cotton and ≥80% cotton rich compositions are suitable for both mechanical and chemical recycling. The factor determining the decision will be the colour (mono-colour versus multi-colour). Each data point suitable for both recycling pathways will be assigned to the mechanically recyclable fraction and not double counted for chemical recycling.

2.4.1.2. Presence of disruptors

Metal and plastic hardware is regarded as mechanically removable disruptors, since already for several years this process has been operational within garneting/tearing lines in Europe[56]. The classification of a disruptor depends on the recycling process targeted[57]. Some chemical recycling technologies can accept the presence of labels and other textiles, so the level of pre-processing will vary from one recycler to another. All types of disruptors to recycling that were classified in this study can be found in D1. While this is an extensive list, it lacks more detailed information (such as chemical composition) on various coatings, repellents, laminates or prints[58] that most likely occurred in the sample, but were not identified in the data collection process.

2.4.1.3. Colour

For mechanical recycling, the feedstocks need to be colour sorted and so in the share of the sample deemed suitable for mechanical recycling only colour items are included. The items classified by sorters as multicolour, where one dominant colour was impossible to assign, could only be suitable for chemical recycling.

2.4.1.4. Layers

Multi-layered items can be disassembled manually or automatically before being sorted based on their composition, but there is no business case for their disassembly in Europe so the multi-layered items are considered non-recyclable and have been excluded from all the results. In total 5.2% of the aggregated sample consisted of multi-layered items like jackets and coats and most of them were managed as reusable garments exported outside the EU.

2.4.1.5. Structure (knitted and woven)

During the analysis, sorters indicated the knitted or woven structure of the garment. Both structures are considered fit for mechanical and chemical recycling according to the Recycler Database[59]. However historically only, or mostly, knitted garments and jeans were accepted by mechanical recyclers, and so this could still be a preference in many cases. In this study, both knitted and woven items were classified as suitable for both mechanically and chemically recyclable, but the indication was made in the following chapters to display how the potential volumes would change if the mechanical recyclers had more strict criteria. In any case, to not double-count garments suitable for both recycling ways, the priority was given to mechanical recycling as an already scaled-up technology.

---

[56] Refashion (2023) Technical monitoring of optical sorting, recognition and disassembly technologies for textiles at European scale .Retrieved from: Refashion website

[57] Refashion (2023) Technical monitoring of optical sorting, recognition and disassembly technologies for textiles at European scale .Retrieved from: Refashion website

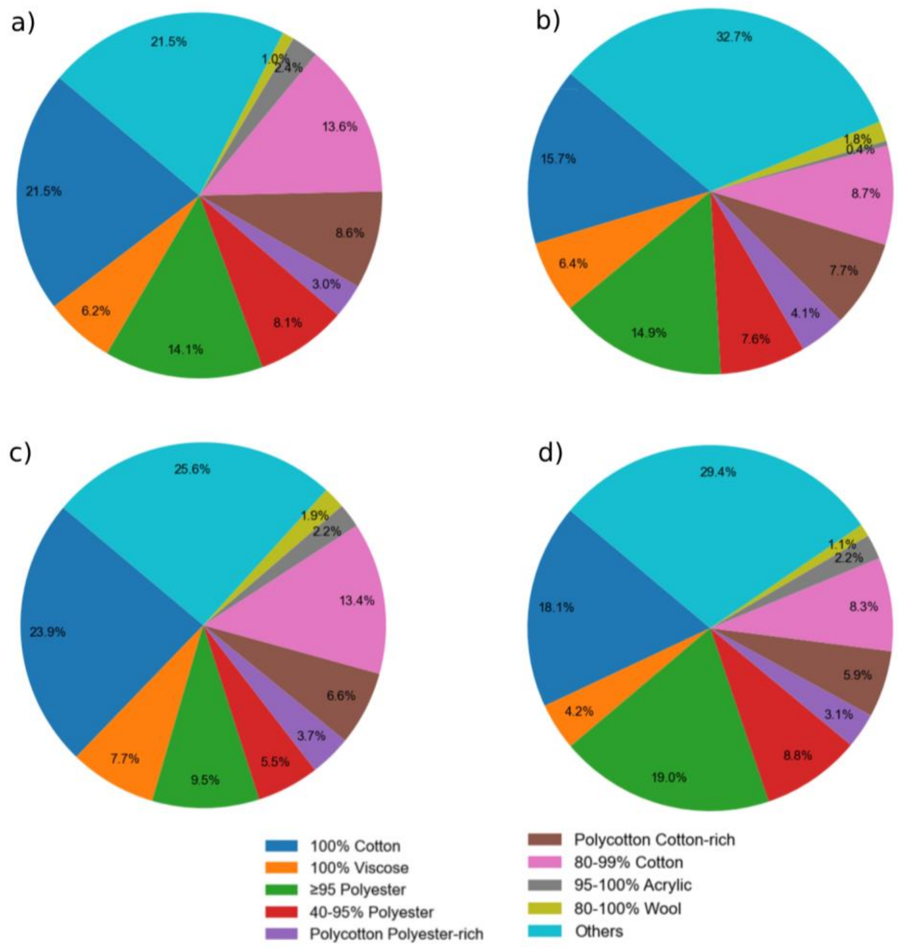
[58]Stubbe, B.; Van Vrekhem, S.; Huysman, S.; Tilkin, R.G.; De Schrijver, I.; Vanneste, M. (2023) White Paper on Textile Fibre Recycling Technologies. Retrieved from: centexbel website

[59]WRAP. (2023). Textiles Sorting and Recycling Database. Retrieved from: WRAP website

2.4.2. Fibre composition

In terms of material composition, in general, the compositions are similar across re-wearable and non-re-wearable fractions (Figure 6). Other blends (29%, weighted average) and 100% cotton (18%, weighted average) represent the biggest share in all the samples, followed by polyester and polyester-rich blends (16%, weighted average) and cotton-rich blends (10%, weighted average). At the same time, viscose is present in all fractions (6%, weighted average). Wool- and acrylic rich-materials make up about 1.5%, when expressed as a weighted average. Cotton-rich materials are most abundant in the fraction Re-use in the EU and Recycling (Figure 6).

Figure 6. Fibre composition of the sorted textile waste fractions: (a) re-use in the EU, (b) Re-use non-EU, (c) Recycling and (d) Energy/recovery/disposal (full dataset available upon request).



Source: Own work.

2.4.3. Recyclability

To identify the recyclable fractions the criteria outlined above were applied to aggregated datasets. Whilst in some Figures below the Reuse EU fraction will be shown, it is agreed that these garments should not end up in recycling, and probably would not end up in recycling due to their value on the second-hand market, therefore they are excluded from the recyclable sample results. For the Non-EU fraction, it is agreed that these textiles should follow the waste hierarchy and so the second-hand market is the highest value destination for them.

For the recyclability assessment of TIR, the Non-EU, Recycling and Energy recovery/Disposal fractions have been considered, as they are mostly non-rewearable or lower-value re-wearable and so it should not disrupt the business model of a sorting facility to direct them towards recycling when proper revenues are collected..

2.4.3.1. Fractions suitable for mechanical recycling

In the aggregated sample, on average only 8.2% of garments are readily available for closed-loop mechanical recycling, without any further processing (Table 6). This number is the average between three samples: Non-EU, Recycling and Energy recovery/Disposal fraction. Textiles suitable for recycling are dry, without disruptors, knitted or woven, monolayer and mono-colour and with suitable material composition.

While this number might be considered low, it must be noted that it is still very optimistic. From these garments, the care labels would still have to be removed before recycling and the presence of elastane within each garment would have to be detected by the sorter or recycler, as the NIR technology used in this study will not recognise <5% of elastane in the blend. This is further explained under study limitations (Annex 2).

Historically mechanical recyclers had very strict material composition, colour and structure requirements. When it comes to structure, within the samples we have identified mainly woven garments, specifying that 52.4% are woven structures in the Energy recovery/Disposal fraction, 66.2% in Recycling and 90.6% woven in the Non-EU fraction.

The textiles with metal or plastic disruptors represent on average 7.4% in each sample (Table 6). These are dry, knitted or woven, monolayer and mono-colour garments with metal or plastic disruptors and with suitable material composition so they require mechanical removal of disruptors, which recyclers are prepared to process. This finding also indicates that the disruptors to recycling need to be removed to increase the size of the recyclable fraction and that calls for further scaling up and professionalisation of the preparation for the recycling process to be able to cope with all the types of disruptors at scale.

Table 6. The average percentage (%) of textiles suitable for mechanical recycling, without any disruptors and with removable disruptors. Data are aggregated (across countries and analysis rounds) results for each sorted sample from which textiles could be redirected towards recycling and have suitable material composition. Hence, the total share of textiles that can theoretically be recycled upon disruptor removal are displayed in the right-hand column.

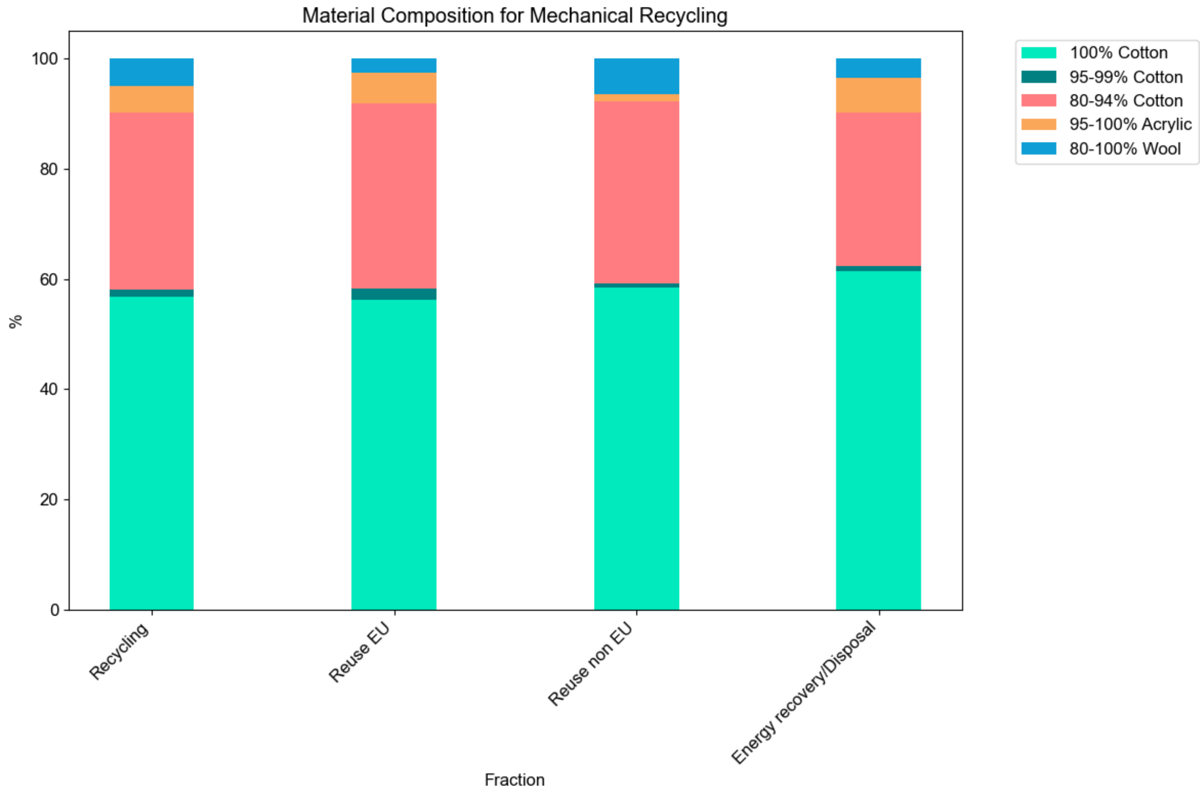
	no disruptors	metal or plastic disruptors only	any disruptor type
Re-use non-EU	5.5%	11%	21%
Recycling	15.9%	9.6%	35.1%
Energy recovery/Disposal	3.3%	1.7%	24.2%

Source: Own work.

The material composition of the mechanically recyclable fraction, including all disruptors, is illustrated in Figure 7. In this fraction, the predominant composition across all samples is pure cotton garments (around 60%; as well as a negligible percentage of 95-99% cotton blends). This is followed by approximately 30% cotton-rich blends and about 10% acrylic and wool blends (Figure

7). The 100% polyester composition was directed towards chemical recycling, since presently, polyester could only be mechanically recycled into non-woven textiles[60].

Figure 7. The material composition of fractions suitable for closed-loop mechanical recycling.



Source: Own work.

Volumes of recyclable textiles in the TMW sample have also been calculated, but that is considered as a purely theoretical exercise since their volumes are too fragmented, require hand picking, drying and washing and so realistically they could only be regarded as recyclable if they were diverted to a separate textile collection bin.

Within the total 164 kg of TMW, from areas with separate textile collection, we identified 27 kg as suitable for mechanical and 30 kg for chemical recycling, while within 192.7 kg of TMW from areas without separate collection, we identified 12.8 kg of textiles suitable for mechanical recycling and 17.5 kg for chemical recycling.

2.4.3.2. Fractions suitable for chemical recycling

For chemical recycling, the share of recyclable garments is much higher (Table 7). On average across all samples, 12.4% of all garments are suitable for chemical recycling without any further processing, further on 12.6% have mechanically removable disruptors and 39.4% contain more disruptors in different combinations.

[60] WRAP. (2023). Textiles Sorting and Recycling Database. Retrieved from: WRAP website

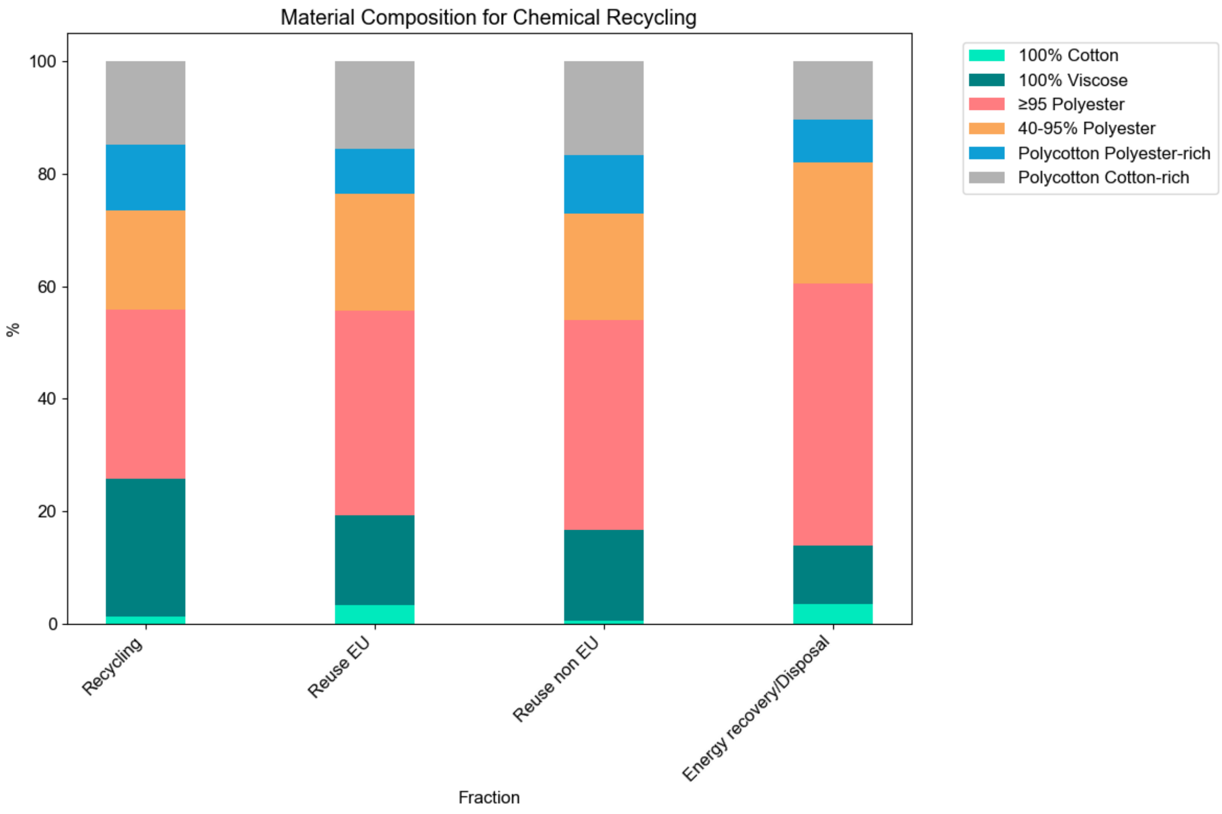
Table 7. Average percentage (%) of textiles suitable for chemical recycling, without any disruptors and with removable disruptors. Data are aggregated (across countries and analysis rounds) results for each sorted sample from which textiles could be redirected towards recycling and have suitable material composition. Hence, the total share of textiles that can theoretically be recycled upon disruptor removal are displayed in the right-hand column.

	no disruptors	metal or plastic disruptors	any disruptor type
Non-EU	13.2%	14.6%	41.7%
Recycling	14.8%	10%	33.8 %
Energy recovery/Disposal	9.2%	11.9%	42.7 %

Source: Own work.

The composition of the total chemically recyclable fraction, across the samples, with all the disruptors is presented in Figure 8. With cotton garments redirected towards mechanical recycling, the dominant material composition here is polyester-rich blends (≥ 95% polyester), which constitute between 25% and 40% of each sample and are most prevalent in the Energy recovery/disposal sample. Additionally, 100% viscose and polyester-rich blends make up a significant portion of these samples, followed by polycottons and negligible amounts of 100% cotton.

Figure 8. The material composition of fractions suitable for closed-loop chemical recycling.



Source: Own work.

3. Recommendations for future studies

3.1. Learnings for Upcoming Waste Composition Studies

This project showed the importance and challenges of cross-boundary on-the-ground research and how necessary and powerful it is for establishing effective circular economy value chains in the EU. By giving ownership to country leads, the methodology was enriched, tailored to the local landscape, replicated and handed over to multiple professionals of diverse backgrounds. It allowed us to truly align on definitions, processes and insights, which is strictly necessary to allow for comparable results. A list of learnings was solidified together with country leads throughout the time of this study.

