D5.3 Guidelines and Workbook for Application of the Conceptual Framework and Blueprint Regionally

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LIST OF ABBREVIATIONS

Abbreviation	Definition
AI	Artificial intelligence
DPP	Digital Product Passport
EPR	Extended Producer Responsibility
LCA	Life Cycle Analysis
LCC	Life Cycle Costing
NIR	Near infrared
PET	Polyethylene terephthalate
PLA	Polylactic acid
R&D	Research and development
TRL	Technology Readiness Level

Executive Summary

The overall objective of the tExtended project is to develop a knowledge-based Blueprint, which is a master plan for a sustainable textile ecosystem where utilization of textile flows is optimized, aiming for retention of value of materials in a safe and sustainable way. Within tExtended project we will develop technological and digital solutions enabling efficient textile cycles, carry out real scale demonstrator and show potential to reduce textile waste by 80 %. More about the project in https://textended.eu/.

The purpose of this report is to translate the tExtended Blueprint and Conceptual Framework into practical guidance for regional implementation. The Blueprint describes a collaborative, data-driven textile ecosystem in which products and materials are retained at their highest feasible value through durable design, responsible production and use, reuse, repair, remanufacturing and recycling. The Conceptual Framework, implemented in the Textendifier tool, supports the selection of suitable circular routes by matching textile waste characteristics with technically feasible strategies and considering economic, environmental and circularity impacts.

The main finding from the five regional studies is that Europe already has many of the capabilities needed for textile circularity, but they are unevenly distributed and are not yet connected into stable value chains. Across all regions, separate collection is expanding faster than economically viable capacity for sorting, reuse and recycling. Reuse remains the principal higher-value route, while fibre-to-fibre recycling is limited and much recycled material is directed to nonwoven or other open-loop applications. Experience from existing facilities shows that technical capacity alone is insufficient: investments can fail when feedstock quality, financing, responsibilities and demand for outputs are not secured.

Implementation should build on complementary strengths rather than attempt to establish complete national value chains in every country. Central Europe offers mature reuse systems, advanced sorting and machinery expertise; the Nordic region contributes with recycling innovation and coordinated collection experience; the Baltic region has specialised manual sorting, repair and remanufacturing potential; Eastern Europe combines collection networks, mechanical outlets and social-economy capabilities; and Southern Europe links textile manufacturing with established mechanical recycling and preprocessing. Cross-border cooperation is particularly important where national feedstock volumes or processing capacity are insufficient.

For implementation, a hub-and-spoke approach can connect local quality-preserving collection, reuse and repair with regional fine sorting, preparation for reuse and recycling grade feedstock production, and with specialised industrial recycling facilities. Circularity hubs or ecosystem coordinators can align with public authorities, producer responsibility organisations, companies, research and education organisations, reuse actors, recyclers and users of secondary materials. Extended producer responsibility should finance the full net cost of the system, while eco-modulated fees and other incentives reward durability, repairability, safe materials, disassembly and realistic recyclability.

The key conclusion is that increasing collection volumes is not equivalent to increasing circularity. Regional actors should prioritise prevention, direct reuse, repair and preparation for reuse before recycling; combine manual product-value assessment with reliable material identification; and expand processing capacity only when suitable feedstock, verified outputs and committed demand exist. A staged transition—based on shared objectives, measurable targets, coordinated investment, transparent data and continuous learning—offers the most credible route to regionally appropriate circular textile ecosystems across Europe.

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1 Introduction

The overall objective of the tExtended project was to develop a knowledge-based Blueprint, i.e. a master plan for a sustainable textile ecosystem. The basis of the Blueprint is a Conceptual Framework determining the optimized utilization of textile flows, aiming for retention of value of materials in a safe and sustainable way. As part of the research work, we have implemented a real scale demonstrator, as well as studies replication potential of circular ecosystem in selected regions.

The textile sector is undergoing a fundamental transition from a predominantly linear model of production and consumption towards a circular economy. In the current linear system, large quantities of raw materials are used and processed into products, which are used for relatively short periods and eventually discarded. This linear model contributes to resource depletion, greenhouse gas emissions, pollution and increasing volumes of textile waste. At the same time, valuable products and materials are lost because they are not kept in use or are not recovered effectively. Circular economy offers an alternative approach that aims to reduce the use of virgin resources, prevent waste and retain the value of textile products and materials for as long as possible.

In a circular textile economy, circularity is considered throughout the product lifecycle. Textiles are designed to be durable, safe, repairable, reusable and recyclable, and their production increasingly relies on renewable or secondary raw materials. Product lifetimes are extended through responsible use, maintenance, repair, reuse, refurbishment, remanufacturing and repurposing. When products can no longer be used, they are collected, sorted and directed to the most suitable utilization i.e. for reuse or recycling. According to the EU waste hierarchy, reuse should be prioritized and recycling should recover materials at the highest feasible value and support their use as secondary raw materials in textile manufacturing or other appropriate applications. Incineration and disposal should remain the last options for materials that cannot be retained in circulation.

Achieving circularity requires more than individual technologies or isolated improvements. It involves coordinated changes in product design, manufacturing, business models, consumption, collection, sorting, logistics, reuse and recycling. Reliable information on product composition, origin, use and condition is also essential for directing products and materials towards suitable circular pathways. Digital traceability and transparent data sharing can support decision-making across the value chain and enable more efficient management of material flows.

The transition also depends on cooperation between companies, public authorities, research and education organisations, waste-management actors, consumers and civil society. The stage of the transition vary in different countries and regions in Europe. Circular solutions must be technically feasible, environmentally beneficial, economically viable and socially acceptable. They also need to reflect regional circumstances, including available infrastructure, market demand, regulatory conditions, skills and material flows. As these conditions vary between regions, successful models cannot always be transferred directly from one context to another. Instead, circular textile systems must be developed through shared objectives, coordinated investment and gradual implementation that connects collection and processing capacity with reliable demand for reused products and recycled materials.

This deliverable report consists of three main parts. Explanation of the basis of knowledge-based textile circular system i.e. tExtended Conceptual Framework and Blueprint is included as Chapter 2. Overview of results from replication study i.e. replication of textile circularity regionally is included as Chapter 3. Chapter 4 contains guidance and practical steps that can be taken towards circularity. AI tools have been used to support writing of parts of the report.