Replicating in new geographies through partnerships with country leads makes evident the differences in understanding, nomenclature and TIR management processes. These differences were addressed in the initial training and bi-weekly calls, however, in the future, more resources need to be dedicated to building a shared understanding and bridging the knowledge and communication gaps between country leads and industrial partners, who mostly work with this level of analysis for the first time. Conducting steps of the analysis together would be a more truthful and informative approach for the project consortium in the future, especially when some of the knowledge partners have not worked within the TIR or TMW context before. In future studies, the importance of liaising with the industry partners as a consortium, rather than country lead only, multiple times cannot be underestimated.

The study relied on the ownership of local partners on their own on-the-ground activities and data collection. Whilst this contributed to a more collaborative approach, all partners did encounter challenges in setting up the research (e.g. sample preparation). In future studies, more time should be available for partners to share lessons learned, also in person, throughout the on-the-ground analysis to avoid encountering similar logistical challenges.

Another downside of the time-efficient approach taken in this study was that it proved that when working in a TIR facility for one day only, the planned productivity of data collection was impossible to obtain. In one of the facilities, the average efficiency was 14 kg per hour, with 22 kg per hour expected. Country partners needed to commit additional time to complete the analysis and therefore the funds to mobilise the TIR and TMR partners were used fully to secure sufficient capacity.

Given that each TIR facility employs its own sorting methods and collaborates with different trading partners, national studies should aim to form a coalition with these facilities. This coalition would work together to identify shared best practices, common data requirements, and mutual interests in scaling fiber sorting and recycling practices at a national or regional level.

3.2. Outstanding data needs for upcoming waste composition studies

This study enabled the mapping of the composition of TIR waste originating from three European countries, which is an expansion from seven countries mapped previously.

Data gaps that further studies could help address include:

- In the countries selected for this study, the data gaps regarding collection rates and processing of textile waste are significant. Composition studies of TIR and TMW were never conducted there before and sources quantifying the overall volumes presented disparities, especially in the Czech Republic and Romania.

- To gain a deeper understanding of the market realities of TIR, which dictate the destinations and processes applied to re-wearable and non-renewable textiles, a more extensive overview of prices of sorted and exported textiles and feedstocks is needed. This could be used to calculate a business case for obtaining feedstocks for recyclers, as well as sorters who want to become feedstock providers. It would also outline the scale of funding requirements. Such a business case requires a long-term and trust-based relationship to obtain business-sensitive data while offering: anonymity, shared objectives and incentives.
- Complimentary to the point above, a good understanding of the fluctuation of prices of recycling feedstocks globally is needed to inform scenarios for a European recycling ecosystem and a firm business case. For price and quality specifications of open and closed-loop recyclers Refashion and Reverse Resources could be further consulted.
- More detailed insights about the differences and correlations between the regions and their collection methods to confirm how can different collection systems (for example charity shops and textile bins) best work together towards sorting for reuse and recycling
- More detailed insights into chemical disruptors to recycling are present in TIR. In such an approach, a database of different chemical disruptors present in TIR could be created through both NIR and lab testing, next to validation or testing with recycling providers.
- With overall minimal rates of TIR recycling, further experimentation with sorters and recyclers on processing TIR as feedstock is needed.

4. Recommendations for enhancing sustainable textile waste management

4.1. Developing improved fibre-sorting practices and disruptors-removal solutions – prerequisites of closed-loop recycling at scale

All used textiles – even those entering reuse markets – will gradually decrease in quality and become waste over time. Ideally, by then they are in a geography where the infrastructure is available to collect, sort, and direct them towards the highest-value, lowest-impact application possible. Databases such as EU Comext and UN Comtrade only report first export destinations, failing to capture the complexity of global flows, where TIR originating from the EU is first processed by European sorters, then exported outside of the EU and then very likely re-exported.

For the textiles to be suitable as feedstock for closed-loop recycling, they need to be sorted based on their exact material composition, and often colour and structure. Disruptors need to be removed, either by the sorter, recycler or an intermediary party. To enable this preparation for recycling, investments are required in infrastructure, technology and staff for automated sorting and hardware removal. Some chemical recyclers report not having the current capacity for disruptor removal at their facilities, relying solely on sorters and third parties to prepare their feedstock.

A previous analysis by EigenDraads[61] 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 TIR from their current destinations to closed-loop recyclers results in a return on investment of around 8 years, which is not a realistic time frame for private investors. A return on investment of 5 years can be realised in case a subsidy is available for the CAPEX investments of € 1.8 million.

More promisingly, solutions including hand-held devices for sorting based on composition are already available on the market. These can be incorporated into TIR sorting facilities' current operations at any scale with less extensive investment (although they could also be subsidised). In addition, fully and semi-automated fibre sorting costs could be at least partially financed through EPR fees.

Automating sorting for reuse is more complex, given the variable and subjective nature of textile reusability. There are at present no technologies currently available that could replace the categorisation of textiles based on their value for reuse on domestic and global second-hand markets, nor is it clear how these could be developed. Therefore, adding automated sorting to the process will most likely not reduce the overall volume of non-re-wearable textiles being exported for global second-hand markets in the short-term. Additionally, to accommodate the needs of recyclers in terms of viable inputs and minimum order quantities, an additional step is needed to aggregate recycling feedstocks. It can be assumed that storing this aggregated feedstock requires

[61] EigenDraads. (2022). Van woorden naar draden. Available at: https://eigendraads.com/1260-2/

space and represents a cost to sorters, and therefore potentially another roadblock to them becoming more prominent providers of feedstocks for recycling.

4.2. Enabling economies of scale for reuse and recycling

Scaling recycling capacity and fostering reuse and recycling economies will require several interconnected actions. The linear model of garment production and consumption largely determines the destinations of TIR and TMW. The demand for TIR sorted for recycling is closely tied to the pricing and costs associated with purchasing and investing in fiber sorting and closed-loop recycling infrastructure. The market for sorted TIR depends on the development and economic viability of closed-loop recycling technologies, or potentially other high-value recycling open-loops. Interventions and further actions from regulators, retailers, and recyclers are necessary to enhance the desirability of TIR as feedstock for recycling and to redirect it from currently highly competitive destinations. Lastly, a major barrier to chemical recycling is the fact that existing technologies remain predominantly in the R&D or pilot stages. The capacity of emerging chemical recycling solutions is still marginal against the scale of textile waste being produced. Chemical closed-loop recycling at scale could explicitly positioned as part of a broader suite of solutions for valorising textile waste.

5. Conclusions

This study, provides based on validated approaches comparable and detailed results on TIR and TMW streams from regions previously under-researched in waste mapping and recycling sorting. It was found that the majority textiles exported for reuse have no or few noticeable defects (grade 4-5), but also that a significant share of ~25% has noticeable defects. Further qualitative and quantitative research is needed into the nature of exported TIR as literature data on the percentage of waste within exported used clothing bales is highly variable; estimates from other studies suggest up to 40%, while importers' associations claim only a maximum of 5% of imported clothing is waste. With growing volumes of TIR collected in the EU, large volumes of textiles will likely continue to be directed towards global sorting hubs and second-hand markets, following the business-as-usual approach. The amended Waste Shipments Regulation, which came into force in May 2024, aims to make safeguards for textile exports more stringent and ensure sustainable treatment in receiving countries. Therefore, it is highly relevant to what extent to investigate if low-value used and waste textiles can be recycled.

The material composition of PCT makes it largely recyclable, with 66% of the TIR sample analysed deemed recyclable, with chemical recycling (39%) able to process more materials than mechanical recycling (27%). Specifically, this means 66% of textiles currently directed towards reuse outside the EU, open and closed-loop recycling, or end-of-life would be fit for fibre-to-fibre recycling. Additionally, 24% of the TMW sample was deemed recyclable. The current state of recycling technologies mirrors the material composition of the analysed sample. Mechanical recyclers dominate in cotton and cotton-rich materials, while chemical solution providers handle cotton and viscose-rich, as well as polyester, poly-cotton, and polyester-rich blends. It is clear that the recyclability of TIR is not a matter of complex material composition but value chain creation and business case.

However, PCT includes numerous disruptors requiring manual, automated, or semi-automated processing to unlock their potential. Thus, the current and future recyclability of TIR is complex to model and capitalise on. Feedstock prices paid by current destinations (e.g., wipers) are sometimes higher than those offered by fiber-to-fiber recycling facilities, disincentivizing sorters from establishing new collaborations for closed-loop recycling. To scale up PCT recycling, recyclers need access to homogeneous material at scale, which sorters could provide if a positive business case is established.

Used and waste textiles were often ending up in mixed waste, particularly in Romania where they made up 14% of the mixed municipal waste. This suggests that some textiles sorted and placed on the market for local re-use in Eastern Europe may contribute to a higher than EU-average textile waste generation, and points to the need to scale up separate textile waste collection promptly. When discarded as mixed waste, textiles fully lose their reusability or recyclability potential. They become dispersed among large volumes of mixed waste, making them vulnerable to pollution and weather conditions. Their recovery, cleaning, and drying costs cannot be justified by their value, even when their material composition and quality grades identified in this study would otherwise qualify them as recyclable or reusable. This points to a need for a proper sorting at EU sorting centres to ensure effective and durable local re-use.

Sorting for reuse is a highly skilled profession, and it cannot be expected that citizens disposing of textiles will decide whether a garment is more suitable for reuse or recycling. This decision should be made by professional sorters within facilities that act as aggregators of materials and possibly as preparators for recycling or reuse. This decision is based on quality, cultural and market fit, and fluctuating prices between second-hand and waste traders globally managing TIR material streams today.

With the growing amounts of PCT being collected around the EU-27, textile waste management systems need further advancement, alongside harmonised legislation to consolidate regional efforts. Today, low-value textiles are largely exported out of the EU. Even within the EU, there is a movement of waste from higher to lower-income countries and from better-regulated to less-regulated environments. To address this, a sound business case for processing low-value TIR for recycling within the EU is required.

References

Lege Website (2024). Administration of waste depots and/or municipal waste disposal facilities. Available at: https://lege5.ro/Gratuit/gyydgnjsgy/administrarea-depozitelor-de-deseuri-si-sau-a-instalatiilor-de-eliminare-a-deseurilor-municipale-regulament?dp=g43demjuhe4ds#:~:text=Art.,%C5%9Fi%20autoriza%C5%A3iilor%20prev%C4%83zute%20de%20legisla%C5%A3ie

Candido, R.G (2021). Recycling of textiles and its economic aspects. In Fundamentals of natural fibres and textiles (pp. 599-624). Woodhead Publishing.

CBI (2024). The European market potential for recycled fashion. Netherlands Ministry of Foreign Affairs. Available at: https://www.cbi.eu/market-information/apparel/recycled-fashion/market-potential

Consultancy EU (2024). Europe's booming second-hand market to reach €86 billion by 2028. Available at: http://consultancy.eu/

Corertex (2024). Available at: http://corertex.it/

Czech Statistical Office (2024). Population. Available at: https://www.czso.cz/csu/czso/population

Diakonie Broumov.org (2024). Seznam sběrných kontejnerů. Available at: https://diakoniebroumov/

Ecologic (2021). Waste storage and sorting capacities in Romania. Available at: https://ecologic.rec.ro/capacitatile-de-depozitare-si-sortare-a-deseurilor-din-romania/

EcoTessili (2024). About Us. Available at: https://ecotessili.it/en/about-us/

EEA (2022a). Early warning assessment related to the 2025 targets for municipal waste and packaging waste. Czechia. Available at: https://www.eea.europa.eu/themes/waste/waste-prevention/countries/2023-waste-prevention-country-fact-sheets/czechia_waste_prevention_2023

EEA (2022b). Early warning assessment related to the 2025 targets for municipal waste and packaging waste. Italy. Available at: https://www.eea.europa.eu/publications/many-eu-member-states/italy

EEA (2022c). Early warning assessment related to the 2025 targets for municipal waste and packaging waste. Romania. Available at: https://www.eea.europa.eu/publications/many-eu-member-states/romania

EEA (2023). EU exports of used textiles in Europe's circular economy. European Environmental Agency. Available at: https://www.eea.europa.eu/publications/eu-exports-of-used-textiles

EEA (2024). Management of used and waste textiles in Europe's circular economy. Available at: https://www.eea.europa.eu/publications/management-of-used-and-waste-textiles

EigenDraads (2022). Van woorden naar draden. Available at: https://eigendraads.com/1260-2/

ErionTextiles (2024). Available at: https://eriontextiles.it/en/

EUR-LEX (2022). EU strategy for sustainable and circular textiles. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0141

European Parliament (2020). The impact of textile production and waste on the environment. European Parliament. Available at: https://www.europarl.europa.eu/topics/en/article/20201208STO93327/the-impact-of-textile-production-and-waste-on-the-environment-infographics#:~:text=On%20average%20Europeans%20use%20nearly,kilos%20of%20them%20every%20year

Eurostat (2019). Demographic change in Europe — Country factsheets: Romania. Available at: https://ec.europa.eu/eurostat/documents/12743486/14207633/RO-EN.pdf

Fibre2Fashion (2023). Mandatory collection of textile waste from 2025 in the Czech Republic. Available at: https://www.fibre2fashion.com/news/sustainability-news/mandatory-collection-of-textile-waste-from-2025-in-czech-republic-291746-newsdetails.htm

Fondazione per lo Sviluppo Sostenibile (2022). Il riciclo in Italia. Available at: https://www.fondazionesvilupposostenibile.org/wp-content/uploads/dlm_uploads/Il-Riciclo-in-Italia-2022.pdf

Forewear (2024). Available at: https://www.forewear.cz/

Ghana Used Clothing Dealers Association (2024). An evaluation of the socio-economic and environmental impact of the second-hand clothes trade in Ghana. Available at: https://usedclothinggh.org/published-papers/an-evaluation-of-the-socio-economic-and-environmental-impact-of-the-second-hand-clothes-trade-in-ghana/

Gray, S (2017). Mapping clothing impacts in Europe: the environmental cost. WRAP & ECAP. Available at: http://www.ecap.eu.com/wp-content/uploads/2018/07/Mapping-clothing-impacts-in-Europe.pdf

Green-Forum (2024). Romania reuses and recycles up to 10% of textile waste. Available at: https://www.green-forum.eu/environment/20240607/romania-reuses-and-recycles-up-to-10-of-textile-waste-1165

Harta Reciclării (2024). România este în al 12-lea ceas cu gestionarea deșeurilor. Available at: https://hartareciclarii.ro/noutati/romania-este-in-al-12-lea-ceas-cu-gestionarea-deseurilor/

Huygens, D., Foschi, J., Caro, D., Patinha Caldeira, C., Faraca, G., Foster, G., Solis, M., Marschinski, R., Napolano, L., Fruergaard Astrup, T., & Tonini, D (2023). Techno-scientific assessment of the management options for used and waste textiles in the European Union. Publications Office of the European Union, Luxembourg. doi:10.2760/6292, JRC134586.

Instituto Nazionale do Statistica (2024). Experimental statistic: Municipal demographic projections. Available at: http://istat.it/

ISPRA (2022). Rapporto Rifiuti Urbani. Available at: https://www.isprambiente.gov.it/files2022/pubblicazioni/rapporti/rapportorifiutiurbani_ed-2022_n-380_agg-23_12_2022.pdf

Jonasova, S.K., Zoumpalova, T., & Moldan, B (2022). Analysis of the amount of textile waste in mixed municipal waste in the Czech Republic between 2016 and 2021. Waste Forum, 4, 271-283.

Köhler, A., Watson, D., Trzepacz, S., Löw, C., Liu, R., Danneck, J., Konstantas, A., Donatello, S., & Faraca, G (2021). Circular Economy Perspectives in the EU Textile sector. EUR 30734 EN, Publications Office of the European Union, Luxembourg. ISBN 978-92-76-38646-9. doi:10.2760/858144, JRC125110.

Luiza Loredana NĂSTASE (2023). Circularity and Municipal Waste in Romania: An Evaluation between 2011 and 2021. Available at: https://intapi.sciendo.com/pdf/10.2478/picbe-2023-0136

Matoha (2024). Fabrics identification information. Available at: https://matoha.com/fabrics-identification-information

McKinsey (2022). Scaling textile recycling in Europe—turning waste into value. Available at: https://www.mckinsey.com/industries/retail/our-insights/scaling-textile-recycling-in-europe-turning-waste-into-value

Mezzadri, A (2016). Class, gender and the sweatshop: on the nexus between labour commodification and exploitation. Third World Quarterly, 37(10), 1877–1900. https://doi.org/10.1080/01436597.2016.1180239

Ministero della Transizione Ecologica (2023). Tessile/Moda: MASE, per sostenibilità e minore impatto su ambiente arriva la responsabilità estesa del produttore. Available at: https://www.mase.gov.it/comunicati/tessile-moda-mase-sostenibilita-e-minore-impatto-su-ambiente-arriva-la-responsabilita

Prada Group (2022). The RE.CREA Consortium is born. Available at: https://www.pradagroup.com/content/dam/pradagroup/documents/2022/ottobre/inglese/RECREA_ENG (1).pdf

QMagazine (2024). Karina Bolin, HUMANA: Changing Lives Through Disposed Clothes. Available at: https://www.qmagazine.ro/karina-bolin-humana-changing-lives-through-disposed-clothes/

Refashion (2023). Technical monitoring of optical sorting, recognition and disassembly technologies for textiles at European scale. Available at: https://refashion.fr/pro/sites/default/files/rapport-etude/240428_Synth%C3%A8se_Veille-technos-tri-d%C3%A9lissage_VF-EN.pdf

Renewable Matter (2023). Cobat Tessile, a Cross-cutting Approach to EPR. Available at: https://www.renewablematter.eu/en/cobat-tessile-a-cross-cutting-approach-to-epr

Retex.Green (2024). Available at: https://retex.green/

Sandin, G., Peters, G.M (2018). Environmental impact of textile reuse and recycling – A review. Journal of Cleaner Production 184, 353–365. doi:https://doi.org/10.1016/j.jclepro.2018.02.266

Statista (n.d.). Value of the second-hand fashion market in the European Union (EU) from 2017 to 2025. Available at: https://www.statista.com/statistics/1368038/eu-second-hand-fashion-market-size/

Stubbe, B., Van Vrekhem, S., Huysman, S., Tilkin, R.G., De Schrijver, I., Vanneste, M (2023). White Paper on Textile Fibre Recycling Technologies. Available at: https://www.centexbel.be/sites/default/files/node/publication/sustainability-16-00618.pdf

TextileEco (2024). Sběr použitého šatstva. Available at: https://www.textileco.cz/

Textile Exchange (2024). The 2025 Recycled Polyester Challenge was designed to accelerate change. Available at: https://textileexchange.org/2025-recycled-polyester-challenge/

UNEP (2019). UN Alliance For Sustainable Fashion addresses damage of 'fast fashion'. United Nations Environment Programme. Available at: https://www.unep.org/news-and-stories/press-release/un-alliance-sustainable-fashion-addresses-damage-fast-fashion

UNEP (2022). Inside the clean seas campaign against microplastics (no date). UNEP. Available at: https://www.unep.org/news-and-stories/story/inside-clean-seas-campaign-against-microplastics#:~:text=According%20to%20a%202020%20UNEP,and%20washing%20them%20less%20often van Duijn, H., Papú Carrone, N., Bakowska, O., Qianjing, H., Akerboom, M., Rademan, K., Vellanki, D (2022). Sorting for Circularity Europe. Available at: https://reports.fashionforgood.com/report/sorting-for-circularity-europe/

WRAP (2023). Textiles Sorting and Recycling Database. Available at: https://www.wrap.ngo/resources/tool/textiles-sorting-and-recycling-database

List of abbreviations and definitions

EPR	Extended Producer Responsibility (EPR) is a policy tool that extends the producer's financial and/or operational responsibility for a product to include the management of the post-consumer stage, in order to help meet national and European recycling and waste recovery targets. EPR policies thus generally shift the waste management cost or physical collection partially or fully from local governments to producers.
TIR	Textiles intended for reuse and recycling (TIR) are separately collected post-consumer textiles aggregated and processed at sorting facilities.
TMW	Textile waste managed as municipal waste (TMW) are textiles disposed with municipal waste or mixed municipal waste.
MMW	Mixed municipal waste (MMW) also called mixed municipal solid waste, consists of a mixture of waste including general household waste, office waste, waste from retail stores or other businesses, other miscellaneous, and non-hazardous waste.
Open-loop recycling	Open-loop recycling in this report encompasses all reprocessing steps of discarded textiles aimed at creating new consumer or industrial products, in a process that is usually mechanical (cutting, shredding, bonding and more). 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 often of lower economic value than the original source of the material, also known as downcycling. The most common open-loop solutions for post-consumer textiles include the manufacturing of industrial wipers, also known as absorption products.
Industrial wipers	Industrial wipers are made of various compositions, mainly cotton rags that are mechanically or semi-automatically cut into approximately 30 by 30 cm squares, packaged, labelled and then used for cleaning machinery as well as for hand wiping in the industrial setup. The wipers are used in industrial setups and immediately after use become a waste stream of cotton-rich fibre contaminated with industrial dirt, most often oil and similar dirt classified as hazardous waste . Its treatment and disposal is regulated by law. In this route, TIR represents an alternative to wipers made of virgin materials. Manufacturing of wipers entails manual or semi-automated removal of seams, metal and hard plastic disruptors from the garment. The cut-off parts of the garment will become waste and it can be assumed that the wiper manufacturer will direct that waste towards incineration or the RDF management route. The exact proportion of the garment lost when making a wiper is not researched, however, what might serve as an indication, is a common practice of making a

	40x40cm wiper from the back of a men's shirt, with all the rest becoming waste. While denim is not used for wipers, it is also a typical practice to cut off the top part of denim jeans until below the crotch seam to direct only the leg part towards recycling.
Mechanical open-loop recycling	Mechanical open-loop recycling is defined as shredding or garnetting, which is a mechanical process leading to the opening up of the material into a fluffy, fibrous condition fit for the application of these fibres into non-wovens, insulation, automotive filling, furniture filling, mattress filling or other applications, that are not textile to textile applications.
Closed-loop recycling	Closed-loop recycling also known as high-value textile-to-textile recycling encompasses all textile recycling processes (mechanical, chemical and thermochemical) where the output is suitable to be used in similar applications for which it was first developed, meaning in textile applications by effectively replacing some percentage of a primary (virgin) material with the recyclate in garments. The process starts with shredding or cutting garments and home textiles into smaller pieces which then can be treated as valuable feedstock for further mechanical, chemical or thermochemical recycling.
Mechanical closed-loop recycling	Mechanical closed-loop recycling is the process by which textiles are cut, shredded and opened into fibres usable for yarn spinning. Due to shredding, the fibres are shortened, so characterised by shorter staples , which is usually compensated for by blending the recyclate with virgin fibres in order to obtain final yarns that are suitable to be woven or knitted back into quality textile applications. Still, feedstock such as used knitted textiles and denim are currently in high demand from TIR sorters to feed into closed-loop recycling . The mechanical recycling market is mature, with energy- and cost-efficient technologies at scale (see overview in Table 1). Mechanical recyclers mostly process knitted fabric structures, which is why in the data collection process the garment structure will be indicated to be able to more realistically indicate the sample's suitability for recycling.
Chemical closed-loop recycling	Chemical closed-loop recycling is the process by which fibres are broken down to their basic building blocks, either to polymer or monomer levels. There are diverse recycling technologies encompassed under this archetype, including amongst others pulping processes to recycle cotton and viscose, solvent-based processes to recycle polyester and polycotton, to processes such as glycolysis, hydrolysis and enzymatic that take polyester and polyamide back to monomers .
RDF	Refuse-derived fuel (RDF) is a management route for textile products that are finely shredded, often mixed with plastic waste and then used as fuel or co-fuel in incinerators or waste-to-energy infrastructure to produce energy and heat. To be

	sold as RDF, the shredded mix must meet the incinerability standards, such as high calorific value, low moisture, low heavy metal content and low chlorine content. Physical properties of ideal RDF should have a particle size of 10-300 mm and bulk density of 120-300 kg/m3 with 10-30% moisture content. The optimum calorific value should be >8.3 MJ/kg and 75-80% of volatile matter followed by 10-20% ash contentThe average calorific value of RDF in the EU is 15 MJ / kg and on textile waste whether TIR or TMW meets these criteria. ↵

List of figures

List of tables

Annexes

Annex 1. Full description of the sampling and measurement design for TIR and TMW

Study Objectives and Approaches

The study outlines the most prevalent selection criteria for the categorisation of Post-Consumer Textiles (PCT) for reuse, repair, and (fibre-to-fibre) recycling. The study assesses current management routes of Textiles collected separately for Reuse and Recycling (TIR) and Textiles disposed of with mixed waste (TMW) disposed of in Italy, the Czech Republic and Romania - three countries that collect and/or process considerable amounts of PCT but remain without public and extensive quantification analyses of waste flows and composition to date.

Table A1. Study objectives and proposed approaches to meet them

Objective	Approach
Take a representative sample from TMW and TIR in the focus countries;	Apply the project sampling strategy at the facilities of relevant TMW and TIR handlers in the focus countries
Quantify and characterise textiles that end up in mixed solid waste (TMW) and textiles intended for reuse and recycling (TIR) in selected EU Member States;	On-the-ground analysis using NIR technology in TMW and TIR facilities orchestrated by the country partners
Assess the current management routes and financial value of TMW and TIR.	Interviews with implementation partners (TIR and TMW facility representatives).

The above-mentioned objectives will be achieved using the methodologies described in this document.

Methodology

Identifying geographical coverage and focus countries

Due to time and budget constraints, this study focuses on three EU Member States only: Italy, Czech Republic and Romania. Next to TMW and TIR managing facilities in these three countries, the study will include one TIR sorting facility in Bulgaria as well, which processes TIR collected in Italy. The focus countries were selected based on the following stratification drivers:

- **Legislative and governmental settings:** This study assesses the volumes and characteristics of textiles in both municipal waste as well as that which is separately collected. Since multiple countries can be assessed, the study will focus on countries with diverse collection profiles; a country with a well-established textile collection scheme (Czech Republic, with a collection rate of 30%[62]), a country with a lower collection rate (Italy, 11%[63]) and a country where data on collection rates is not available (Romania).

- **Imports of used textiles:** Textiles sorting does not always take place in the country where the textiles were collected. High imports of used textiles indicate the presence of considerable sorting capacity within a country. Out of the 10 top EU importers of used textiles identified in the 2021 JRC study, five had already been analysed through the Sorting for Circularity Europe project (Belgium, Germany, the Netherlands, Poland, Spain, and the United Kingdom). Therefore, this study aims to conduct a complimentary analysis of the nature and volume of textile waste flows in three of the remaining 'top 10 EU importers of used textiles': Romania, Italy and Bulgaria. Since the study aims to investigate textiles originating from three EU Member States and Bulgarian sorters mainly sort imported textiles (from Italy), a fourth top importer was added to the study, the Czech Republic (#11 EU importers of used textiles).

Establishing a representative sample composition for focus countries

To construct the most representative sample of materials in each country we considered the following stratification drivers:

- **Socio-economic conditions:** The level of income highly determines the quantity and quality of textiles consumed, which in turn influences the reuse and recycling potential of the collected textiles. Also, neighbourhoods with citizens with high levels of environmental awareness tend to have higher collection rates than others. These conditions will be discussed with the industrial partners in order to select a sample that is representative of the area as a whole.
- **Demographic conditions:** Consumption and disposal patterns can differ depending on the degree of urbanization and the average age of the population. The sample will be selected based on the origin of materials, using the knowledge of participating industrial partners to define a representative sample.

Samples will be prepared and analysed at waste companies and sorting facilities after collection, handling and storage. As a result, the origin of individual batches or materials will not be traceable to the exact point of collection, as the TMW and TIR facilities operate on a mass balance basis. However, by discussing the stratification drivers with participating industrial partners through the interviews in Phase 1, a representative sample will be combined of volumes from a number of collected batches from across the country in question. The report will include a reflection on the most probable origins of each study sample, and potential implications of over- or underrepresentation of some origins (if applicable).

Establishing a representative sample volume for focus countries

In addition to sample composition, the methodology also considers determining the most effective way to establish a representative sample.

To determine the sample size of statistical significance, we would depend on the desired confidence level of at least 90% (Z = 1.645), an acceptable margin of error of 5% (e = 5%), and the standard

[62] https://publications.jrc.ec.europa.eu/repository/bitstream/JRC125110/jrc125110_ce_perspectives_for_eu_textiles_tr_10.06.2021_final.pdf

[63] JRC, 2021

deviation (σ = 21.68)[64]. Unfortunately, a more reliable standard deviation rate cannot be obtained from any previous comparable study.

$$n \geq \frac{N \cdot Z^2 \cdot \sigma^2}{(N-1) \cdot e^2 + Z^2 \cdot \sigma^2}$$

To calculate the sample size using the formula above, it is important that the baseline data for the characterisations is highly reliable to avoid deviations in the final results. Currently, this baseline data is unavailable or only partially available, for the focus countries, and data about the content of textile waste within mixed municipal waste is not available in Romania.

A detailed segmentation could be applied as depicted in the following Table A2 to reflect socioeconomic backgrounds as well as access to separate textile collection schemes and would require a collection of 20 samples in one season.

Table A2. Overview of strata

	Metropolitan		Urban		Suburban		Rural	
	with a collection scheme	without a collection scheme	with a collection scheme	without a collection scheme	with a collection scheme	without a collection scheme	with a collection scheme	without a collection scheme
Czech Republic	v	v	v	v	v	v	v	v
Italy	v	v	v	v	v	v	v	v
Romania	x	v	x	v	x	v	x	v

To determine the number of samples using the formula above, we would arrive at equal samples needed from each stratum and fraction. This method requires significant planning effort, specifically to be able to access volumes from sampling sites in metropolitan, urban, suburban and rural areas twice a year in all focus countries.
This stratified approach presented above would only be possible if samples were directly collected from street containers. As previously described, the TMW and TIR partners identified in the study agreed to provide materials for sampling in the aggregated form - once they reach the central sorting facility and after they have been mixed during the collection and transport. Therefore, the origin of the sample will be described through the disclosures made in the interviews with the sorting partners.

[64] https://anepma.es/boletin/wp-content/uploads/2021/01/Gu%C3%ADa-composici%E0%B8%82n-de-residuos_v01Ingl%C3%A9s36667.pdf

An annual analysis is normally recommended for reliable waste composition analysis studies. To enable an optimal temporal distribution, the samples should be distributed throughout the year in each quarter. This is impossible due to the total length of the project, and therefore samples will be analysed twice quarterly (November-February, March-June).
It may be argued that collecting detailed regional and subregional data about the volume and nature of textile waste, is only relevant when the envisioned circular pathways are also localised. The majority of circular pathways and processes (whether re-use abroad, open or closed loop recycling) require aggregated, sorted or even homogenised flows to be operational (for example when the minimal capacity of the recycling plant must be met to deliver quality outputs). Therefore the effort required to analyse a large number of smaller samples will be replaced by analysing a small number of larger samples.
Within the given timeline, budget, as well as the availability of the NIR scanners that need to be shared between the focus countries, the study aims to balance the complexity involved in conducting the analysis, against any gains in the representativeness of the samples and therefore the strategies below were identified as the most suitable going forward.

Sampling strategy for TIR

The TIR analysed at sorting facilities will already have been sorted into different product categories, or fractions, before the analysis (the so-called 'main sort'). Fractions are categories by which collected used textiles are sorted for different reuse and recycling purposes, which are sold on different local and global markets and are specific to each facility and regularly updated based on market demand, resale prices, waste shipment regulations and other factors. The facility-specific fraction names will not be shared in the JRC report to protect the strategic know-how of the facilities participating in the study. Instead, the results will be shared using the sample description as outlined in the TIR Protocol and below.

The target TIR sample will consist of:

- Textiles sorted as suitable for re-use in the EU - volume 375 kg per facility
- Textiles sorted as suitable for re-use outside the EU - volume 375 kg per facility
- Textiles sorted as not suitable for re-use, going towards wipers, downcycling and fibre-to-fibre recycling - volume 375 kg per facility
- Textiles sorted as not suitable for re-use going towards energy recovery, incineration or land-filling - volume 375 kg per facility

Participating sorters will nominate in the interviews with country partners the facility-specific fractions to be included in the sample that will correspond to the general categories listed above to create a representation suitable for re-use and not suitable for re-use textiles they process. The textiles will be picked out from non-consecutive bales to diversify the sample. All nominated and selected fractions will be of the same volume (as listed above) to maximise the representativeness of the sample. That means that the sample size is not representative of the relative share of the materials being sorted at the facility.

It is important to understand that a fixed criteria list defining whether the garment is fit for re-use or not does not exist at the moment, however, it is expected to appear soon under the End-of-Waste criteria for re-use publication. It is a common business practice for facilities to have sorting manuals or guidelines and to train the staff diligently on the job to be able to recognise these criteria as efficiently as possible and also to reward staff for excellent productivity or particular skill in recognising products of the highest value. This indicates that the reusability and fit for the particular market, which eventually dictates the price, are based on the subjective decision of the sorter who has to consider: the facility manual, usability, trend, colour, brand and visible damages. These factors are not weighted equally, so for example the usability might be compromised when the trend and brand are a high fit and in demand for a specific market.

Publicly available, schematic assessment sheets do exist, but do not deep dive into the specifics of the garments on the second-hand market, instead only confirming that exact criteria depend on each operator with regard to trademarks, types, quality classes, product age, completeness, and degree of soiling. The only general industry guidelines have been published by Euric Textiles describing the procedure for adequate handling, storage and sorting of textiles, however, they do not reveal any specifics regarding the factors that define the market fit, usability and future management routes of the textiles sorted and therefore we will propose our own criteria of product characterisation as outlined in chapter 3.

Sampling strategy for TMW

The TMW sampling strategy and methodology were developed based on the tested procedure for the waste analysis of mixed municipal waste conducted by INCIEN in the Czech Republic so that the analyses performed are repeatable and the results are based on clearly defined processes. The methodology is based on the Methodology for Determining the Composition of Mixed Municipal Waste from Municipalities and Municipal Waste (Result V4)[65], which was developed by the Brno University of Technology for the Czech Ministry of the Environment as part of the project Forecasting Waste Production and Determining the Composition of Municipal Waste.

Textiles disposed of within the mixed municipal waste represent a majority of all textiles disposed of in focus countries. In the countries with data available, around 38% of new textiles placed on the market were eventually collected separately[66], but it must be recognised that these estimates of the total separate collection are survey-based (and it is rare that all organisations reply) with data only from 6 countries and 1 region[67], including only Czech Republic from our focus country list. In Italy, the rate was recorded based on volumes received in collection banks (without collection rates from second-hand shops) and for Romania, no estimate is available, as only a low share of the population is covered by a high convenience collection service and there are no plans published to increase separate collection for textiles[68].

Differences between focus countries in terms of data available on textile waste generated and collected are displayed below in Table A3.

[65] English version available at https://docs.google.com/document/d/1anxddlbrHv6oYM3x8yyOKAfIOEjWzfo5/edit#heading=h.gjdgxs
[66] https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/729405/EPRS_BRI(2022)729405_EN.pdf
[67] https://publications.jrc.ec.europa.eu/repository/handle/JRC125110
[68] https://www.eea.europa.eu/publications/many-eu-member-states/romania

Table A3. Textile waste collection in focus countries

	Population	Textile waste generated annually	Textile waste collected separately (TIR)	% of textile waste within mixed municipal waste (TMW)
Czech Republic	10,8 mln[69] (2023)	78 k tonnes (JRC, 2021)	15% (14k tonnes) (JRC, 2021)	6.16%[70] (average between 2016-2021)
Italy	58,8 mln[71] (2022)	615 k tonnes (JRC, 2021)	15-20% (277 k tonnes) (McKinsey, 2022)	5%[72] (average between 2014-2019)
Romania	19,4 mln[73] (2019)	149 k tonnes (JRC, 2021) and up to 180 k tonnes (McKinsey, 2022)	15% (27 k tonnes) (McKinsey, 2022)	no capture rates could be calculated because information on the composition of residual waste is not available[74]

To meet the planned sample, each TMW facility must provide waste weighing 1000 kg, which will consist of at least two samples as indicated below. These are normal samples from different types of areas (urban, suburban, rural, houses and flats) mixed together and it will only be possible to identify their origin based on the declaration made in the interview before the analysis.

The target TMW sample will consist of:

- Originating from the designated area / region / district where there are dedicated textile bins - volume 500 kg per facility
- Sample 2: Originating from the area / region / district where there are no dedicated textile bins - volume 500 kg per facility

Unsorted textiles will be hand-picked out of the total 1000 kg sample of mixed waste.