2 Blueprint for Textile Circularity

In the tExtended project we have visioned a knowledge-based textile ecosystem. This vision is called a Blueprint, and it is introduced in subchapter 2.1. The theoretical basis for optimization of flows in that system is called a Conceptual Framework, which is introduced in subchapter 2.2. The creation of circular systems and circular hubs are discussed in subchapter 2.3.

2.1 Masterplan for Circular Textile Ecosystem

A responsible and circular textile ecosystem of the future is collaborative, data-driven and designed to retain the value of products and materials for as long as possible. This systemic transition requires operational environment that supports change. Overview of system is shown in Figure 1.

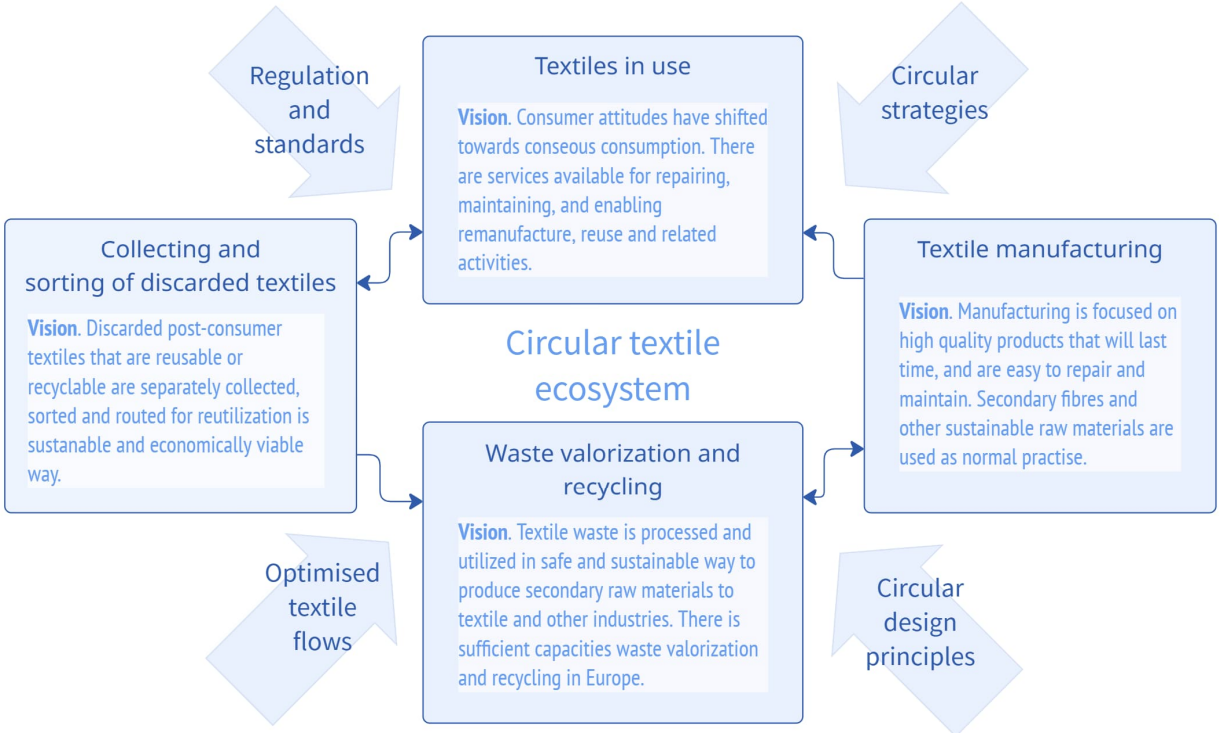


Figure 1 Overview of Blueprint - a master plan for a sustainable textile ecosystem.

In this visioned future system textile products are designed to be of high-quality, durable, easy to repair and maintain, and recyclable. Ecodesign principles are applied and secondary fibres and other sustainable raw materials are used as normal practise. Textiles are produced sustainably, equipped with transparent information, and provided to users via business models that prioritise circular strategies like reduced consumption, reuse, repair, refurbishment and repurposing. Consumer attitudes have shifted towards conscious consumption. There are services available for repairing, maintaining, and enabling remanufacture, reuse and related activities. Discarded post-consumer textiles that are reusable or recyclable are separately collected, sorted and routed for reutilization in sustainable and economically viable way. Thus, efficient collection and sorting direct discarded textiles to their highest-value use, and recycling is applied only when further product or material use is no longer

feasible. There are sufficient capacities for waste valorisation and recycling in Europe, and recycling produce secondary raw materials to textile and other industries.

Data of raw materials and intermediate products is aggregated in every phase during manufacturing. Textile products are equipped with identifiers that enable comprehensive traceability and information access throughout their lifecycle. This information guide users and actors in textile value chain in maintenance, repairing, sorting, dismantling and recycling of products. Updates to DPP with use-phase data would provide full product history, provide textile providers unprecedented possibility to interact with user after sales and help management of circular flows in collecting sorting and recycling. To achieve this, many things need to happen in the textile industry and consumer behaviour. Infrastructure and systems for collecting, sorting, and recycling needs to be built. New regulation and standards are created to support transition and the future system.

More information about tExtended views of circular textile ecosystem for example in:

- Redesigning Value Chains, tExtended D1.2 report https://textended.eu/wp-content/uploads/2024/10/tExtended_D1-2_Redesigning_REVISION1-.pdf
- Blueprint visualizations, tExtended D5.2 in project webpage https://textended.eu/textile-ecosystem-in-europe/

2.2 Conceptual Framework for Optimizing Circular Textile Streams

One of the key challenges of circular textile ecosystem is determining how discarded textile waste streams can be utilized in the most effective way to maximize value retention while reducing waste in a safe and sustainable manner. tExtended has built a knowledge- and data-driven approach for optimizing the circulation of textile products and materials within a circular economy. The framework combines information on the properties of collected and sorted textile waste with knowledge of technical capabilities of the available reuse, recycling, and other R-strategies as presented in Figure 2. The optimization of the utilization route for a given textile waste stream also considers economic, environmental and circularity impacts of the circular strategies. The Conceptual Framework has been implemented as a web-based tool called Textendifier. Through the tool, users can improve their understanding of textile waste, explore available textile waste pathways, and make more informed decisions by considering the overall sustainability of different circular strategies.