---

[69] https://www.czso.cz/csu/czso/population

[70] https://publications.cuni.cz/bitstream/handle/20.500.14178/1632/WF_4_2022_analysis_of_the_amount_of_textile_waste.pdf?sequence=1&isAllowed=y

[71] https://www.istat.it/en/archivio/resident+population

[72] https://www.eea.europa.eu/publications/many-eu-member-states/italy

[73] https://ec.europa.eu/eurostat/documents/12743486/14207633/RO-EN.pdf

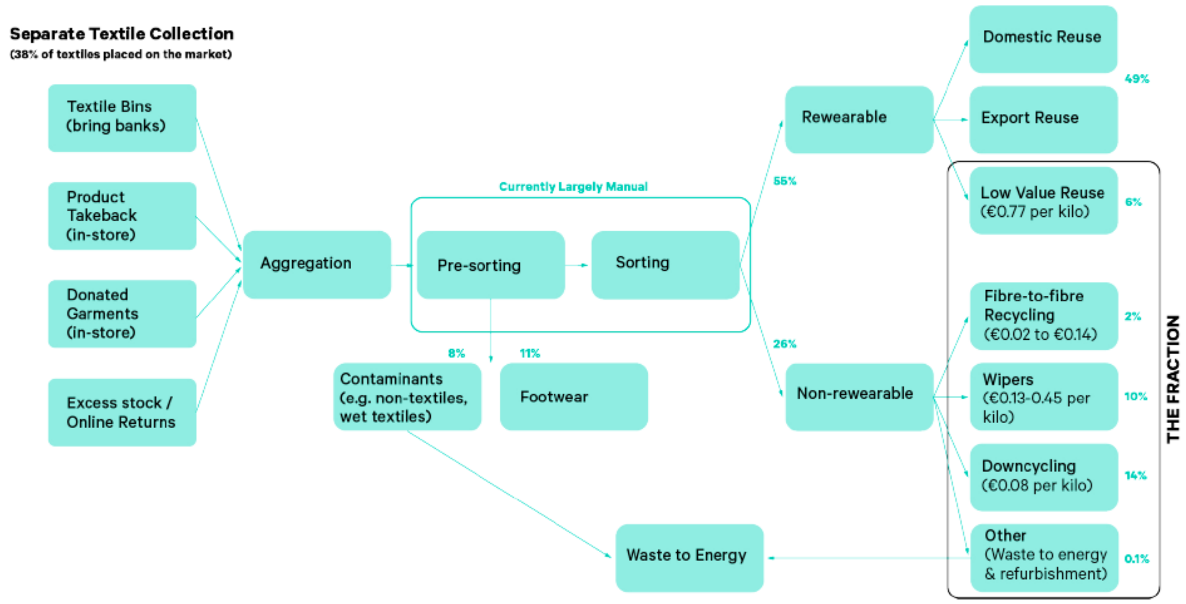
[74] https://www.eea.europa.eu/publications/many-eu-member-states/romania

The study sample will consist of garments and household textiles. Other materials found (mattresses, footwear, or toys) are excluded from the study sample.

Collaborating with country partners on data collection

This study is conducted with collaborating organisations from all three focus countries. The national counterparts of Circle Economy in this study are Humana People to People in Italy and Bulgaria[75], INCIEN in the Czech Republic and the National Research and Development Institute for Textiles and Leather in Romania. At the project start, these national counterparts have been requested to gather country-specific data on textile volumes, sorting capacity and any research findings from previous relevant analyses in the TIR and TMW context. An initial overview of textile flows and destinations will be created for the three countries, similar to the overview generated in the Sorting for Circularity Europe project shown below in Figure A1.

Figure A1. Sorting for Circularity Europe summary, 2022



The initial overview of textile flows will be validated in interviews with implementation partners (TIR and TMW facilities). Together with national counterparts and JRC, a format was created for the Protocols that are signed before kicking off the WP 3 (on-the-ground data collection).

Organisation of sampling campaigns

- *Seasons*

The study will be conducted in TMW and TIR processing facilities in these countries in two seasons: fall/winter - November 2023 to May 2024 and spring/summer 2024 - February to May 2024 to account for seasonal differences in textile composition.

[75] The Humana facility in Bulgaria sorts textiles collected in Italy and therefore while we will conduct analysis there, Bulgaria is not a focus country of this study.

- *Product Characteristics*

The study sample will consist of garments and household textiles. Other materials collected through textile collection schemes (mattresses, footwear, toys and other non-textile accessories arriving at sorting facilities) are excluded from the study sample.

Each garment in the TMW and TIR sample will be characterised through an NIR scan and by manual characterisation of product features. The scan is executed using a Matoha Fabritell device, the result of which will be saved in a dedicated folder on the Matoha cloud and will be accompanied by all the product characteristics. This approach was developed for the Sorting for Circularity Project created by Fashion for Good and Circle Economy and tested in six European countries, India and the USA.

Below is the list of product characteristics that will be tracked on the Matoha app and saved during the on-the-ground analysis.

I. Mono-layer or Multi-layer[76]

II. Material composition (NIR scan or manual input if not recognised by the scanner and legible composition label present)

The scanner can recognise the following pure materials and all two-component blends of these materials (in 1% increments, usually ±10%):

- Cotton
- Polyester
- Viscose
- Wool
- Elastane
- Polyamide
- Silk
- Acrylic
- Acetate

For the purpose of the Sorting for Circularity Project and to improve its identification performance, the detection algorithms of the Matoha FabriTell scanners have been adjusted based on the NIR footprints of the reference textile materials library developed by Refashion and Terra in 2021. It is therefore expected that the material compositions that can be found in the Refashion textile materials library should be more accurately recognised by the scanner.

III. Product type

The following product categories are based on a simplified version of Refashion's product categories (those tracked for the purpose of the EPR in France). These were tracked during the analysis in the Sorting for Circularity Project and are proposed for this analysis as well. A first selection will require a choice of age (see below) followed by a second and third choice in terms of the product category (as indicated in Table A4 below).

[76] Products that are made from more than one distinct layer, each of which may be composed of different materials. 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 Matoha app.

The product user's age is used to estimate the product weight. Product weight estimations have been collected from brands who collaborated in the Sorting for Circularity study and calibrated during the data collection. This approach enables the analysis of a larger sample by avoiding the weight measurement of every item.

Table A4. Product categories recorded

Age	Category label	Product category	List of products within category
Adults	Tops	Coats	Coat, large jacket type coat, cape, poncho, duffle-coat, canadian, overcoat, pea coat, parka, winter jacket (bomber, teddy, etc) - excluding denim
Adults	Tops	Lightweight jackets	Windstoppers, blazers, light jacket, waistcoat under jacket, ultralight down jacket, poncho jacket, workwear jackets - excluding denim
Adults	Tops	Heavy jackets	Ski jacket, big puffer jacket (short, long, with or without sleeves), ski suit, quilted jackets, leather jackets - excluding denim
Adults	Tops	Denim jackets	Only denim jackets, blazers, overcoats
Adults	Tops	Shirts, blouses (woven)	Shirt, blouse, blouse, tunic, other woven top
Adults	Tops	T-shirts and polos (knits)	T-shirt (whatever its shape: wrap, top with straps, halter top, V-neck, round neck, tank top, etc.), polo shirt (long and short sleeves), rugby polo shirt, undershirt, sports jersey , technical T-shirt (thermal / UV) or other knitted t-shirts (eg. jersey, morley, piqué).
Adults	Tops	Waterproof rainwear	Waterproof trench coat, rain cape, rain poncho
Adults	Tops	Sweaters (knits)	Heavy or light knit sweater (long sleeves, short sleeves, sleeveless, poncho sweater, turtleneck, V-neck, round neck), sweatshirt, bolero, fleece hoodies, cardigans, jumpers, tracksuit top, jogging top - excluding large jacket types coat
Adults	Bottoms	Sports trousers (knits)	Sweatpants or jogging pants, leggings, jeggings, tregging, tapered pants, long johns - excluding denim
Adults	Bottoms	Trousers (woven)	Pants, capris, knickers, jodhpurs, fatigues, chinos, harem pants - excluding denim
Adults	Bottoms	Denim trousers	Pants, capris, knickers, jeans, jodhpurs, fatigues, chinos, harem pants - all in denim

Adults	Bottoms	Skirts	Skirt, culottes, petticoat - including tulle skirt (tutu type)
Adults	Bottoms	Shorts, Bermuda shorts	Shorts, Bermuda shorts up to knee length - excluding denim
Adults	Bottoms	Denim skirt	Skirt, culottes - all in denim
Adults	Bottoms	Denim shorts	Shorts, Bermuda shorts up to knee length - all in denim
Adults	Underwear	All bottoms	Panties, briefs, thongs, boyshorts, hipster, bodysuit, boxer shorts, boxer briefs - including sheathing, sheath, panty, shaping jumpsuit, period panties - excluding long underwear
Adults	Underwear	Bras and lingerie	Bra (half cup, push-up, full cup, bandeau, shell, brassiere, etc), top with integrated bra, corset, waist cinche, bustier, camisoles, garter belt, leotards
Adults	Underwear	Swimwear	Swim brief, swimming trunks, one-piece swimsuit including neoprene, two-piece swimsuit, tankini, neoprene top, neoprene jacket - excluding T- UV and off shirt Full neoprene suit (only)
Adults	Underwear	Socks and hosiery	socks, hosiery
Adults	Overall	Jumpsuits, overalls (including workwear)	Jumpsuit, short jumpsuit, overalls, one-piece workwear (overalls, jumpsuits, aprons) -excluding denim and ski suits
Adults	Overall	Denim dresses, overalls and jumpsuits	Long, short, midi dress, ceremony dress, cocktail dress, evening dress, Jumpsuit, short jumpsuit, overalls, one-piece workwear (overalls, jumpsuits, aprons) - all in denim
Adults	Overall	Home wear	Kimono, negligee, night gown, pajama sets, nightgown, loungewear
Adults	Overall	Dresses	Long, short, midi dress - including sweater dress -, ceremony dress, cocktail dress, evening dress - including wedding dress
Adults	Overall	Reflective safety wear	Reflective safety waistcoats, jackets, pants, jumpsuits
Adults	Overall	Costumes and disguises	Costumes and disguises (e.g. halloween costumes and accessories)

Children	Tops	Coats	0-14 years old. Coat, large jacket type coat, cape, poncho, duffle-coat, canadian, overcoat, pea coat, parka, winter jacket (bomber, teddy, etc) - excluding denim
Children	Tops	Lightweight jackets	0-14 years old. Windstoppers, blazers, light jacket, waistcoat under jacket, ultralight down jacket, poncho jacket, workwear jackets, blousons - excluding denim
Children	Tops	Heavy jackets	0-14 years old. Ski jacket, big puffer jacket (short, long, with or without sleeves), ski suit, quilted jackets, leather jackets - excluding denim
Children	Tops	Denim jackets	0-14 years old. Only denim jackets, blazers, overcoats
Children	Tops	Shirts, blouses (woven)	0-14 years old. Shirt, blouse, blouse, tunic, other woven top
Children	Tops	T-shirts and polos (knits)	0-14 years old. T-shirt (whatever its shape: wrap, top with straps, halter top, V-neck, round neck, tank top, etc.), polo shirt (long and short sleeves), rugby polo shirt, undershirt, sports jersey , technical T-shirt (thermal / UV) or other knitted t-shirts (eg. jersey, morley, piqué).
Children	Tops	Waterproof rainwear	0-14 years old. Waterproof trench coat, rain cape, rain poncho
Children	Tops	Sweaters (knits)	0-14 years old. Heavy or light knit sweater (long sleeves, short sleeves, sleeveless, poncho sweater, turtleneck, V-neck, round neck), sweatshirt, bolero, fleece hoodies, cardigans, jumpers, tracksuit top, jogging top - excluding large jacket types coat
Children	Bottoms	Sports trousers (knits)	0-14 years old. Sweatpants or jogging pants, leggings, jeggings, tregging, tapered pants, long johns - excluding denim
Children	Bottoms	Trousers (woven)	0-14 years old. Pants, capris, knickers, jodhpurs, fatigues, chinos, harem pants - excluding denim
Children	Bottoms	Denim trousers	0-14 years old. Pants, capris, knickers, jeans, jodhpurs, fatigues, chinos, harem pants - all in denim
Children	Bottoms	Skirts	0-14 years old. Skirt, culottes, petticoat - including tulle skirt (tutu type)
Children	Bottoms	Shorts, Bermuda shorts	0-14 years old. Shorts, Bermuda shorts up to knee

			length - excluding denim
Children	Bottoms	Denim skirt	0-14 years old. Skirt, culottes, petticoat - all in denim
Children	Bottoms	Denim shorts	0-14 years old. Shorts, Bermuda shorts up to knee length - all in denim
Children	Underwear	All bottoms	0-14 years old. Panties, briefs, boyshorts, bodysuits, boxers, boxers
Children	Underwear	Bras and lingerie	0-14 years old. Bras for little girls
Children	Underwear	Swimwear	0-14 years old. Swim brief, swimming trunks, one-piece swimsuit including neoprene, two-piece swimsuit, tankini, neoprene top, neoprene jacket - excluding T-UV and off shirt Full neoprene suit (only)
Children	Underwear	Socks and hosiery	0-14 years old. socks, hoisery
Children	Overall	Jumpsuits, overalls (including workwear)	0-14 years old. Jumpsuit, short jumpsuit, overalls - excluding denim and ski suits
Children	Overall	Denim dresses, overalls and jumpsuits	0-14 years old. Jumpsuit, short jumpsuit, overalls - excluding denim and ski suits
Children	Overall	Home wear	0-14 years old. Kimono, negligee, night gown, pajama sets, nightgown, loungewear
Children	Overall	Dresses	0-14 years old. Long, short, midi dress - including sweater dress -, formal dress
Children	Overall	Reflective safety wear	0-14 years old. Reflective safety waistcoats, jackets, pants, jumpsuits
Children	Overall	Costumes and disguises	0-14 years old. Costumes and disguises (e.g. halloween costumes and accessories)
Babies	-	Clothes	0-3 years. Jumpsuit, pilot, over-pajamas, coat, shirt, t-shirt, romper, sweater, bloomers, blouse, waistcoat, sweatshirt, dress, overalls, pants, shorts, leggings, polo shirt , jogging, growsuits, pajamas, bodysuits
Babies	-	Underwear and accessories	0-3 years. Panties, bib, hat, scarf, cloth diapers, slippers, socks, tights, gloves
Accessories	-	Medium accessories	Scarf, shawl, scarf, stole, chèche, snood, choker, sarong

Accessories	-	Hats and headwear	Hat, beret, bob, cap, toque, balaclava, visor, beanie, chapka and headgear in general
Accessories	-	Gloves and mittens	Gloves for protection against the cold, fashion accessory, gardening, sport, welding, or mittens for use as washcloth - including exfoliant, oven mitt, potholder, cleaning glove (microfibre or other), scrub glove
Accessories	-	Small accessories	Tie, bow tie, mock collar, mock cuff, fabric belt, pocket square, mantilla, suspenders, handkerchief
Other	-	Fabrics by the metre	Fabrics by the metre for clothes (3 yards = 1 pcs) or for curtains, mosquito net, bed linen, bath linen, table linen (3 metres = 1pcs)
Other	-	Household linen	Covers, Duvet covers, Bed linen, Table linen, Curtains, Sheets, Pillow/bolster cases and protective covers, Bath linen and carpet (wet area), Towels, Tablecloths, Napkin, Placemats, Shades
Other	-	Other	Articles that do not fit any of the categories above

IV. Disruptors to recycling

For each product a multichoice menu is available on the Matoha app for the sorter to indicate the types of disruptors present in the garment, being: Metal, Plastic, Fabric, Embroidery, Other and None in case of no disruptors at all. Different apparel accessories have been classified as examples of disruptors in Table A5 below and will be introduced to sorters (with images) during the training, which will be conducted at each facility at the start of the analysis by the country partners, to enable a correct classification.

The correct classification of the types of disruptors present will serve during the data analysis to indicate the recyclability of the product with the assumption that metal and plastic hardware are removable disruptors suitable to be removed prior to recycling activities, while 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. This excludes the lurex thread which is metal, but is considered non-removable and constitutes approximately 1% of all textiles. Maintaining this classification enables us to obtain results comparable to those yielded in the Sorting for Circularity studies.

Table A5: Examples of disruptors and classification

Metal Disruptors Examples	Fabric Disruptors Examples
Zipper	Elastic
Button	String

Rivet	Ribbon
Hook and bar	Patch
Fastener	Pompon (if different than the main fabric)
Buckle	Insert/Yoke (if different than the main fabric)
Snap button	Pocket (if different than the main fabric)
Carabiner	
Hook and eye	Other Disruptor Examples
Underwire (bra)	Leather
Eyelet or Ring	Fur
Charm	Pendant (multiple materials)
Lurex Thread	Print
Sequin	Brandenburg trim (wood)
Plastic Disruptors Examples	
Zipper	Buckle
(snap) Button	Pearl
Reflective strip	Beads
Velcro	
Epaulette	
Collar support	
Fastener	

V. Reusability

For the purpose of this study the following single-choice question will be added to characterize the reusability levels of textiles in the TIR and TMW sample in order to add more nuance to the currently existing knowledge regarding customer textile disposal behaviour. The reusability scale presented below in Table A6 is inspired by Anna Schytte Sigaard and has been applied in multiple picking analyses of textiles.

Table A6 : Reusability scale

Reusability	Grade 1	Not usable (fully damaged)	Multiple stains, multiple holes, missing buttonnes and/or broken zippers, including clothes impossible to identify (mutilated)
Reusability	Grade 2	Barely usable (major damages)	Multiple stains and holes, missing button and/or zippers but the garment possible to identify, however, the garment would require significant interventions to be reusable.
Reusability	Grade 3	Noticeable damages	Few and small stains or holes and/or some discolouration and/or pilled or thinned to a major extent.
Reusability	Grade 4	Minor damages	An item is visibly worn with perhaps minor hole(s) or stain(s) or fabric being to a minor extent thinned or pilled (not all of these factors together).
Reusability	Grade 5	Perfect condition	New items with tags, without tags, or like new. No visible damages.

VI. Moist

For the purpose of this study the additional single choice YES / NO question will be added to collect data regarding the moisture of textiles in the TIR and TMW samples. Instead 'moist' could also be added in the Matoha App under the iv. Disruptors multichoice menu above.

VII. Volumes

Budget and time constraints limit the size of the sample that can be analysed. Based on the previous research, the estimated capacity for the on-the-ground analysis of TMW is 10 kilos of municipal waste per man hour (Incien, 2023) and 22 kilos of TIR per man hour (Fashion for Good & Circle Economy, 2022). Based on 8 man-days per facility per season, and taking into account the time needed for training and startup of the on-the-ground activities, the sample size per season per facility is expected to be 1,000 kilos of municipal waste and 1,500 kilos of TIR.

Therefore, the total sample size analysed in this study for all three countries combined could amount to 6,000 kilos of municipal waste and 12,000 kilos of TIR (as specified in Table A7 below). This study includes three municipal waste facilities (1 per country) and four TIR sorting facilities (two facilities sorting Italian PCT, one facility sorting Czech PCT, one facility sorting Romanian PCT). The study will be conducted at two facilities sorting Italian PCT to account for the higher volume of PCT collected in that country, explained in more detail in the section on multipliers below.

Table A7. Overview of TMW and TIR samples to be analysed in this study

Fall/winter 2023	Type	Month	Hours	Sorters	kg
Italy	Training	Oct 2023	8	8	-
Italy	TIR facility	Nov 2023	8	8	1500
Italy	TMW facility	Nov 2023	8	8	1000
Bulgaria (sorting Italian textiles)	TIR facility	Nov 2023	8	8	1500
Romania	TMW facility	Dec 2023	8	8	1000
Romania	TIR facility	Jan 2024	8	8	1500
Czechia	TMW facility	Jan 2024	8	8	1000
Czechia	TIR facility	Feb 2024	8	8	1500
Spring/summer 2024					
Italy	TIR facility	Feb 2024	8	8	1500
Italy	TMW facility	Mar 2024	8	8	1000
Bulgaria (sorting Italian textiles)	TIR facility	Mar 2024	8	8	1500
Romania	TMW facility	Apr 2024	8	8	1000
Romania	TIR facility	Apr 2024	8	8	1500
Czechia	TMW facility	May 2024	8	8	1000
Czechia	TIR facility	May 2024	8	8	1500
Total Sample Size					**18000**
	TIR				12000
	TMW				6000

VIII. Productivity

Productivity is a decisive factor determining the size and diversity of the sample that can be tackled. In the Sorting for Circularity Europe study, the productivity in the TIR analysis was 41 seconds per scan, which translates to approximately 22 kilos of textiles per person, per hour. The type of feedstock sorted and the functionalities of the software used for inputting garment characteristics were two elements that impacted the productivity of the process. The latter element was significantly improved after the first analysis. In all, depending on the feedstock analysed, a productivity of 700 - 900 scans per hour was achieved with 10 professional sorters. This time was spent mostly on manually entering information about each garment - the actual NIR scan time is 1 second per scan. The number of fractions included in each of the samples is also expected to impact the total sample size that will be reached at each facility.

For the TMW analysis, the productivity is foreseen at 10 kilos of municipal waste per man hour based on existing tested approaches[77]. Here the analysis time will be mostly spent on unpacking waste-picking textiles and separating textiles suitable for the analysis, but no time will be spent on switching from one sub-sample to another, as there are only 2 sub-samples for TMW and 4 sub-samples for TIR.

IX. Extrapolation

The sample data will be extrapolated to country-level volume estimates, using weight data from PCT collected in the focus countries available through prior literature. A multiplier indicates the number of times the characteristics of one item were used to generate an estimate of the composition of country-level volumes. The multiplier is calculated by dividing the volume of textiles collected in a country by the sample volume. A lower multiplier is beneficial since the sample will need to be extrapolated less to calculate country-level equivalents. For instance: an item weighing 0.250 kg with a multiplier of 33,000 would account for 8,250 kilos in the country-level volume (33,000 times the sample volume).

The average country multipliers in the Sorting for Circularity study ranged from 43,193 (Germany) to 7,158 (Belgium). Table A8 below shows the projected country multipliers for this study based on the sample volumes of TIR offered. The table only includes the multipliers used for TIR, since the Sorting for Circularity study only assessed quantities and characteristics of these textiles.

Table A8: Overview of PCT collected in project countries and average multipliers proposed

Country	**Volume of PCT collected (tonnes/year)**	**Sample volume of TIR (kilo)**	**Average multiplier (-)**
Italy	146,000	6,000	24,333
Czech Republic	20,000	3,000	6,667
Romania	30,360	3,000	10,120

As illustrated in the table above, the offered sample volumes of TIR result in similar multipliers as the research conducted in the Sorting for Circularity Europe project. The sample size suggested for

[77] Incien, 2023, https://www.mzp.cz/C1257458002F0DC7/cz/metodika_stanoveni_sko_ko/$FILE/OODP-V4_Metodika_slozeni_final-20211101.pdf

the quantification and characterisation of TMW of 3,000 kilos of municipal waste per country is in line with previous studies conducted on this topic by Incien[78].

Analysis steps for TIR

The steps of the detailed TIR analysis will follow the actions below:

1. Selecting the correct fraction name being scanned. The different fractions for each facility must be defined in the operational protocol and must be added to the Matoha app prior to the start of the analysis. The preferred names are following the naming system Facility name_Fraction name_date.

2. Bunch the fabric and place it over the sensor of the NIR scanner. The screen will display the composition of the item (i.e. 100% cotton or 57% acrylic/43% cotton)

3. When the scanner identifies the composition, it automatically appears on the tablet or smartphone connected to the scanner. Here, the product categories must be tracked and saved on the Matoha app. Product characteristics like type of garment or item, colour and presence of disruptors are captured in the app through a predefined survey. In case the necessary characteristic is not predefined in the app, the sorter can, but is not requested to, insert the information in an adaptable field.

4. If the item consists of more than one layer, the layers must be scanned and tracked separately. Through the app, the second scanned layer must be added to the categorisation of the first layer by clicking on the button "Add to previous sample".

5. If the scanned item provides an “unknown” result on the NIR scanner’s display screen, the sorters must input the composition claims manually on the Matoha app, as seen on the care label of the item. If the care label is missing or not legible, only the product category information must be tracked on the Matoha app.

In the data analysis, the data inputs classified as unknown will be excluded from the dataset. In the previous study, the unknown result was 2% (Fashion for Good and Circle Economy, 2022).

Analysis steps for TMW

The TMW sampling will happen one day before the analysis, therefore it is necessary to obtain information from the TMW facility representative through an interview and by filling in the TMW Protocol. The steps of the detailed TIR analysis will follow the actions below.

1. The sample identified will be stored away overnight under the roof in containers or bins. On the analysis day, the sample will be first weighted to ensure it is the exact desired size and then it will be spread on the ground and unpacked to begin the picking process.

2. There needs to be enough tables for max. 8 sorters and max 2 coordinators to work there.

[78] https://www.mzp.cz/C1257458002F0DC7/cz/metodika_stanoveni_sko_ko/$FILE/OODP-V4_Metodika_slozeni_final-20211101.pdf

First sorters will pick out textile waste from the mixed municipal waste and put it into designated bins and then they will scan each article and describe it following the methodology. This is done to make the process more efficient and avoid the scanners becoming dirty from the waste being analysed. The sorting workplace needs at least 1 power socket per sorter, a stable Wi-Fi connection, access to toilets, and a water source.

3. The facility manager is responsible for providing the following equipment: extension cords, an industrial scale, empty containers for waste other than textiles, empty boxes for weighing, tarps, tables, bags, gloves, protective suits, face masks, first aid kit, and disinfectant sufficient for all the staff working on the analysis. If any of these are not available, this needs to be communicated ahead of time.

4. During the analysis, textile waste is taken to the analysis site where it will be scanned and the data will be manually collected in the same order as for TIR.

5. Upon the completion of the data collection, the total TMW sample will be weighed.

In the TMW a high percentage of soiled and humid textiles is anticipated. Three approaches can be taken:

a. **Washing and drying the TMW sample:** Washing and drying was the approach used by the Sorting for Circularity USA research team and provides a reliable indication of the waste composition, however, is time and energy-consuming and delivers an overly positive result, by adding potentially reusable and recyclable textiles to the sample which would not be fit for these processes under normal conditions. Therefore approach a. will not be applied.

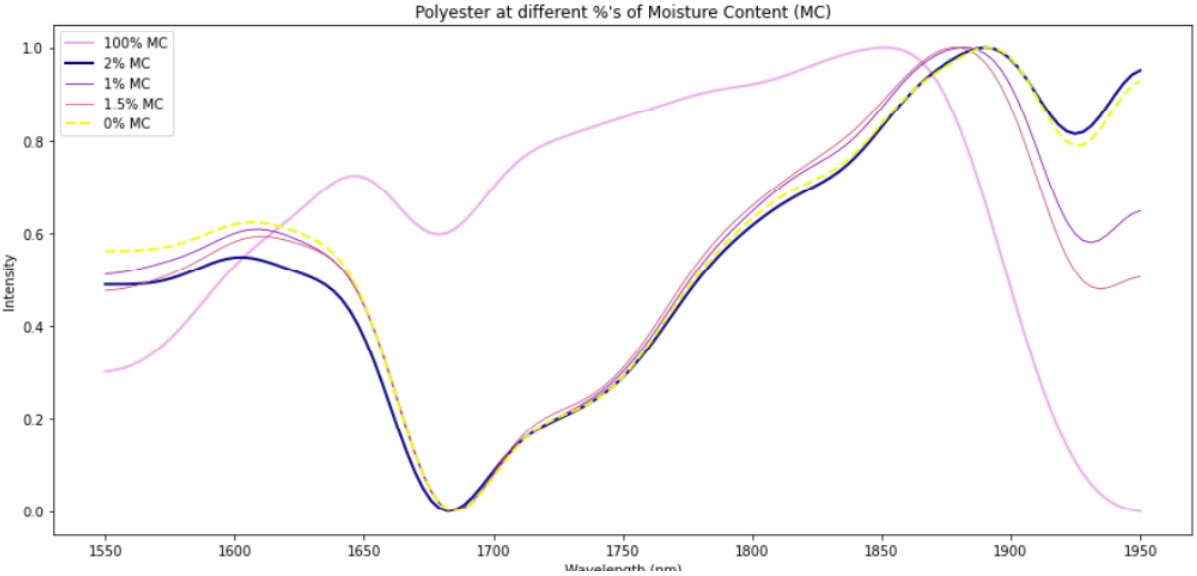
b. **Scanning all the textiles including the wet ones and establishing the way to manipulate the material composition results obtained through NIR scanning in order to obtain verified results and adding composition manually as indicated on the label:** Approach b. is currently not possible due to a lack of data on the exact difference in NIR spectrum measurement reading between different moist content levels for different fibres.

c. **Scanning only the suitable textiles that are not too soiled and not too wet and adding composition manually as indicated on the label:** Figure A2 represents to what extent the presence of water changes the results of the NIR spectrum result of the Matoha Fabritell device. The tests have been conducted on a 100% polyester sample, but it is assumed that the same applies to other samples. It has been tested that for the 100% moisture content (i.e. dripping wet), the machine gives an unknown result as the spectrum is completely different.

   It is advised to follow the approach c. as the machine is not guaranteed as waterproof so applying excessively wet samples is not advised. At the same time, for moderately moist samples, as indicated by Figure A2, the results of the measurement are reliable for the moist content between 0 and 2%. However, it is difficult, if not impossible, to separate the effect of water presence from other contaminants present like elastane. So for example it will not be clear whether the contaminant % identified by the machine is water presence or the presence of other fibers. Matoha Fabritell does not contain a moisture sensor at the moment, so the exact analysis of the level of moisture would be only based on the hand feel of the sorter.

Option c. is also the most desired as it limits the risk of contaminating the sensor. Whenever that happens, it must be cleaned with a piece of clean cloth.

Figure A2. NIR readings of the 100% polyester sample at different % of moisture content by Matoha Fabritell



Annex 2: Study limitations

Human error

Whilst NIR scanners allow for the automated recognition of the composition of textiles, the outcomes of this Project have been prone to human error as the data from the scanners were complemented with information on other characteristics of the textile product using an app. This was information about product type (which determined the average product weight), moisture, number of layers and presence of disruptors. 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 data collection process, similarly to sorting, is a multi-hour, repetitive activity, where human error is impossible to avoid. With the number of hours worked, the productivity increases, until it settles on a stable level, but also the number of mistakes is higher at the start and at the end of the day due to firstly the newness of the process and later due to the fatigue. The list of errors that have led to data points being erased from the dataset is listed in Annex 4.

Volumes estimation

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 were 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 Refashion, resulting in the average weight per product type shown in Annex 3. 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 technology limitations

NIR-based technologies enable efficient recognition of the composition of textiles, but there are limits to their accuracy. The thickness and colour of the fabric scanned as well as the presence of coatings and finishes can reduce the accuracy of the composition analysis of the NIR scanners used. In this analysis blends were only recognised up to 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 (below 5%) is a major limitation of NIR technologies considering the abundant presence of elastane in textiles sold on the market. Another limitation is its inability to detect composition when textiles are dyed with carbon black ink[79].

Extrapolation to country volumes

To extrapolate the identified recyclable feedstock estimate to country TIR volumes an average multiplier can be used of 24,333 for Italy, 6,667 for the Czech Republic and 10,120 for Romania.

This means every item scanned was counted 13,703 times on average to constitute an estimate of the recyclable feedstock available. Analysing 12,000 kgs of TIR is a vast endeavour, and whilst this is a considerable research sample its representativity for the total TIR volume (estimated at 318,000 tonnes per year across 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.

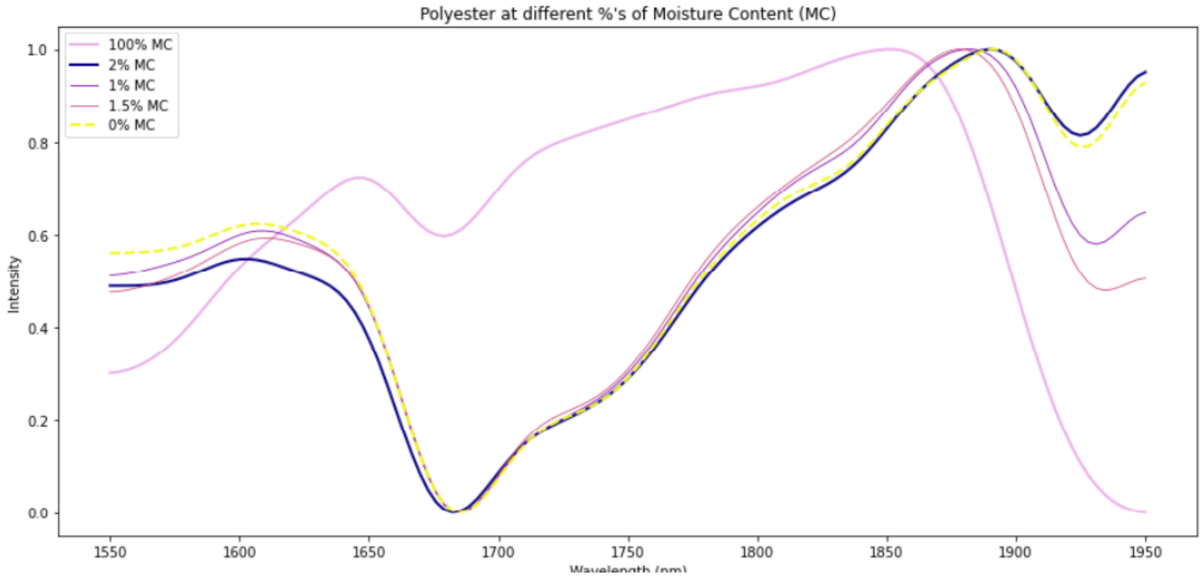
NIR technology and the polluted TMW samples

So far limited studies have been conducted on the recyclability of TMW. The NIR technology is operating only in TIR collection and sorting environments, where the polluted, wet or soiled textiles are removed in the first sort. In this study, the country leads and their staff scanned all samples that were reasonably dry, however, the exact levels of moisture were not measured and therefore the composition indication of TMW is likely inexact.

For the 100% moisture content (i.e. dripping wet), the machine gives an unknown result as the spectrum is completely different. For dry or moderately wet samples that were collected in this study, as indicated by Figure A3, the results of the measurement are reliable for the moist content between 0 and 2%. However, it is difficult, if not impossible, to separate the effect of water presence from other contaminants present like elastane. So for example it will not be clear whether the contaminant % identified by the machine is water presence or the presence of other fibres.

[79] Matoha. (2024) Fabrics identification information. Retrieved from: Matoha website

Figure A3. NIR readings of the 100% polyester sample at different % of moisture content by Matoha Fabritell



Annex 3. Quality requirements for the management of TIR and TMW

Introduction

With this document, we aim to provide an overview of the criteria applied during the sorting stage of TIR and propose minimum requirements for the quality of used textiles for different management routes including re-use, open and closed-loop, mechanical and chemical recycling.

Management routes for TIR and TMW explained

It is recognised that waste prevention and following the waste hierarchy[80] is the priority under the Waste Framework Directive and therefore the preparation for reuse and reuse are the prioritised activities of TIR sorters. At the same time, new standards and activities need to be defined and promoted to increase the share of used textiles directed towards recycling. This approach is reflected in the sample analysed across focus countries, which contains four equal sub-samples listed below.

- Textiles sorted as suitable for re-use in the EU
- Textiles sorted as suitable for re-use outside the EU
- Textiles sorted as not suitable for re-use, going towards wipers and open and closed loop recycling
- Textiles sorted as not suitable for re-use going towards energy recovery, incineration or landfilling

Garments collected and sorted as unfit for re-use in their original form and those made of multiple layers[81] will be subject to management routes listed below. Before any of the routes can be realised (except for ultimate waste), all disruptors (as defined in D1) must be removed in a mechanical, or semi-automated process and could also be done manually.

Management Routes explained

Open-loop recycling in this report encompasses all reprocessing steps of discarded textiles aimed at creating new consumer or industrial products, in a process that is usually mechanical (cutting, shredding, bonding and more). 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 often of lower economic value than the original source of the material, also known as downcycling. The most common open-loop solutions for post-consumer textiles include the manufacturing of industrial wipers, also known as absorption products.

- Industrial wipers are made of various compositions, mainly cotton rags that are mechanically or semi-automatically cut into approximately 30 by 30 cm squares, packaged, labelled and then used for cleaning machinery as well as for hand wiping[82] in the industrial setup.

[80] https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en
[81] At the moment multilayered garments are only directed towards re-use or disposal and not considered feedstock for recycling as the time and cost of obtaining material for recycling from one or both of the layers is too high.
[82] Henry Day (n.d.). WASTE TEXTILE TERMS AND DEFINITIONS. Available online: https://www.henryday.co.uk/documents/Waste-Textile-Terms-and-Definitions.pdf

The wipers are used in industrial setups and immediately after use become a waste stream of cotton-rich fibre contaminated with industrial dirt, most often oil and similar dirt classified as hazardous waste[83]. Its treatment and disposal is regulated by law. In this route, TIR represents an alternative to wipers made of virgin materials.