The Textendifier version 1.0 developed in tExtended is primarily intended for textile value chain and circular economy actors who are entering the market or looking to increase their understanding of textile circularity. It offers both knowledge on circular economy in textiles and a practical tool to deepen that knowledge. The economic, environmental, and circular impacts provided by the tool have been calculated as industry averages and based on a number of simplifying assumptions. Hence, the impact values should be treated as indicative instead of precise truth. Providing a general tool with precise optimization of circular strategies is unrealistic due to the extensive database required and the limited access to process-specific data. Instead, to make the tool even more valuable, the developed model should be used to build actor/company specific tools which offer more precise decision support based on the actors' and their partners' actual data. To allow this development beyond tExtended, the theoretical model is planned to be shared in a form of a scientific publication.

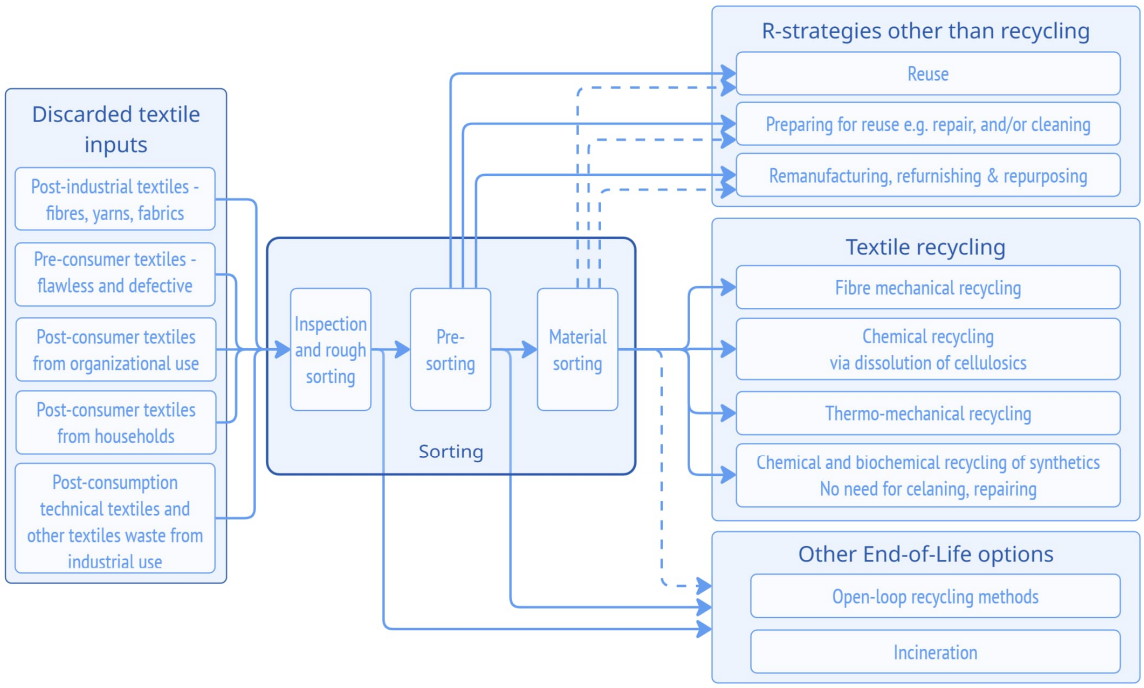


Figure 2 Overview of textile flows in tExtended Conceptual Framework.

Lessons learned related to the development of Conceptual Framework. Building a comprehensive tool for optimizing circular routing of textile waste streams proved to be challenging due to the sheer amount of different textile waste characteristics and possible processing routes. During the process, *we learned that* it was not possible to build a comprehensive textile waste classification system which would both contain all the textile waste characteristics and be practical to use for three key reasons; 1) the suitability of materials to the different processing routes is depends on small and numerous details; 2) current sorting actors are mostly relying on manual or augmented sorting; 3) many of the details are not detectable visually or not even with non-destructive characterization methods. Hence, we decided to make a simplified classification based on characteristics that can be visually observed.

We also discovered that it was not possible to include all technologies, process variations, and alternative pre-processing steps in the impact calculations as 1) there are multiple alternative, and distinct processes under the main textile recycling process categories: 2) blended textiles may require separation either as pre- or after-treatment, but in some cases separation can be done simultaneously (in the same machinery) as recycling process; 3) impacts of one process may vary depending on factors such as used machinery, chemicals, location, and purity of raw materials; 4) processes and the market are continuously developing, keeping the tool up-to-date would be impossible without continuous funding; 5) impacts of processes in the lower TRL level are expected to change when TRL increases. Therefore, we decided to simplify the model to cover only the main process types including fibre mechanical recycling, chemical recycling for cellulosics, thermo-mechanical recycling for synthetics, and chemical recycling via depolymerization for synthetics.

The next challenge we discovered was building the sustainability impact database including especially economic, environmental, social impact data for all the possible circular strategies and specific textile waste characteristics. Gathering data across companies and processes on the required detail-level by LCA and LCC tools and in a way that the data can be compared across processes is difficult but essential for being able to make truly optimal circular decisions. We made many decisions to narrow scope, prioritise certain recycling

processes, and several assumptions about processes. Although the database is not perfect and exhaustive, it is a good start to making circular data transparent and comparable, and an important step towards increased transparency.

In the big picture, particularly recycling technologies are still quite immature and do not perform well in economic terms compared to waste incineration. Increasing the technological maturity is hence key. Furthermore, the remanufacturing of textiles remains a rather broad and poorly understood concept. This cannot fully be captured in a tool like this at the moment. This work *validated our assumption* that finding optimal circular strategies for textile waste is complex, as the material itself is complex and the processes are still rather immature and rigid. If the focus is purely on economic aspects, the circular textile economy beyond reuse and chemical recycling of cotton is hardly interesting in the short and medium term. Hence, our tool does not focus only on the economics but also brings the environmental and circularity aspects into the decision-making. Tools like Textendifier are needed to simplify the decision-making.

Overall, we *succeeded* at building the theoretical, logical, and mathematical model behind the Conceptual Framework. It turned out to be rather simple, robust, and possible to apply across industries. The user interface and the impact database, on the other hand, still require work. Currently, the Conceptual Framework targets a very wide group of stakeholders with different needs for details. Therefore, it focuses on the most important processes at the expense of making generalizations. On the other hand, the first version of the tool provides a basis that can be expanded later. The lessons learned also allowed us *to conclude that* better targeting would make the tool more valuable for its users, as it enables deeper dive into the textile waste and process details, and higher scrutiny of the impacts.