Manufacturing of wipers entails manual or semi-automated removal of seams, metal and hard plastic disruptors from the garment. The cut-off parts of the garment will become waste and it can be assumed that the wiper manufacturer will direct that waste towards incineration or the RDF management route. The exact proportion of the garment lost when making a wiper is not researched, however, what might serve as an indication, is a common practice of making a 40x40cm wiper from the back of a men's shirt, with all the rest becoming waste. While denim is not used for wipers, it is also a typical practice to cut off the top part of denim jeans until below the crotch seam to direct only the leg part towards recycling.

- Mechanical open-loop recycling[84] is defined as shredding or garnetting, which is a mechanical process leading to the opening up of the material into a fluffy, fibrous condition fit for the application of these fibres into non-wovens, insulation, automotive filling, furniture filling, mattress filling or other applications, that are not textile to textile applications.

Closed-loop recycling also known as high-value textile-to-textile recycling encompasses all textile recycling processes (mechanical, chemical and thermochemical) where the output is suitable to be used in similar applications for which it was first developed, meaning in textile applications by effectively replacing some percentage of a primary (virgin) material with the recyclate[85] in garments._The process starts with shredding or cutting garments and home textiles into smaller pieces which then can be treated as valuable feedstock for further mechanical, chemical or thermochemical recycling.

- Mechanical closed-loop recycling is the process by which textiles are cut, shredded and opened into fibres usable for yarn spinning. Due to shredding, the fibres are shortened, so characterised by shorter staples[86], which is usually compensated for by blending the recyclate with virgin fibres in order to obtain final yarns that are suitable to be woven or knitted back into quality textile applications. Still, feedstock such as used knitted textiles and denim are currently in high demand from TIR sorters to feed into closed-loop recycling[87]. The mechanical recycling market is mature, with energy- and cost-efficient technologies at scale (see overview in Table A9).

  Mechanical recyclers mostly process knitted fabric structures, which is why in the data collection process the garment structure will be indicated to be able to more realistically indicate the sample's suitability for recycling.

- Chemical closed-loop recycling is the process by which fibres are broken down to their basic building blocks, either to polymer or monomer levels. There are diverse recycling technologies encompassed under this archetype, including amongst others pulping processes to recycle cotton and viscose, solvent-based processes to recycle polyester and polycotton, to

[83] https://lindstromgroup.com/services/industrial-wipers/
[84] Textile Exchange (n.d.). Glossary. Available online: https://textileexchange.org/glossary/
[85] https://publications.jrc.ec.europa.eu/repository/handle/JRC131531
[86] https://recoverfiber.com/newsroom/recover-and-rieter-lead-sustainable-innovation
[87] Sorting for Circularity, 2022

processes such as glycolysis, hydrolysis and enzymatic that take polyester and polyamide back to monomers[88].

Refuse-derived fuel (RDF) is a management route for textile products that are finely shredded, often mixed with plastic waste and then used as fuel or co-fuel in incinerators or waste-to-energy infrastructure to produce energy and heat.[89] To be sold as RDF, the shredded mix must meet the incinerability standards, such as high calorific value, low moisture, low heavy metal content and low chlorine content.[90] Physical properties of ideal RDF should have a particle size of 10-300 mm and bulk density of 120-300 kg/m^3 with 10-30% moisture content. The optimum calorific value should be >8,3 MJ/kg and 75-80% of volatile matter followed by 10-20% ash contentThe average calorific value of RDF in the EU is 15[91] MJ / kg and on textile waste whether TIR or TMW meets these criteria.[92]

Ultimate waste is a management route for wet, damp, significantly soiled, stained and damaged textile products which are not fit to be sold in any of the above markets, or when there is no incineration capacity in the region.

Previous research[93] confirms that the TIR sample will represent the four of the management routes as listed above, excluding the ultimate waste, which is normally removed in the main sort upon arrival to the facility. The TMW could theoretically contain materials of the same quality initially, but due to waste handling practices, used textiles would become contaminated or damaged during collection and/or storage and therefore will all be processed as ultimate waste or feedstock for RDF. This is mainly because there is no existing management route to recapture and direct them towards higher-value processes after the disposal stage (perhaps due to a lack of business case to do that). The existing qualified estimate of the technical supervisor of previous analyses of TMW, states that only approximately 15%[94] of the TMW quality is as low to be considered the ultimate waste. This study aims to further quantify this hypothesis.

Requirements for textile quality standards for closed-loop recycling

The requirements of feedstock for closed-loop recycling are described below for mechanical and chemical recycling separately and with detailed assumptions for each.

The suitability of textiles as feedstock for recycling is determined by the following characteristics:

- Fabric composition of the product,
- Presence of disruptors,
- Colour (multi-colour excluded from mechanical recycling) and
- Layers (multi-layer excluded from any recycling).

Metal and plastic hardware are regarded as removable disruptors, meaning that they can be removed either manually or automatically in preparation for recycling. All other disruptors found in

---

[88] https://www.mckinsey.com/industries/retail/our-insights/scaling-textile-recycling-in-europe-turning-waste-into-value
[89] IMPEL (2017). Refuse-derived fuel. Available online: https://www.impel.eu/en/projects/refused-derived-fuel-rdf-project
[90] https://ec.europa.eu/environment/pdf/waste/studies/rdf.pdf
[91] https://www.researchgate.net/publication/265251963_Residue_Derived_Fuels_as_an_Alternative_Fuel_for_the_Hellenic_Power_Generation_Sector_and_their_Potential_for_Emissions_Reduction#pf9
[92] https://dergipark.org.tr/en/download/article-file/836228
[93] Sorting for Circularity, 2022
[94] https://publications.cuni.cz/bitstream/handle/20.500.14178/1632/WF_4_2022_analysis_of_the_amount_of_textile_waste.pdf?sequence=1&isAllowed=y

textiles as well as combinations of different types are considered as non-removable disruptors for the purpose of both closed and open-loop recycling activities. TIR containing all types of disruptors, both mechanically removable and non-removable, can be considered as potential feedstock for chemical recycling. In the case that non-removable disruptors cannot be processed by recyclers, only 19%[95] of the total potential feedstock for chemical fibre-to-fibre recycling would be available.

Multi-layered items can be disassembled manually or automatically before being sorted based on their composition, but there is no business case for their disassembly in Europe so the multi-layered items are considered non-recyclable. In Sorting for Circularity Europe 7% of the volumes consisted of multi-layered items like jackets and coats.

Closed-loop recycling feedstock specifications

Table A9. Feedstock requirements for mechanical and chemical fibre-to-fibre recycling

	Mechanical	**Chemical**
Layers	Monolayer (or multilayer of the exact same material composition)	Monolayer (or multilayer of the exact same material composition)
Material composition	Pure cotton, pure wool, pure acrylic, cotton-rich and wool-rich blends (>80%). The textile surface cannot contain lurex, cannot be glitter, rubber or PVC coated.	Pure polyester, poly-cotton, polyester-rich blends other than with cotton (>40% polyester content), pure viscose and pure cotton that are not suitable for mechanical recycling. The textile surface cannot contain lurex, and cannot be glitter, rubber or PVC coated.
Disruptors	No disruptors of any type (metal, hard plastic, labels, embroidery and print need to be removed) Certain % of elastane also constitutes a disruptor	No metal or hard plastic disruptors, no plastic print96, the permanent press finishing97 or water-resistant finishing also constitutes a disruptor to some recyclers98, and so do the restricted chemicals99
Colour	Needs to be colour sorted and multi-colour items are excluded	No colour sorting is required, including multi-coloured items
Structure	Knitted or denim	Any
Moist	Dry	Dry (below 8% by weight)

95 Sorting for Circularity, 2022
96 https://www.renewcell.com/en/wp-content/uploads/sites/2/2021/11/renewcell-feedstock-specification-11.pdf
97 https://www.sciencedirect.com/topics/engineering/durable-press-finish
98 https://www.renewcell.com/en/wp-content/uploads/sites/2/2021/11/renewcell-feedstock-specification-11.pdf
99 Renewcell refer to the Restricted Substances List published by the Affirm Group. Source: https://www.afirm-group.com/afirm-rsl/

The more detailed assumptions regarding feedstock requirements have been developed and tested in the previous study[100], upon constructing a database of over 100 closed and open-loop recyclers. The creation of the database was based on extensive outreach to businesses worldwide and processing their inputs. While conducting this study, additional responses and updates[101] have been incorporated into the database, to inform the assumptions and future scenarios. This type of data collection and aggregation was necessary in the absence of publically available feedstock specifications from recyclers, with the exception of Renewcell[102] (who update their spec annually) and T-Rex study results[103] that provide such guidance, which was taken into account in the criteria formulated.

Table A10: Summary of closed-loop recycling capacities as indicated in the Recyclers Database

	Mechanical	***Chemical***
	Based on information from 64 recyclers	Based on information from 38 recyclers, including 15 EU based, and 3 recyclers both mechanical and chemical
Current Capacity	- 3 at pilot scale; - 3 at scale with post-industrial waste and piloting post-consumer waste; - 27 at scale (no capacity given); - For the rest, the capacity at scale ranges from 50 tonnes/annum (t/a) to 780 000 t/a or 136 000 t/a of waste processed	- 4 recyclers did not provide scale; - 4 demo plants; - 11 pilot/research scale; - 12 at scale (no capacity given); - For the rest, the capacity ranges from 264 t/a to 60 000 t/a
Future Capacity (2025 - 2030)	- 2 recyclers intend to maintain their capacity - 15 recyclers have provided future capacity which ranges from 800 t/a to 36 000 t/a	- 11 recyclers have provided future capacity which ranges from 5 000 t/a to 500 000 t/a
Input	- 23 recyclers of post-industrial - 18 recyclers of post-industrial and pre-consumer	- 10 recyclers of post industrial - 2 recyclers of post industrial and pre consumer

[100] Sorting for Circularity, 2022
[101]https://docs.google.com/spreadsheets/d/19gd_PbKdpH3TnyZfoLWLfFH72VXSElZ7xAjLkFgvfNo/edit#gid=1359833340
[102]https://www.renewcell.com/en/wp-content/uploads/sites/2/2021/11/renewcell-feedstock-specification-11.pdf
[103] https://trexproject.eu/wp-content/uploads/2023/05/T-REX-Project-D1.1.pdf

(post-industrial pre-consumer post-consumer)	- 11 recyclers of all inputs (includes mattresses and footwear) - 10 recyclers of post-consumer - 1 recycler of pre-consumer	- 8 recyclers of all input types - 8 recyclers of post consumer - 9 recyclers of post consumer and post industrial - 1 did not specify
Fabric structure	Only 8 recyclers indicated the types of fabric structure accepted - 4 recycling all structures (including shoes) - 1 recycling only knits - 3 recycling knits and wovens (including the recycler with the largest current capacity volume)	Only 8 recyclers indicated the types of fabric structure accepted - 5 recycling all structures - 1 recycling only their own products - 2 accepting knits and wovens
Materials recycled (input)	- 38 list cotton as the primary material - 12 list wool as the primary material - 21 recyclers are highly specialised and accept only one material type: down, leather, wool, acrylic, aramid, cashmere, cotton, polyamide, or polyester - 18 recyclers accept blends (acrylic polyester, acrylic polypropylen, cotton blends, polycotton blends, polyealstane blends and more) - 1 focused only on footwear	- 12 list cotton as the primary material - 11 list polyester as the primary material - 22 recyclers are highly specialised and accept only one material type: cotton, elastane, leather, nylon 6, nylon 6.6[104], polyester - 7 recyclers accept blends (mainly cotton blends and polycotton) - 5 did not indicate materials

Taking into account the assumptions listed above and building on the existing best practice[105], more detailed sorting steps and criteria can be outlined as necessary to prepare TIR for reuse and recycling.

---

[104] A special distinction needs to be made between polyamide 6 (PA6) and polyamide 66 (PA66). In most cases, garments are either composed of PA6 or PA66, but they are seldomly combined in the same garment. Mixing occurs at a meta-level, i.e. in a container full of garments. Recyclers of polyamide, such as Aquafil and BASF need the highest possible fraction of PA6, as PA66 is not recycled in the process. At the same time, NIR devices such as Matoha Fabritell, Fibersort or TOMRA do not detect the difference between PA 6 and PA66. Source: https://trexproject.eu/wp-content/uploads/2023/05/T-REX-Project-D1.1.pdf

[105] https://euric.org/resource-hub/position-papers/handling-sorting-specifications-for-re-use-and-recycling-of-used-textiles

Preparation for re-use steps (Sorting for Reuse)

The high-quality sorting process shall be aimed at preparing the collected post-consumer textile waste for reuse or, if reuse is not possible, for subsequent recycling. It is a complex process that differs from operator to operator, but the following requirements shall be the mandatory basis to ensure high-quality sorting:

1. Removing all foreign materials from the collected post-consumer textile waste, this includes unpacking from (plastic) bags, picking out all other types of waste that occur (usually manu-ally from the conveyor belt)
2. Removing all significantly soiled and polluted textiles including textiles visibly soiled, wet, covered in paint[106], or otherwise significantly mutilated (usually manually from the conveyor belt) - these will most likely go directly to the ultimate waste management route or RDF where possible
3. Sorting into main categories as agreed by the TIR facility to produce defined qualities for subsequent reuse (eg. toys, shoes, accessories, garments, home textiles)
4. Sorting into subcategories as agreed by the TIR facility as defined with the trading partners in receiving countries and dictated by the value on the global second-hand market (eg. qual-ity grades 1-5, creme and vintage, wipers and recycling)

Sorting for Reuse will consider the cultural-fit criteria like trend and size relevance per reuse market, or item personalization (for example embroidery or print including owners name or initials limits the reusability potential), as well as physical conditions criteria such as the presence of stains and holes, fabric thinning and pilling.

There are currently no automated or unified procedures available to identify the reusability of the collected post-consumer textile waste. Automated sorting can only be used in the sorting process for streams that have already been presorted manually as not suitable for reuse. That means that textiles identified in Step 4 as suitable for wipers and recycling, can be further sorted based on material composition using NIR or other suitable technology.

Manual sorting does not provide the level of detail and certainty needed with regards to the exact fabric composition that is necessary for the recycling management route, nor do the labels, with research showing that only 59%[107] of the TIR garments have accurate and legible labels. At the same time, both sorting for reuse and sorting for mechanical recycling rely on professional sorters to identify materials by sight and touch, as exemplified by the different wool types, which are identical to the NIR technology as well as to sort wool into dozens of colour schemes before recycling[108].

[106] Already at the initial sorting step some culture specific factors come to play. As professional sorters will know, some heavily stained items might belong to a high value cream fraction, which is smallest in volume and highest in value and therefore such item needs to be identified as soon as possible to be send towards verification and to avoid its further contamination. An example can be this iconic Maison Martin Margiela 'mud painter' sneaker selling second hand at over 400USD. Source: https://www.vestiairecollective.com/men-shoes/trainers/maison-martin-margiela/grey-leather-replica-maison-martin-margiela-trainers-34072448.shtml

[107] https://assets-global.website-files.com/5d26d80e8836af2d12ed1269/5e9feceb7b5b126eb582c1d9_20200420%20-%20Labels%20Check%20-%20report%20EN%20web%20297x210mm.pdf

[108] Mechanical wool recycling is a well established industry both in Europe (Prato) as in Pakistan (Karachi), some recyclers are inclucded in the Recyclers Database as well as here https://iwto.org/recycled-wool/ or https://textileexchange.org/app/uploads/2022/10/Textile-Exchange_PFMR_2022.pdf

Some research indicates, however, that the sorting industry in Europe faces challenges in retaining these skilled workers[109], possibly due to a shortage of staff in the EU labour market or work quality issues.

It is important to understand that a fixed criteria list defining whether the garment is fit for re-use or not does not exist at the moment, however, it is expected to appear soon under the End-of-Waste criteria for re-use publication. It is a common business practice for facilities to have sorting manuals or guidelines and to train the staff diligently on the job to be able to recognise these criteria as efficiently as possible and also to reward staff for excellent productivity or particular skill in recognising products of the highest value. This indicates that the reusability and fit for the particular market, which eventually dictates the price, are based on the subjective decision of the sorter who has to consider: the facility manual, usability, trend, colour, size, brand and visible damages. These factors are not weighted equally, so for example the usability might be compromised when the trend and brand are a high fit and in demand for a specific market.

Publicly available, schematic assessment sheets[110] do exist, but do not deep dive into the specifics of the garments on the second-hand market[111], instead only confirming that exact criteria depend on each operator with regard to trademarks, types, quality classes, product age, completeness, and degree of soiling.

Upon detailed analysis of TIR suitability for reuse, each garment shall be directed towards the highest application management route possible, and highest value second-hand market possible, with the exception of garments that might seem reusable at the first glance, but perhaps after a deeper investigation reveals more flaws (for example are a counterfeit) and should be redirected to lower value second-hand markets, wipers or recycling (if applicable) or RDF.

Preparation for Recycling (Sorting for Recycling)

Open loop (wipers)

1. Item was deemed unfit for reuse or representing a low value on the reuse market, or perhaps was sent to the local reuse market (retail chain) and returned from the store unsold (eg. white bed linens)
2. Item is monolayer
3. Item is not covered in any waterproof treatment, coating or excessive accessories (metal thread, sequins)
4. Item is made of (ideally) white, or colour cotton-rich material
5. Hard plastic, metal, plastic print and seams are mechanically removed by the wipers manufacturer (or sorter, if they manufacture themselves)

Open loop (insulation or filling material)

1. Item was deemed unfit for reuse or representing a low value on the reuse market, or perhaps was sent to the local reuse market (retail chain) and returned from the store unsold (eg. acrylic jumper)

---

[109] https://www.valpak.co.uk/wp-content/uploads/2023/04/VAL00000_Valpak-Waste-To-Worth-1.pdf

[110] https://www.umweltberatung.at/download/?id=Prep-for-Re-Use_end-of-waste-guide_Austria_2019.pdf

[111] In some projects, like Sorting for Circularity India, an indication for resellability was framed based on insights collected from the resale platforms who indicated being interested specifically in items with tags of recogniseable value, premium, designer and luxury brands.