More information about the tExtended Conceptual Framework and Textendifier, for example, in:

- Educational contents from Textendifier tool included as Appendix 1 of this report
- Optimization of textile flows in Blueprint visualizations (tExtended D5.2) in project webpage https://textended.eu/textile-ecosystem-in-europe/
- Textendifier tool https://textendify.willab.fi/optimise/[1]

2.3 Creation of Circular Systems and Hubs

Circular economy transformation requires whole value chains turning circular, and value creation in business changes. Whole industrial and business sectors do not turn circular overnight, but gradually. *Hubs for Circularity* can accelerate the circular transformation. According to A.SPIRE[2], the European Association for Sustainable Process Industries, *Hubs for Circularity* are self-sustaining regional industrial ecosystems that implement industrial and industrial–urban symbiosis at full scale. They bring together industry, SMEs, public authorities, research and education organisations, and civil society to close material, energy, water and data loops. The hubs combine technologies, infrastructure, expertise, governance and financing to develop and manage circular solutions. Their aim is to make resource use more efficient, profitable and climate-neutral while strengthening regional cooperation, investment, employment and social acceptance.

[1] Target is to keep the tool available up to five years after the end of the project, although this period may need to be shortened depending, for example, on available resources and technical feasibility

[2] https://www.aspire2050.eu/p4planet/hubs4circularity; https://www.aspire2050.eu/p4planet/p4planet-sria-2050

The circular textile ecosystem requires a wide range of actors, including textile producers, manufacturers and retailers; commercial and municipal waste-management providers; companies that collect and sort pre- and post-consumer textiles; recyclers; communities, cities and citizens; and supporting organisations such as research institutions and digital service providers. The circular textile system is also interconnected with other sectors. These connections can create new circular business opportunities by mobilising underutilised resources—including materials, energy, water, by-products, waste streams, production capacity and expertise—across the textile ecosystem. A hub for circularity for textiles could act as orchestrators that connect stakeholders, knowledge, technologies and infrastructure across the textile ecosystem. They can improve access to reliable information, coordinate material flows, identify opportunities for collaboration and investment, and support the development of new circular value chains.

Within tExtended project, local, national and international hub models were assessed by their themes, activities, stakeholders, strengths and weaknesses. A national hub was evaluated in more details, because many circular-economy systems, such as extended producer responsibility, are organised nationally. However, it should link all value-chain actors across borders and connect with European and global networks. The proposed actions may also support local and international hubs. Within wider European networks, also local and national hubs can also promote common practices, cross-sectoral cooperation and the replication of successful solutions.

More information about creation of circular systems and circular hubs, for example, in:

- Redesigning Value Chains, tExtended D1.2 report, https://textended.eu/wp-content/uploads/2024/10/tExtended_D1-2_Redesigning_REVISION1-.pdf
- Vision for H4C for textiles, tExtended D1.5 report, https://textended.eu/project-deliverables/

3 Replication of Circular Textile System

This chapter consists of executive summaries regional studies carried out in five regions (sub-chapter 3.1) and overview of replication study (3.2).

This report synthesises the findings of the five regional assessments carried out within the tExtended project, covering the Nordic region[3], the Baltic States[4], Central Europe[5], Eastern Europe[6] and Southern Europe[7]. The objective is to identify the key barriers, opportunities and replication conditions for the development of the circular textile ecosystems across Europe.

The analysis is based on a combination of literature review and more than 100 stakeholder interviews conducted throughout the textile value chain, including collectors, sorters, reuse operators, recyclers, technology providers, producer responsibility organisations and policymakers. The regional studies examined collection, sorting, reuse, repair, remanufacturing, recycling and Extended Producer Responsibility (EPR), while considering differences in market maturity, infrastructure and policy development.

To enable comparison across regions, the findings were analysed thematically rather than geographically. The assessment focuses on identifying common system gaps, regional strengths and enabling factors across the key stages of the circular textile value chain. Particular attention is given to the conditions required to scale circular solutions and support the replication of economically viable and resource-efficient textile ecosystems throughout Europe.

3.1 Regional Studies

3.1.1 Nordic Countries: Finland, Sweden, Norway and Denmark

This chapter summarises the current state of circular textile ecosystems in Denmark, Finland, Norway and Sweden, or the “Nordic region” as referred to from hereon. The assessment excludes Iceland, due to its remote location. The assessment of the Nordic region is done by examining collection, sorting, reuse and recycling capacities, regulatory developments, market conditions and system-level gaps. The findings combine a literature review with interviews conducted from March to October 2026 with 30 stakeholders representing collectors, sorters, recyclers, reuse operators, brands, consultancies, trade associations and producer responsibility organisations.

[3] Nordic study was carried out in collaboration of VTT (Marjo Määttänen, Ella Kärkkäinen, Aravin Periyasamy, Eetta Saarimäki) and RISE (Jamilla Nilsson). 30 experts were interviewed in Finland, Sweden, Denmark and Norway.

[4] Baltic study was carried out by ZALA conducting the work in Latvia and with subcontractors in Estonia and Lithuania.

[5] Central Europe study was carried out by CTB (Edwin Maes, Ine De Vilder, Philippe Colignon and Rémi Tilkin) and covered Belgium, France, Germany and the Netherlands. The analysis combined stakeholder interviews and desk research with internal knowledge exchange and insights derived from other relevant Centexbel projects.

[6] Eastern Europe study was carried out by NARA.

[7] Southern Europe study was carried out by CITEVE (Ana Filipa Costa and Joana Gomes) in collaboration with AIMPLAS (Nacho Montesinos and Emma Wagner).

Across the Nordic region, separate textile collection has increased volumes and visibility of used textiles, but it has not yet delivered economically viable circular systems. The separate collection of textiles started in Finland in 2023, and in the other countries in 2025 as the European mandate came into effect. All the Nordic countries are characterised by collection that often expanded before sufficient sorting, recycling and market capacity was available. In the interviews, stakeholders consistently reported declining input quality, contamination, higher transport and labour costs when it comes to collected textile waste. The contaminated, low-value textile waste and uncertainty over responsibilities and financing during the transition to extended producer responsibility (EPR) increase the challenges in Nordic textile ecosystems. Historically, non-profit organisations have been responsible for textile waste collection in the Nordics, usually in co-operation with the municipalities. After the implementation of separate textile collection, charities are faced with growing volumes of low-quality materials requiring handling, and uncertainty regarding their future role within EPR-based collection systems.