2. Item is not covered in any waterproof treatment, coating or excessive accessories (metal thread, sequins)
3. Item is made of acrylic, or acrylic rich blend
4. Hard plastic, metal, plastic print and seams are mechanically removed by the end recycler (most probably not in Europe)

Mechanical closed-loop recycling

1. Item was deemed unfit for reuse or representing a low value on the reuse market, or perhaps was sent to the local reuse market (retail chain) and returned from the store unsold (eg. woollen jumper, cotton t-shirt or cotton rich jeans)
2. Item is monolayer
3. Item is of knitted structure or made of denim
4. Item is not covered in any waterproof treatment, coating or excessive accessories (metal thread, sequins)
5. Item is made of wool-rich material or cotton-rich material
6. Items are further sorted based on exact composition using the NIR or other suitable technology
7. Items are further sorted by colour by the sorter, recycler or pre-processor
8. Hard plastic, metal, plastic print and seams are mechanically removed by the recycler, sorter or pre-processor

Chemical closed-loop recycling

1. Item was deemed unfit for reuse or representing a low value on the reuse market, or perhaps was sent to the local reuse market (retail chain) and returned from the store unsold (eg. cotton rich jeans, cotton t-shirt, polyester blouse, polycotton sweatshirt, or polyester knit)
2. Item is monolayer or all layers made of the same composition material
3. Item is of knitted or woven structure
4. Item is not covered in any waterproof treatment, coating or excessive accessories (metal thread, sequins)
5. Item is made of cotton-rich, polyester-rich or polycotton material
6. Items are further sorted based on exact composition using the NIR or other suitable technology
7. Hard plastic, metal, plastic print and seams are mechanically removed by the recycler, sorter or pre-processor

Comparative analysis of the management routes and quality standards

Comparison of feedstocks fit for more than one management route in current and future scenarios

Existing analysis indicates that 18% to 26%[112] of textile waste can be suitable for closed-loop recycling, but it must be recognised that TIR and potentially TMW represent only a fraction of that

112 https://www.mckinsey.com/~/media/mckinsey/industries/retail/our%20insights/scaling%20textile%20recycling%20in%20europe%20turning%20waste%20into%20value/scaling%20textile%20recycling%20in%20europe%20turning%20waste%20into%20value.pdf?shouldIndex=false

volume. Within the TIR fraction analysed in six European countries, consisting of non-rewearables and low-value rewearables, up to 75%[113] were suitable for closed-loop recycling. Currently, recyclers have high feedstock quality standards, as they rely on sorted and clean post-industrial and pre-consumer waste most of the time, rather than post-consumer and no tests of TMW recycling are known.

As explained above, *Textiles sorted as not suitable for re-use, going towards wipers and open and closed loop recycling* sub-sample in the study represents a mix of feedstocks suitable for multiple management routes. Currently, the factor determining the management route of that fraction remains the selling price, so the highest bidder gets the sorted feedstock. Some of the feedstocks that are of the highest value and could be applied to multiple management routes are cotton-rich white knitted and woven materials and cotton-rich denim.

There is a common misconception that textiles that cannot be sold on second-hand markets are 'valueless' and could be obtained as feedstock for closed-loop recycling at little to no cost[114], while in reality, prices paid for feedstock for closed-loop recycling need to compete with the current average income sorters make by selling or manufacturing wipers, in order to redirect textiles towards recycling instead. As closed-loop recycling is not yet a mature industry at scale, its prices need to be defined. It is not only the lack of unified criteria but perhaps the price and prevalent current business model that slow down the scaling of closed-loop solutions.

The price estimates presented here were obtained from textile sorters and recyclers in 2021 during the Sorting for Circularity Europe study and will be complemented by estimates provided by the project partners. Not all projected prices are competitive with current prices received by sorters in Europe (Table A11). This means that the volume that might technically be available as feedstock for closed-loop recycling will continue to be sent to existing destinations, like the wipers industry, in the future, unless there is a legislative or economic incentive in place to do otherwise.

The wipers industry currently offers to European sorters € 0.13 to 0.45 per kilo, open-loop mechanical recycling € 0.08 per kilo and closed-loop recycling € 0.02 to € 0.14 per kilo[115]. Sorters currently sell cotton, wool and acrylic textiles as feedstock for closed-loop mechanical recycling, and increasing volumes of cotton textiles are being sold to chemical recyclers, but the wipers industry remains a steep competition. At the same time, low-value re-wearable garments can be sold at € 0.77 per kilo on average[116]. For further price and quality specifications of open and closed-loop recyclers Refashion and Reversed Resources could be further consulted.

Current price scenarios will be updated pending input from country partners, namely pending input on prices from TIR Romania, TIR Czechia, TMW Czechia, and TMW Italy. Prices from TIR Bulgaria and Italy were obtained and once all prices are collected an average will be shared for the final report.

[113] Sorting for Circularity Europe, 2022
[114] Sorting for Circularity Europe, 2022
[115] Sorting for Circularity Europe, 2022
[116] Sorting for Circularity Europe, 2022

Table A11: Closed-loop recycling solutions feedstock specifications overview (based on Sorting for Circularity Europe interviews, 2022)

	price	input
Chemical	0,20 eur/kg	≥95 polyester, <5% other
	0,20 eur/kg	≥60% polyester, <40% cotton, < 10% others
	0,20 eur/kg	Mainly: ≥95% cotton, <5% others, no protein-based fibres Also possible: ≥88% cotton, <12% others (lower cotton content is also possible, but this decreases the profitability of the process)[117]
Mechanical	0,40 eur/kg	≥80% cotton
	0,09 eur/kg	≥95% acrylic
	1,20 eur/kg	≥80% wool

End of Waste criteria and how they can support fibre-to-fibre recycling

A set of EU-wide criteria that will indicate when TIR stops being processed as waste, but instead represents textiles ready for re-use or recycling is under development and will be published in January 2026.

So far, the most advanced is the French legislation offering distinctive criteria for re-use[118] and wipers[119] but it does not provide the level of detail as present in this report.

117 Based on specifications of the BASF recycler in the T Rex project https://trexproject.eu/wp-content/uploads/2023/05/T-REX-Project-D1.1.pdf

118 https://www.legifrance.gouv.fr/loda/id/JORFTEXT000037832774?init=true&page=1&query=crit%C3%A8res+sortie+du+statut+de+d%C3%A9chet&searchField=ALL&tab_selection=all

119 https://www.legifrance.gouv.fr/loda/id/JORFTEXT000037832774?init=true&page=1&query=crit%C3%A8res+sortie+du+statut+de+d%C3%A9chet&searchField=ALL&tab_selection=all

A French ordinance from December 11, 2018, sets the criteria for exiting waste status for objects and chemical products that have been prepared for reuse and includes criteria for textiles that are specified by one of the codes 19 12 08, 20 01 10 or 20 01 11. This is a code description of textile waste as non-hazardous waste under EWC-Stat categories[120] including worn and used textiles, but does not sufficiently clarify the condition of the worn textiles to indicate whether that would be fit for reuse, as it happens in the day-to-day practice of TIR sorters.

A decree from February 25, 2019, sets the criteria for exiting waste status for cut wiping cloths made from used textiles. Textiles cease to be waste when all of the following criteria are met:

a) Textiles must originate from sources specified in the decree, section 1 of Annex I;
b) Textiles must be treated in accordance with the criteria established in section 2 of Annex I;
c) The wipers must meet the criteria established in section 3 of Annex I;
d) The operator must meet the requirements and conclude a transfer of goods accordingly to Articles 4 to 8 of the ordinance[121].

To summarise the requirements of this ordinance TIR needs to be sorted according to the following criteria:

- Damp, very torn and dirty textiles are removed and redirected to a suitable waste treatment channel;
- Textiles are sorted by textile category[122]
- Disruptors must be removed (the ordinance mentions: buttonnes, zippers, metal parts and hard plastic, excess thickness, pockets, collars, cuffs, and buttonholes
- Quality assurance of the wipers batch must be conducted to ensure the batches comply with the criteria above and detect used textiles which may contain undesirable substances or organisms (in particular oils, solvents, fungi).

According to the ordinance, only waste from specific sources can be accepted as suitable materials for wipers:

- Textile packaging and packaging waste collected separately at the municipal level;
- Absorbents, wiping clothes and protective clothing;
- Textile waste from medical or veterinary care (as long as no risk of infection);
- Separately collected household textile waste;

It would require further research to verify whether EU-based wiper manufacturers comply with the criteria above. Interestingly the size of the wiper rag is not specified in the ordinance.

[120] https://ec.europa.eu/eurostat/documents/342366/351806/Guidance-on-EWCStat-categories-2010.pdf/0e7cd3fc-c05c-47a7-818f-1c2421e55604

[121] https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000038232813

[122] This is not further clarified by the Ordinance, but assuming implies high cotton content

Outlining Gaps, Challenges and Potential Impact of different management routes identified

Collection and sorting rates from the Czech Republic, Romania and Italy and their current management routes

Table A12. Textile waste collection and management routes in focus countries

	Population	Textile waste generated annually	Textile waste collected separately (TIR)	% of textile waste within mixed municipal waste (TMW)	Current management routes (interview based)
Czech Republic	10,8 mln[123] (2023)	78 k tonnes (JRC, 2021)	15% (14k tonnes) (JRC, 2021)	6.16%[124] (average between 2016-2021)	re-use in the Czech Republic 2% re-use outside EU 25-30% 50% wipers and insulation 5-10% Charity donation 10% incineration
Italy	58,8 mln[125] (2022)	615 k tonnes (JRC, 2021)	15-20% (277 k tonnes) (McKinsey, 2022)	5%[126] (average between 2014-2019)	<u>Sorted in Bulgaria</u> re-use in the EU 26% , re-use outside EU 44% , wipers 11% , closed-loop 12% , incineration 7% <u>Sorted in Italy</u> re-use in the EU 25%; re-use outside EU 40%; wipers 15%, knitwear recycling 10% incineration 5%, RDF 5%

[123] https://www.czso.cz/csu/czso/population

[124] https://publications.cuni.cz/bitstream/handle/20.500.14178/1632/WF_4_2022_analysis_of_the_amount_of_textile_waste.pdf?sequence=1&isAllowed=y

[125] https://www.istat.it/en/archivio/resident+population

[126] https://www.eea.europa.eu/publications/many-eu-member-states/italy

Romania	19,4 mln[127] (2019)	149 k tonnes (JRC, 2021) and up to 180 k tonnes (McKinsey, 2022)	15% (27 k tonnes) (McKinsey, 2022) - no formal textile waste collection system	no capture rates could be calculated because information on the composition of residual waste is not available[128]	Re-use in Romania 90% Disposal 10%[129]

Gap: lack of fibre sorting and disruptors removal as a prerequisite of closed-loop recycling at scale

For the textiles to be suitable as feedstock for closed-loop recycling, they need to be sorted based on their exact material composition, colour, and structure and then the disruptors need to be removed by either sorter, recycler or intermediary party. In case these activities need to take place in European countries (for instance at sorters' facilities, as preparation for the recycling step), investments are required in technologies and staff for automated sorting and hardware removal. Some chemical recyclers[130] currently declare not having any disruptor removal capacity at their facilities and therefore rely on sorters and third parties to prepare their feedstock.

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[131]. 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 TIR from their current destinations to closed-loop recyclers results in a return on investment of around 8 years, which is not realistic for private investors. A return on investment of 5 years can be realised in case a subsidy is available for the CAPEX investments of € 1.8 million.

At the same time, solution providers available on the market of sorting textiles and market offer handheld devices, which can be incorporated into TIR sorting facilities with less investment and at any scale.

Both for fully and for semi-automated fibre sorting, the financial compensation, for example, through an EPR scheme is required to cover the costs associated with sorting based on material composition. 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

127 https://ec.europa.eu/eurostat/documents/12743486/14207633/RO-EN.pdf
128 https://www.eea.europa.eu/publications/many-eu-member-states/romania
129 Rates obtained from a small charity collection and sorting partner - DGASPC Sector 6
130 This was declared by all three chemical recyclers engaged in the pilot T-Rex project (BASF, CuRE and IFC) source: https://trexproject.eu/wp-content/uploads/2023/05/T-REX-Project-D1.1.pdf
131 EigenDraads (2022). Business case for automated sorting and hardware removal in the Rotterdam region. Available upon request.

automated sorting to the process will most likely not reduce the overall costs of sorting considerably[132].

Additionally, to accommodate the needs of recyclers in terms of preferred feedstock and the minimum order quantity, an aggregation step is needed. It can be assumed that the storage space represents a cost to sorters and therefore potentially another roadblock to them becoming more prominent providers of feedstocks for recycling.

Lastly, a major barrier to chemical recycling remains its pilot stage capacity, against the scale of textile waste being produced.

Gap: lack of waste management infrastructure in export countries

All used textiles initially sorted and treated as suitable for re-use after extended periods of use, or multiple cycles of resale, will gradually decrease in quality and become unfit for re-use. Ideally, by then they are in a geography where the infrastructure is available to collect and sort them and direct them towards the highest application pathway possible. Currently, this is not guaranteed, with only 38% of textile waste collected separately in the EU and 1.7 million tonnes exported from the EU in 2019. [133]

Within the EU we recognise a few major import-export hubs of TIR sorting and export, namely Germany, Italy, the Netherlands and Poland[134]. Yet, the traceability of the exported TIR route is almost impossible at the moment, unless tracking devices are used[135]. Still, it is well estimated that 46% of European PCT goes to Africa and 41% to Asia. Asia highly likely represents an end destination only for a fraction of all imports. We recognise major international sorting hubs like Pakistan and the United Arab Emirates that process textiles in dedicated industrial zones. There, upon sortation, textiles are turned into wipers or filling material (open loop recycling), go into the local market for re-use (often informal) and are re-exported for re-use mainly to Africa. Therefore, it is the African countries that represent the final re-use markets, often with insufficient waste management solutions available to process the volumes of non-recyclable garments received and disposed of.

Several African countries have been debating banning used textile imports which indicates that imports, while bringing significant employment, both formal and informal, also bring negative social and environmental impacts that local governments have failed to address successfully so far.

Further research into the infrastructure needs of major TIR receiving countries is necessary, but already in Ghana and Tunisia, estimates are made that about 40% of imported TIR is not fit for re-use and ends up in landfills, burned in the open and leaks into the environment[136]. The waste management system in Tunisia relies on landfills, which are often semi-controlled and unsanitary[137].

---

[132] Sorting for Circularity, 2022

[133]https://www.eea.europa.eu/publications/eu-exports-of-used-textiles#:~:text=Between%202000%20and%202019%2C%20the,2020%20(EEA%2C%202022)

[134] https://www.eionet.europa.eu/etcs/etc-ce/products/etc-ce-report-2023-4-eu-exports-of-used-textiles-in-europe2019s-circular-economy

[135] https://www.aftonbladet.se/nyheter/a/jlME1e/aftonbladet-investigation-into-h-m-s-recycling-airtags-in-items

[136] Ghana: Ahiable and Triki, 2021; Ricketts and Skinner, 2019; Tunisia: Boukhayatia, 2022

[137] Reverse Resources and Blumine, 2021

Lack of sorting, sanitary waste management, recycling[138] or waste-to-energy infrastructure in end destinations of TIR exported from the EU, represents a significant gap in global circular value chains.

Gap: lack of economies of scale

Multiple roadblocks come to light in this report, as well as previous research[139] on the topic. The current linear garment production and consumption value chain is predominant and dictates the destinations of the majority of TIR and TMW so far. More pull is needed from regulators, retailers and recyclers to increase the desirability of TIR as feedstock for recycling and redirect it from currently highly competitive destinations (as in white cotton being locked into wipers). This could be enacted by creating more publicly available recycler feedstock specifications or databases for the industry and general public, as well as clear criteria for the inclusion of recycled TIR in new products placed on the EU market.

At the same time, the existing global second-hand market is well established and only slightly disturbed by the resale innovators, such as Vinted, Depop or Vestiaire Collective, who deprive it of access to cream fraction by giving the agency to consumers to sell their valuable garments themselves. With growing volumes of separately collected TIR and no detailed checks at the export and custom declaration level, we can expect that large volumes of low-value textiles will still be directed towards global sorting hubs and might end up disposed of as they are today rather than recaptured for higher value applications.

It remains to be seen how the end of waste and preparation for reuse and recycling criteria will be enforced to ensure that materials enter the appropriate management routes.

Still, the demand for TIR sorted for recycling is closely linked to the pricing and costs of purchasing and investing in fier sorting and closed-loop recycling infrastructure. The market for sorted TIR is contingent on closed-loop recycling technologies, or potentially other high-value recycling open-loops[140].

To date, recycled fibre and fabrics are priced higher, which is intimately related to the higher costs required to process TIR or industrial waste. As the percentage of non-rewearables entering collection facilities continues to rise, further development of recycling technologies could spur the uptake of post-consumer textiles. In this regard, this may lead to economies of scale that will decrease the price of recycled fibre[141].