As collection obligations have expanded more rapidly than downstream reuse, sorting and recycling capacity, many actors report difficulties in finding economically viable outlets for collected textiles, raising concerns about the long-term sustainability of existing collection models. For example, in Finland the closure of LSJH's national textile sorting hub in 2025 illustrates this broader challenge across the Nordic region. The experience suggests that investments in collection and sorting must be coordinated with market development, recycling infrastructure and producer responsibility schemes to ensure long-term sustainability

The Nordic region is home to several globally recognized textile brands, including H&M, Ganni, Helly Hansen, and Marimekko. This strong industrial base has fostered collaboration between brands and recyclers, helping to accelerate the development of circular textile value chains. For example, H&M has been an early adopter of Circulose® (formerly Renewcell), a Swedish textile-to-textile recycling technology, and in 2025 strengthened its long-term partnership to support the scale-up of recycled cellulosic fibres. Similarly, Marimekko launched a capsule collection in 2022 incorporating SPINNOVA® fibre, developed by the Finnish fibre technology company Spinnova, demonstrating the commercial potential of next-generation textile materials. Ultimately these actions contribute to the emergence of recycled fibre markets. Finland and Sweden currently have more developed textile recycling ecosystems than Denmark and Norway, largely because they host several of the Nordic region's key fibre-to-fibre recycling and automated sorting initiatives, such as Circulose and SPINNOVA, SipTex and Infinited Fibre Company. Together, these investments have positioned Finland and Sweden at the forefront of Nordic textile circularity and provide an important foundation for scaling textile recycling across the region. Sweden hosts Circulose with the annual recycling capacity of 60,000 tonnes and currently aiming to up-scale to 100,000 tonnes/year. The Finnish Spinnova can currently produce 1000 tonnes of SPINNOVA fibre per year, but Finland has a mechanical refinement capacity of 12,000 tonnes yearly. Denmark has emerging chemical recycling capacity, with operators such as Dissolva currently piloting at 100 kg/day and actively scaling-up to 10,000 tonnes per year. On the other hand, the Norwegian mechanical fibre-to-fibre recycler reportedly recycled 364 tonnes of textiles in 2025 but aims to scale up and reach a capacity of 30,000 tonnes/year.

Despite the recycling initiatives, reuse remains the principal value-retention route and finances much of the current collection and sorting system, yet domestic demand is limited and low-cost new clothing puts second-hand operators under pressure. Large volumes therefore continue to be exported, incinerated or otherwise managed outside domestic circular value chains. The Nordic region is estimated to consume 350,000 tonnes of textiles yearly, according to a 2015 estimate. 2020 data suggest that the Nordic sector generates 7 – 15 kg textile waste per capita, translating roughly into 284,000 tonnes. According to the latest numbers published in 2026, the reuse rate has not increased, but as the amount of textile waste has increased in separately collected streams and in household waste, also the exports have increased.

The four countries offer complementary strengths. Denmark combines established municipal collection, sorting innovations, reuse expertise and emerging chemical recycling. Finland has broad collection networks, industrial mechanical recycling and advanced cellulose-based recycling development, but the closure of its national sorting hub demonstrates the risk of building capacity without secure outlets. Norway has extensive charity-led collection and is progressing rapidly towards EPR, while remaining highly dependent on export because domestic sorting and recycling are limited, distances are long, and domestic demand for reused textiles remains low. Sweden has the largest and most diverse recycling landscape, including industrial-scale chemical recycling, but the closure of the high-capacity Siptex sorting line and earlier financial difficulties in recycling ventures show that technical capacity alone does not ensure demand or profitability.

Replication should therefore focus on coordinated Nordic value chains rather than isolated national systems. The region needs harmonised material classifications, shipment documentation and end-of-waste criteria; clear EPR roles and stable financing that recognise existing municipal, charitable and social-economy capabilities; separate collection routes for reusable and recyclable textiles; and contracts or verified demand before sorting and recycling capacity is expanded. Investment should prioritise safe automation of bag opening, contamination detection, composition identification and value-based sorting, while technology developers require predictable feedstock, faster commercialisation pathways and access to markets beyond the Nordic region.

It can be concluded that the Nordic countries possess many of the actors, technologies and collection structures needed for circular textile ecosystems, but their replication potential depends on aligning policy, financing, quality-controlled feedstock and end markets. Expanding collection without confirmed downstream use risks increasing costs and incineration rather than circularity. A phased, market-led and regionally coordinated approach is the most credible route to retaining textile value and scaling reuse and fibre-to-fibre recycling.

3.1.2 Baltic Countries: Estonia, Latvia and Lithuania

This chapter assesses the current state and replication potential of circular textile ecosystems in Latvia, Lithuania, and Estonia, drawing on 60 stakeholder interviews conducted between April and July 2026, alongside secondary desk research, across collection, sorting, recycling, other R-strategies, and Extended Producer Responsibility (EPR) system design. Across the region, mandatory separate textile collection became a legal requirement in Latvia in January 2023 and in Lithuania and Estonia in January 2025, in line with the EU requirement - though collection infrastructure had already been developing earlier in Latvia and Lithuania, with a nationwide pilot in Latvia from 2019 and municipal collection in Lithuania from 2018.

Reuse is the most developed circular strategy in all three countries: based on consumption patterns, this accounted for approximately 2.38 kg per capita in Latvia in 2021 and 2.7 kg per capita in Lithuania in 2018, and approximately 3.2 kg per capita in Estonia in 2022, exceeding the European average. Moreover, in 2018 consumption of second-hand textiles accounted for nearly one third of overall textile consumption in the Baltic states; more recent data for Latvia (2021) suggests that reuse continues to represent a substantial share of consumption, in a broadly similar range. Reuse is generally self-financing through market revenue; remanufacture (also referred to as upcycling) and recycling depend on subsidy or grant funding across the region, while repair follows a more mixed picture - largely subsidy-dependent in Latvia and Estonia, but commercially self-sustaining in Lithuania, where established repair networks operate without subsidy.

No commercial-scale recycling capacity for post-consumer textiles exists in Latvia, Lithuania, or Estonia. Latvia has two known small-scale operators (plus a forthcoming facility for recycling rubber-backed industrial textiles), and Estonia has a single value-chain partnership. Lithuania has a large-scale nonwoven producer operating at commercial scale, though currently oriented toward pre-consumer and industrial textile waste rather than post-consumer streams. None of the three has yet reached commercial-scale post-consumer fibre-to-fibre recycling, constrained by the lack of recycling infrastructure, technological capacity, as well as insufficient

volume and purity of domestically available post-consumer textile waste. The volume constraint reflects the region's population size - Latvia, Lithuania, and Estonia have a combined population of approximately 6 million - together with comparatively low per-capita textile consumption. In Latvia, per-capita textile consumption was approximately 9.7 kg in 2021, roughly half the EU-27 average of 17–19 kg. In Estonia, per-capita consumption is a bit higher, at approximately 12 kg. In Latvia and Estonia, lower domestic consumption limits post-consumer volumes generated within each country. Lithuania's figure is less directly comparable: rather than a consumption estimate, available data points to textile waste generation of over 16 kg per capita - close to the EU average - driven largely by the volume of second-hand clothing that remains in the local market rather than being re-exported.

Across the region, the Baltic states import substantial volumes of second-hand garments - particularly from Nordic countries, other EU countries, and the United Kingdom - though most of this imported material is re-exported for reuse abroad rather than retained as domestic recycling feedstock. The remaining share, however, is sold domestically before eventually being discarded. In Latvia, this affects the quality of what is collected: imported second-hand textiles resold locally may enter post-consumer collection already more worn, particularly for lower-durability items, limiting the range of applications the collected material can be used for, with an increasing portion of this lower-quality material directed to Solid Recovered Fuel used in cement production. Stakeholders in Estonia and Lithuania report similar quality pressures, attributing declining quality to the growing volume of ultra-fast fashion garments and to material composition - blended and synthetic fibres, chemical content.

The three countries also differ in how their collection infrastructure is organised. Latvia's network combines waste management companies, charities, and retailer take-back schemes. Latvia became the fourth EU Member State to implement textile EPR, in July 2024, and discussions are underway to increase EPR targets because residents already return more material through containers than current targets fund. Lithuania's system is organised primarily around municipal channels, with container density regulated by law at one unit per 1,000 residents; its EPR framework remains in development, with a planned launch in January 2028. Estonia's collection system is the most fragmented of the three, and its EPR framework is also still in development, targeting operational status ahead of the April 2028 EU deadline.

Cross-border cooperation recurs as a proposed way to address the region's recycling infrastructure gap: Lithuanian stakeholders describe it as the only realistic path to higher-value recycling, Estonian stakeholders list expanded cross-border feedstock and recycling collaboration as a key future opportunity, and Latvian companies report direct experience with Nordic recycling - including a case where a Finnish partner suspended intake of certain materials in 2025 - alongside cost constraints such as high service fees.

The treatment of imported second-hand textiles is an important aspect of EPR system design in the Baltic region. EU legislation prevents the application of EPR fees to imported second-hand goods. As Latvia's EPR system predates the EU framework, it is exempt from this requirement. Lithuania and Estonia must incorporate this requirement despite the significant volumes of imported second-hand textiles that eventually enter textile collection systems, which risks significantly unbalancing the financing of the system and the allocation of responsibility.

Earlier regional analysis (Watson *et al.*, 2020) pointed to the Baltic states' long-standing sewing and garment-making tradition as a basis for upcycling and redesign activity, while noting that market and economic barriers have limited the ability of such businesses to scale. A more recent assessment (Kant Hvass *et al.*, 2026) builds on this, suggesting that rather than exporting collected textile waste for processing elsewhere, parts of the post-consumer value chain - sorting, preparation for reuse, repair, and remanufacturing - could instead be developed within the region, including in the Baltic states, where Nordic countries already send textiles for sorting and where some production capacity remains. Retaining these activities regionally is framed as a way to reduce

transport impacts and keep economic value within local and regional economies. This regional economic potential is reflected more broadly across the circular economy as a whole: 2023 data from the European Environment Agency show Estonia with one of the highest shares of circular employment in Europe, at up to 7.9% of all employment, with Latvia and Lithuania also ranking among the higher-performing EU Member States, at 3.6–4.2%, compared with several Nordic and Western European countries reporting shares below 1.5%.

It can be concluded that the Baltic states have built a strong reuse foundation and have specialized manual sorting capacity that serves both locally collected and imported second hand textiles for primarily reuse purposes. In addition, a diverse and active remanufacturing and repair scene exists, and an increasingly formalised collection infrastructure, but full circularity remains limited by the continued absence of domestic recycling capacity. Progress on recycling is likely to depend on cross-border cooperation, while regional analysis points to an opportunity for the Baltic states to move beyond their current role in regional textile circularity as a manual sorting hub, by developing and scaling up higher value-added activities such as repair, remanufacturing, and other preparation-for-reuse processes, building on a workforce base that already places the region among Europe's leaders in circular employment.

3.1.3 Central Europe: Belgium, Germany, The Netherlands and North France

Central Europe, defined in this report as Belgium, the Netherlands, Germany and France, offers strong replication potential for a circular textile ecosystem, but the current system is still far from fully circular. The region already combines separate textile collection, mature second-hand and social-economy reuse networks, commercial sorting capacity, emerging automated and AI-assisted sorting, operational mechanical recycling, selected chemical-recycling routes, textile machinery expertise and increasingly important EPR policy frameworks. The central conclusion is that circularity cannot be measured by collection volumes alone. It must be assessed by verified lifetime extension, preparation for reuse, repair, refurbishment, recycler-grade feedstock, actual recycling outputs, avoided new production, reduced residual treatment and the full net cost of routing textiles to their highest-value verified destination.

The report shows that the four countries have different maturity levels. France has the most mature textile EPR system, managed operationally by Refashion under State-approved specifications, with national collection, sorting, repair, reuse, recycling and eco-modulation mechanisms. The Netherlands introduced textile EPR in 2023 and is moving from legal establishment to implementation of reuse and recycling targets. Belgium has strong regional collection and reuse systems, social-economy actors and relevant experience with the mattress EPR system but still needs a fully operational textile EPR framework. Germany has the largest textile market in the region, extensive collection and sorting activity, and strong textile machinery capacity, but no fully implemented textile-specific EPR system yet.