Annex 4. Average Garment Weights

[138] There might be informal and therefore not well-quantified mechanical recycling or manual and semi-manual remanufacturing activities, which is to be expected in response to large import quantities continuously flowing in

[139] https://vb.nweurope.eu/media/6811/fibersort-barriers-report-final.pdf

[140] https://vb.nweurope.eu/media/6811/fibersort-barriers-report-final.pdf

[141] https://vb.nweurope.eu/media/6811/fibersort-barriers-report-final.pdf

AgeGroup	multilayer	garment	Average weight (kg)
adults	double	heavy-jacket	0.375
adults		bra-lingerie	0.09
adults		coat	1.06
adults		costume	0.43
adults		denim-jacket	0.71
adults		denim-overall	0.67
adults		denim-shorts	0.32
adults		denim-skirts	0.34
adults		denim-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
adults	double	bra-lingerie	0.045
adults	double	coat	0.53
adults	double	denim-jacket	0.355
adults	double	denim-overall	0.335
adults	double	denim-shorts	0.16
adults	double	denim-trousers	0.255
adults	double	dress	0.09
adults	double	heavy-jacket	0.375
adults	double	home-wear	0.155
adults	double	jumpsuit-overall	0.18
adults	double	light-jacket	0.155
adults	double	polo-shirt	0.125
adults	double	reflective-safety	0.29
adults	double	shirt-blouse	0.08
adults	double	shorts	0.1
adults	double	skirts	0.12
adults	double	socks-hosiery	0.015
adults	double	sport-trousers	0.105
adults	double	sweaters-hoodie	0.155
adults	double	swimwear	0.06
adults	double	trousers	0.18
adults	double	t-shirt	0.08
adults	double	underwear-bottoms	0.045
babies		baby-clothes	0.16
babies		baby-underwear	0.16
babies	double	baby-clothes	0.08
babies	double	baby-underwear	0.08

children		bra-lingerie	0.03
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	0.1
children		Waterproof-rainwear	0.53
children		reflective-safety	0.35
children		shirt-blouse	0.1
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
children	double	coat	0.295
children	double	costume	0.13

children	double	denim-overall	0.095
children	double	denim-trousers	0.14
children	double	dress	0.11
children	double	heavy-jacket	0.225
children	double	home-wear	0.17
children	double	jumpsuit-overall	0.105
children	double	light-jacket	0.175
children	double	polo-shirt	0.05
children	double	Waterproof-rainwear	0.265
children	double	shirt-blouse	0.05
children	double	shorts	0.075
children	double	skirts	0.09
children	double	socks-hosiery	0.01
children	double	sport-trousers	0.11
children	double	sweaters-hoodie	0.085
children	double	swimwear	0.03
children	double	trousers	0.11
children	double	t-shirt	0.05
children	double	underwear-bottoms	0.015
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
other	double	fabrics	0.125
other	double	gloves	0.02

other	double	headwear	0.05
other	double	household-linen	0.175
other	double	medium-accessory	0.035
other	double	other	0.175
other	double	small-accessory	0.015

Annex 5. List of faulty data inputs erased

Italy data processing				
Category	**Items without description**	**Items with more than double layer** **(erased)**	**Changed items to match weight**	**Comments**

Czech Republic data processing				
Category	**Items without description** **(erased)**	**Items with more than double layer** **(erased)**	**Changed items to match weight**	**Comments**
TIR Downcycle	1	6	•blouse to shirt-blouse •long-skirt to skirts •children double denim-jacket to children double heavy-jacket	
TIR Outside EU reuse	3	4	•blouse to shirt-blouse	
TIR Landfill	0	0	•pajama to home-wear	
TIR EU reuse	4	69	•blouse to shirt-blouse •pajama to home-wear •nightgown to home-wear •long-skirt to skirts •childrendoubledenim-shorts to childrendoubleshorts •Indian-baby-clothes to baby-clothes •Kurta to light-jacket •Sari to dress	
TMW no textile bins	0	0	0	
TMW textile bins	0	0	0	The column "materials" and "deviceAnswer" have different material compositions

	(erased)			
TIR wipers	0	0	•blouse to shirt-blouse •pajama to home-wear •nightgown to home-wear •rainwear to waterproof-rainwear	
TIR Outside EU reuse	10 (20,	9	•blouse to shirt-blouse •pajama to home-wear •nightgown to home-wear •rainwear to waterproof-rainwear •long-skirt to skirts •kurta to light-jacket •sari to dress	
TIR Recycling	1	22	• blouse to shirt-blouse •pajama to home-wear •rainwear to waterproof-rainwear •kurta to light-jacket •burqua to dress	
TIR EU reuse	0	20	•blouse to shirt-blouse •pajama to home-wear •rainwear to waterproof-rainwear •double rainwear to double heavy-jacket •long-skirt to skirts	1 light jacket and heavy jacket. (Kept light jacket)

			•Indian-baby-clothes to baby-clothes •Kurta to light-jacket	
TIR Waste	1	8	•blouse to shirt-blouse •kurta to light-jacket •rainwear to waterproof-rainwear •long-skirt to skirts	0 manualcomposition inputs in the total sample
TMW	0	0	•blouse to shirt-blouse	

Bulgaria data processing				
Category	**Items without description** **(erased)**	**Items with more than double layer** **(erased)**	**Changed items to match weight**	**Comments**
Matoha data (1)	2	0	•Rainwear to waterproof-rainwear •Blouse to shirt-blouse •Indian-baby-clothes to baby-clothes •Kurta to light-jacket •Pajama to home-wear •Long-skirt to skirts •Nightgown to home-wear	Unknown category
Matoha data (2)	15	0	•Blouse to shirt-blouse •Kurta to light-jacket •Pajama to home-wear	Unknown category

			•Long-skirt to skirts •Nightgown to home-wear •Rainwear to waterproof-rainwear	

Annex 6. Variability Reuse Grades and Multilayer per fraction in all streams

TIR Recycling

Reuse grades by weight in kg per sample						
Country	**Analysis Round**	**grade 1**	**grade2**	**grade 3**	**grade 4**	**grade 5**
1	**1**	-	411.2	0.3	-	4.1
	2	0.4	3.3	140.7	5.2	-
2	**1**	6.4	95.6	39.8	14.0	8.1
	2	36.9	184.9	60.9	232.6	78.2
3	**1**	-	633.6	-	-	-
	2	-	188.9	-	-	0.6
Total		43.6	1,517.4	241.7	251.7	91.1

Reuse grade in % per sample						
Country	**Round**	**grade1**	**grade2**	**grade3**	**grade4**	**grade5**
1	**1**	0.0%	98.9%	0.1%	0.0%	1.0%
	2	0.2%	2.2%	94.1%	3.5%	0.0%
2	**1**	3.9%	58.3%	24.3%	8.5%	5.0%
	2	6.2%	31.2%	10.3%	39.2%	13.2%
3	**1**	0.0%	100.0%	0.0%	0.0%	0.0%
	2	0.0%	99.7%	0.0%	0.0%	0.3%

Multilayer in kg per sample			
Country	**Round**	**double**	**single**
1	**1**	0	415.6
	2	0.91	148.84

2	1	21.09	142.8
	2	2.52	591.18
3	1	0.53	633.02
	2	0	189.52

Multilayer in % per sample			
Country	**Round**	**double**	**single**
1	**1**	0.0%	100.0%
	2	0.6%	99.4%
2	**1**	12.9%	87.1%
	2	0.4%	99.6%
3	**1**	0.1%	99.9%
	2	0.0%	100.0%

TIR Reuse EU

Reuse grades in kg per sample						
Country	**Round**	**grade1**	**grade2**	**grade3**	**grade4**	**grade5**
1	**1**	-	-	-	0.3	140.2
	2	0.4	-	0.4	51.6	136.8
2	**1**	0.5	2.2	30.3	88.0	55.0
	2	4.5	7.0	6.1	75.4	318.3
3	**1**	-	-	-	-	34.8
	2	-	0.3	-	-	353.6
4	**1**	-	-	-	901.2	279.1
	2	-	-	-	306.3	73.8
Total		5.3	9.5	36.7	1,422.9	1,391.6

Multilayer in kg per sample			
Country	**Round**	**double**	**single**
1	**1**	6.55	134.46
	2	15.48	173.68

2	**1**	12.03	164
	2	15.85	396.24
3	**1**	0	34.81
	2	0	353.92
4	**1**	51.01	1129.25
	2	14.04	366.03

Multilayer in % per sample			
Country	**Round**	**double**	**single**
1	**1**	4.6%	95.4%
	2	8.2%	91.8%
2	**1**	6.8%	93.2%
	2	3.8%	96.2%
3	**1**	0.0%	100.0%
	2	0.0%	100.0%
4	**1**	4.3%	95.7%
	2	3.7%	96.3%

Reuse grade in % per sample						
Country	**Round**	**grade1**	**grade2**	**grade3**	**grade4**	**grade5**
1	**1**	0.0%	0.0%	0.0%	0.2%	99.8%
	2	0.2%	0.0%	0.2%	27.3%	72.3%
2	**1**	0.3%	1.3%	17.2%	50.0%	31.2%
	2	1.1%	1.7%	1.5%	18.3%	77.4%
3	**1**	0.0%	0.0%	0.0%	0.0%	100.0%
	2	0.0%	0.1%	0.0%	0.0%	99.9%
4	**1**	0.0%	0.0%	0.0%	76.4%	23.6%
	2	0.0%	0.0%	0.0%	80.6%	19.4%

TIR Reuse non EU

Reuse grades in kg per sample

Country	Round	grade1	grade2	grade3	grade4	grade5
1	1	-	-	-	307.6	25.6
	2	3.8	3.6	95.1	24.4	-
2	1	-	15.9	57.6	51.4	29.5
	2	0.5	6.4	51.7	199.1	271.2
3	1	-	-	102.5	209.1	-
	2	-	-	42.3	-	-
Total		4.2	25.9	349.2	791.7	326.4

Multilayer in kg per sample			
Country	Round	double	single
1	1	127.39	205.86
	2	17.31	109.67
2	1	12.05	142.36
	2	11.07	518.31
3	1	0.53	310.99
	2	0	42.32

Reuse grade in % per sample						
Country	Round	grade1	grade2	grade3	grade4	grade5
1	1	0.0%	0.0%	0.0%	92.3%	7.7%
	2	3.0%	2.9%	74.9%	19.3%	0.0%
2	1	0.0%	10.3%	37.3%	33.3%	19.1%
	2	0.1%	1.2%	9.8%	37.6%	51.3%
3	1	0.0%	0.0%	32.9%	67.1%	0.0%
	2	0.0%	0.0%	100.0%	0.0%	0.0%

Multilayer in % per sample			
Country	Round	double	single
1	1	38.2%	61.8%

	2	13.6%	86.4%
2	**1**	7.8%	92.2%
	2	2.1%	97.9%
3	**1**	0.2%	99.8%
	2	0.0%	100.0%

TIR Energy Recovery / Disposal

Reuse grades in kg per sample						
Country	**Round**	**grade1**	**grade2**	**grade3**	**grade4**	**grade5**
1	**1**	92.4	82.4	-	-	-
	2	89.3	43.6	-	-	-
2	**1**	156.4	1.0	0.6	0.4	-
	2	63.3	95.0	192.7	53.2	57.4
3	**1**	281.7	-	-	-	-
	2	100.8	-	-	-	0.5
4	**1**	23.7	160.9	440.5	-	-
	2	318.4	347.2	315.7	-	-
Total		1,126.0	730.1	949.5	53.5	57.8

TMW

SEPARATE COLLECTION						
Reuse grades in kg per sample						
Country	**Round**	**grade1**	**grade2**	**grade3**	**grade4**	**grade5**
1	**1**	2.6	2.0	0.9	1.5	0.2
	2	3.8	2.1	-	-	-
2	**1***	2.0	4.5	5.1	7.9	2.7
	2	13.1	6.2	0.3	-	-
4	**1**	-	-	25.9	-	-
	2	9.8	60.2	12.3	0.2	-

NO SEPARATE COLLECTION						
Reuse grades in kg per sample						
Country	**Round**	**grade1**	**grade2**	**grade3**	**grade4**	**grade5**
2	**1**	3.5	4.3	2.1	1.7	0.4
	2	4.6	4.2	2.3	-	-
4	**1**	58.6	15.8	-	-	-
	2	45.2	41.5	7.6	0.9	-

Annex 7. Variability in Material Composition

The table below displays the material composition for each fraction (i.e., Recycling, Reuse EU, Reuse non-EU, and Energy Recovery/Disposal) across different countries and rounds. The fraction with the highest content of each material is highlighted in yellow, while the fraction with the lowest content is highlighted in red. For example, the fraction with the highest percentage of garments made from 100% Cotton is the Recycling fraction for Country 3, Round 2, with 59% (112 kg). Conversely, the lowest content is found in the Energy Recovery/Disposal fraction for Country 2, Round 2, with just 1% (2.71 kg).

Country	Round	100% Cotton				100% Viscose				40-95% Polyester				80-100% Wool				80-99% Cotton				95-100% Acrylic				Polycotton Cotton-rich				Polycotton Polyester-rich				≥95 Polyester				Others			
		Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal
1	**1**	120.46	31.56	12.52	11.51	24.76	15.1	13.25	5.05	13.96	15.56	27.08	23.56	13.83	0.31	17	4.98	68.08	24.42	13.32	10.36	18.7	1.25	1.85	0	26.03	10	5.42	3.17	12.02	4.17	10.28	3.45	29.63	14.45	41.37	46.51	100.44	29.01	192.26	67.22
	2	32.6	31.11	1.94	7.24	8.66	15.26	8.22	8.24	6.83	24.84	14.58	20.55	0	4.41	4.52	0.94	29.58	16.13	6.15	4.48	0	5.42	1.93	0.25	17.09	9.55	4.28	6.91	4.44	3.43	7.87	5.44	11.07	21.99	16.57	21.23	44.25	61.05	62.01	58.83
2	**1**	16.12	36.55	29.45	1.28	6.3	14.01	8.09	0.73	17.04	19.74	8.39	43.01	3.48	0.48	0.36	0.31	8.23	18.16	10.26	3.25	9.61	5.28	0.16	0.66	4.82	11.22	20.43	2.6	2.48	6.87	14.65	13.74	33.13	28.78	16.52	42.06	63.25	38	47.9	51.65
	2	92.05	34.96	118.82	2.71	57.93	37.51	38.69	0	31.98	41.05	21.21	46.12	0.87	0.47	0.32	0.35	105.37	59.57	78.15	8.91	1.69	1.58	0.25	0.35	52.61	36.74	72.11	2.41	27.19	11.78	21.53	4.22	53.63	104.01	76.52	166.54	188.19	101.5	113.3	231.05
3	**1**	150.73	5.3	65.56	42.74	68.2	2.97	24.15	23.61	46.67	4.45	40.61	27.28	24.42	1.31	3.15	4.06	62.81	1.86	22.24	19.31	17.19	0.38	2.42	3.73	29.46	2.05	14.04	13.74	23.34	1.17	6.67	10.76	77.4	6.72	64.7	68.92	144.49	8.98	71.24	70.73
	2	112.13	39.61	10.41	14.91	3.43	36.39	4.75	4.51	4.64	31.86	3.3	8.65	0	3.15	1.34	5.64	20.75	40.58	2.4	4.9	0	11.24	0.07	1.68	14.35	27.47	0.92	1.86	11.13	13.56	1.01	5.61	2.8	58.03	9.75	30.42	22.06	99.54	8.88	23.48
4	**1**	NA	355.51	NA	194.6	NA	49.01	NA	32.95	NA	83.61	NA	33.56	NA	14.66	NA	3.32	NA	198.94	NA	111.73	NA	33.52	NA	18.66	NA	86.9	NA	51.43	NA	35.52	NA	19.89	NA	137.34	NA	59.12	NA	209.54	NA	115.73
	2	NA	100.42	NA	263.8	NA	12.81	NA	49.55	NA	17.2	NA	58.9	NA	5.4	NA	12.77	NA	43.58	NA	83.14	NA	12.42	NA	39.85	NA	71.72	NA	93.32	NA	13.15	NA	29.51	NA	44.12	NA	131.84	NA	86.82	NA	256.15
SUM		524.09	635.02	238.7	538.79	169.28	183.06	97.15	124.64	121.12	238.31	115.17	261.63	42.6	30.19	26.69	32.37	294.82	403.24	132.52	246.08	47.19	71.09	6.68	65.18	144.36	255.65	117.2	175.44	80.6	89.65	62.01	92.62	207.66	415.44	225.43	566.64	562.68	634.44	495.59	874.84

Country	Round	100% Cotton				100% Viscose				40-95% Polyester				80-100% Wool				80-99% Cotton			
	File	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal
1	1	28%	22%	4%	7%	6%	10%	4%	3%	3%	11%	8%	13%	3%	0%	5%	3%	16%	17%	4%	6%
	2	21%	16%	2%	5%	6%	8%	6%	6%	4%	13%	11%	15%	0%	2%	4%	1%	19%	8%	5%	3%
2	1	10%	20%	19%	1%	4%	8%	5%	0%	10%	11%	5%	27%	2%	0%	0%	0%	5%	10%	7%	2%
	2	15%	8%	22%	1%	9%	9%	7%	0%	5%	10%	4%	10%	0%	0%	0%	0%	17%	14%	14%	2%
3	1	23%	15%	21%	15%	11%	8%	8%	8%	7%	13%	13%	10%	4%	4%	1%	1%	10%	5%	7%	7%
	2	59%	11%	24%	15%	2%	10%	11%	4%	2%	9%	8%	9%	0%	1%	3%	6%	11%	11%	6%	5%
4	1	NA	30%	NA	30%	NA	4%	NA	5%	NA	7%	NA	5%	NA	1%	NA	1%	NA	17%	NA	17%
	2	NA	25%	NA	26%	NA	3%	NA	5%	NA	4%	NA	6%	NA	1%	NA	1%	NA	11%	NA	8%
Average		26.02%	18.31%	15.20%	12.41%	6.18%	7.57%	6.91%	4.03%	5.49%	9.59%	8.23%	11.85%	1.55%	1.25%	2.17%	1.57%	12.98%	11.60%	7.08%	6.30%
Average		**17.98%**				**6.17%**				**8.79%**				**1.63%**				**9.49%**			

Country	Round	95-100% Acrylic				Polycotton Cotton-rich				Polycotton Polyester-rich				≥95 Polyester				Others			
	File	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal	Recycling	Reuse EU	Reuse non EU	Energy Recovery/Disposal
1	1	4%	1%	1%	0%	6%	7%	2%	2%	3%	3%	3%	2%	7%	10%	12%	26%	23%	20%	58%	38%
	2	0%	3%	2%	0%	11%	5%	3%	5%	3%	2%	6%	4%	7%	11%	13%	16%	29%	32%	48%	44%
2	1	6%	3%	0%	0%	3%	6%	13%	2%	2%	4%	9%	9%	20%	16%	11%	26%	38%	21%	31%	32%
	2	0%	0%	0%	0%	9%	9%	13%	1%	4%	3%	4%	1%	9%	24%	14%	36%	31%	24%	21%	50%
3	1	3%	1%	1%	1%	5%	6%	4%	5%	4%	3%	2%	4%	12%	19%	21%	24%	22%	26%	23%	25%
	2	0%	3%	0%	2%	8%	8%	2%	2%	6%	4%	2%	6%	1%	16%	23%	30%	12%	28%	21%	23%
4	1	NA	3%	NA	3%	NA	7%	NA	8%	NA	3%	NA	3%	NA	11%	NA	9%	NA	17%	NA	18%
	2	NA	3%	NA	4%	NA	18%	NA	9%	NA	3%	NA	3%	NA	11%	NA	13%	NA	21%	NA	25%
Average		2.19%	2.12%	0.52%	1.31%	6.79%	8.11%	6.33%	4.12%	3.51%	3.06%	4.51%	3.86%	9.41%	14.87%	15.56%	22.62%	25.88%	23.51%	33.48%	31.95%
Average		**1.54%**				**6.34%**				**3.73%**				**15.62%**				**28.71%**			

Additional data from this study are available upon request.