Collection and sorting are already well developed, but they are not yet consistently linked to the highest-value circular route. Increasing separate collection brings more low-quality, wet, contaminated and non-valorizable textiles into the system and can increase logistics, storage, sorting, labour and waste-treatment costs for collectors, sorters and social-economy operators. Evidence from Belgium, including insights from the Walloon reuse network RESSOURCES, the Walloon Region and the Flemish federation HERWIN, illustrates this cost pressure particularly clearly, while France shows similar pressure through exceptional support to sorting operators and the Netherlands through residual-waste leakage and export dependence. Current sorting remains predominantly product- and reuse-oriented, while high-quality recycling requires more material-oriented classification by fibre composition, colour, construction, contamination, coatings, elastane, hard parts and chemical risks. Automated and AI-assisted sorting is emerging unevenly across the region: Belgium contributes with specialised sorting, AI-supported reuse grading and hard-part-removal technology through

Valvan/Fibersort® and related systems; the Netherlands demonstrates commercial Fibersort deployment; Germany demonstrates automated material recognition through SOEX; and France combines automated sorting, hard-part removal and recycling preparation through Nouvelles Fibres Textiles, Pellenc ST and ANDRITZ.

Recycling capacity is present in the region, but it should be interpreted with caution when assessing circularity in relation to closed-loop outcomes. Mechanical recycling is currently the most established route and is used for a range of textile applications, including nonwovens, insulation materials, automotive products, padding, wiping cloths, geotextiles and composites. These outlets can be environmentally relevant, and several are textile products in their own right. However, they do not automatically represent high-value closed-loop textile-to-textile recycling, particularly where recycled fibres are not returned to spinnable fibres or to textile products with comparable material value. In line with the approach set out in CEN/TS 18272-1:2026, closed-loop interpretation should be limited to cases where discarded textiles or textile fibres are returned, through the end-of-life solution, into a textile product again. Recycling capacity should therefore only be reported as closed-loop where the recycled fibre or polymer outputs, and their subsequent use in textile products, are verified. At present, high-end solutions based on spinnable fibres remain limited, meaning that a large share of recycled textile material is still directed towards non-spun textile applications such as nonwovens like padding, isolation material and geotextiles, which some stakeholders consider to be lower-value applications.

Scaling recycling requires dry, clean, compositionally defined and affordable recycler-grade feedstock, including removal of disruptive components such as zips, buttons, labels and trims where required. France and Germany have the strongest textile-recycling and fibre-preparation machinery base, with ANDRITZ Laroche, TEMAFA, Trützschler and DiloGroup relevant to recycling infrastructure. Belgium contributes mainly through recycler operation, process innovation and upstream preparation technology, while the Netherlands combines operational recycling and process innovation but has not clearly identified domestic machine builder of complete textile recycling lines comparable to France or Germany. Emerging chemical routes, including PET or PLA depolymerisation, should be reported separately from verified commercial textile throughput. While individual countries may not have the full machinery manufacturing capacity required across the circular textile chain, the region as a whole has strong potential to combine complementary machinery and technological capabilities to support the necessary scale-up.

Reuse is currently the strongest non-recycling R-strategy, but it is under pressure from declining textile quality, saturated second-hand markets, export dependence and direct price competition from very low-priced new garments sold by low-budget retailers and ultra-fast-fashion online platforms. These products reduce consumers' willingness to pay for second-hand garments and weaken the resale revenues that historically helped finance collection and sorting, while their end-of-life costs are often externalised to reuse, sorting and waste systems. The report distinguishes genuine reuse from redistribution of overstocks, customer returns, unsold seasonal goods and outlet-only products. These flows may avoid immediate destruction, but they should not automatically be counted as circular reuse if they do not extend the lifetime of an already used product or if they stimulate additional production. Repair is gaining policy relevance, especially through the French repair bonus, but remains labour-intensive and skill-dependent. Refurbishment, remanufacturing and repurposing are promising for controlled or higher-value streams but are still fragmented, niche or designer-led for most apparel flows.

EPR is presented as a decisive enabling mechanism, not only as a waste-financing tool. The French Refashion system shows that EPR can finance collection, sorting, repair, reuse, recycling, R&D, communication, eco-design incentives and crisis support for sorting operators. It also shows that mature EPR does not automatically solve downstream market fragility, especially when second-hand prices decline and recycling outlets remain insufficient. The Netherlands illustrates a newer, target-driven model that still must demonstrate stable operational financing, robust data and verified circular outcomes. Future EPR systems should be designed as

full net-cost financing mechanisms. They should cover quality-preserving collection, logistics, storage, manual and automated sorting, preparation for reuse, cleaning, repair, hard-part removal, recycler-grade feedstock preparation, recycling, residual treatment, data reporting and communication. Public evidence supports this full-cost principle, but it does not yet allow a robust universal fee per garment without further cost modelling by product category and route. EPR should therefore use eco-modulated fees and differentiated downstream support to reward durability, repairability, safe chemistry, recycled content, disassembly and realistic recyclability, while avoiding support for overstock liquidation, low-quality export routes or outlet-only production presented as circularity.

The proposed circular textile ecosystem for Central Europe should follow the tExtended Blueprint as an operational routing model. Each product or batch should first be assessed for refusal, reduction and better design, then for direct reuse, repair, preparation for reuse, refurbishment, remanufacturing or repurposing, and only then for recycling or final treatment. The operational routing decision will normally be made downstream by collectors, reuse operators, sorters, repairers and recyclers, while authorities and producer responsibility organisations define the rules, targets, contracts, compensation levels and reporting obligations that steer these decisions.

Implementation is best organised as a regional hub-and-spoke ecosystem: local spokes for quality-preserving collection, repair, reuse and AI-supported value assessment; regional hubs for fine sorting, hard-part removal, refurbishment preparation and recycler-grade feedstock; and specialised industrial hubs for defined recycling routes. Future monitoring should move from activity indicators to outcome indicators, including verified lifetime extension, avoided new production, repair and refurbishment outputs, actual recycler input and output, fibre-to-fibre output, open-loop output, losses, energy recovery, disposal and net system cost. The main implementation gaps are therefore not only technological, but also financial, organisational and definitional: the region needs common routing definitions, comparable mass balances, full net-cost EPR financing, investment coordination and transparent evidence that textiles are routed to the most sustainable verified destination rather than to the easiest or cheapest outlet. The circularity hub is of major importance in implementing the blueprint as it can guide this implementation and align withing the region and beyond.

3.1.4 Eastern Europe: Slovakia and the Czech Republic

The study combines desk research, semi-structured interviews, and an internal data-set compiled through collaboration with Czech regional textile cluster. Desk research mapped actors and pre-populated the common matrix. The internal set comprises an anonymised Czech ecosystem report and actor workbook, six anonymised Slovak interviews and one anonymised Slovak stakeholder workbook. The evidence cut-off is 30 July 2026.

This regional study finds a functioning but incomplete circular textile ecosystem in the Czech Republic and Slovakia. Both countries have mandatory separate municipal collection from 1 January 2025, established charity and commercial collection networks, manual sorting expertise and some mature mechanical-recycling outlets. The weakest links are reliable post-collection data, high-quality sorting, stable domestic demand for recycled outputs and fibre-to-fibre routes. Collection growth can therefore displace material into lower-value applications, export, energy recovery or disposal unless sorting, recycling and offtake expand together.

The Czech system is more developed and has a broader industrial base. Official sources report 59,000 tonnes of formally coded textile waste in 2022, 36,000 tonnes of separate municipal collection in 2022 and almost 23,000 tonnes separated by municipalities in 2024; these figures use different definitions and do not form a stable time series. A 2026 national source estimates total textile waste at 120,000–140,000 tonnes per year, while a 2024 EPR study used an even broader 120,000–200,000-tonne range. The supplied mapping identifies 43 actors, but most material recycling feeds technical or open-loop applications rather than apparel-to-apparel production.

Slovakia's December 2025 strategy reports just under 11,000 tonnes of separately collected household clothing and textiles in 2024, or just under 2 kg per person, against an estimated household potential of about 11 kg per person. It lists nominal preparation-for-reuse capacity of 54,400 tonnes/year and nominal mechanical material-recovery capacity of 11,890 tonnes/year. A June 2026 government evaluation nevertheless classed the planned functional textile system as unfulfilled and stated that data were still unavailable to evaluate recycled or reused tonnage.

Replication potential is therefore highest for coordinated collection and consumer guidance, hub-and-spoke pre-sorting, traceable mass-balance data, hybrid manual/NIR sorting, social-economy reuse and repair, and mechanical outlets linked to public or industrial procurement. Fibre-to-fibre and chemical routes have longer-term potential but need characterised feedstock, demonstrable yield, committed offtake and investment. EU textile and footwear EPR must operate by April 2028; national implementation should finance the full chain and protect reuse actors, while eco-modulated fees reward durability, repairability and recyclability.

3.1.5 Southern Europe: Portugal and Spain

This chapter synthesizes the current state, challenges, and future outlook of textile waste management and circularity practices in Portugal and Spain, based on stakeholder interviews across collection, sorting, recycling, and policy frameworks. The textile sector in Southern Europe is going through a structural transition driven by regulatory pressure, sustainability goals, and market expectations. Companies are increasingly adapting to circular economy principles, particularly through the implementation of EPR, improved waste management systems, and enhanced traceability requirements. While progress is evident, the maturity of systems and infrastructure varies across the value chain.

Textile collection systems in Portugal and Spain operate at similar scales (500–1000 collection points), with Portugal relying on in-store drop-off and containers, while Spain uses more diversified methods. Waste is mainly post-consumer (≈70%), dominated by cotton, polyester, and blends, and is almost entirely sent to sorting. Reuse (36%) and recycling (32%) are the main pathways, followed by export (29%), while refurbishment remains minimal (3%). Systems are largely self-sustaining and are expected to take on a growing role in traceability and regulatory compliance.

Sorting operations are central to the textile value chain, as most incoming waste is unsorted. Facilities, primarily operated by local actors, rely on automated and technology-driven processes, with average capacities of approximately 27 tonnes/day. Reuse remains the dominant output route (≈50), while landfill disposal is relatively low (≈5%). Despite being economically viable, the sector faces growing pressure from increasing waste volumes and insufficient downstream demand for recycled materials. Key improvement areas include advanced sorting technologies, automation, digital traceability, and stronger value chain integration.

The recycling ecosystem is dominated by mechanical processes with established pre-processing and industrial-scale production of nonwovens, insulation, and recycled yarns, while chemical recycling remains limited. Technologies are largely mature (TRL 9), with capacities of 1000–4000 tonnes/year. Feedstocks are mainly cotton-based waste, sometimes blended with virgin materials. Key challenges include contamination, quality loss, and high costs, although demand for recycled fibres is expected to grow. Future progress depends on scaling advanced technologies, improving feedstock quality, and strengthening end-markets.

Repair and fibre-to-fibre recycling are the main R-strategies, though still limited in scale and economic viability, with strong potential if supported by policy and market incentives. Textile EPR systems are at an early stage, expected to improve collection, recycling, eco-design, and transparency under national and EU frameworks. Decisions are driven by technical, economic, and operational factors, while future developments will focus on stricter targets, eco-modulated fees, digital product passports, and improved traceability.

Overall, the transition towards a circular textile economy in Portugal and Spain is progressing, supported by established collection and mechanical recycling systems and increasing regulatory momentum. However, key challenges remain, including limited chemical recycling capacity, insufficient demand for recycled materials, contamination of textile waste, and the need for improved coordination across the value chain. Addressing these gaps through technological innovation, regulatory alignment, and market development will be critical to achieving a scalable and economically viable circular textile system in the coming decade.

3.2 Replication of Blueprint Regionally

This assessment compares the current state and replication potential of circular textile ecosystems across five regions. We are aware that data is not always comparable due to different timeframes and different scopes, still we were able to identify gaps and potentials to replicate the blueprint in the different regions. This chapter summarises and compares the findings for all regions.

Across all five regions, separate collection is expanding more rapidly than the capacity to sort, reuse and recycle the resulting material into economically viable outlets. This is particularly visible in the Nordic region, where separate collection began in Finland in 2023 and in Denmark, Norway and Sweden in 2025. Stakeholders reported declining input quality, contamination, increasing labour and transport costs, and uncertainty concerning responsibilities and financing during the transition to EPR. Similar pressures are observed in Central Europe, where increased collection brings additional wet, contaminated and non-valorizable textiles into established systems, and in Southern Europe, where increasing volumes are not matched by equivalent growth in demand for recycled materials. Eastern Europe demonstrates the same risk: mandatory municipal collection has been in place in the Czech Republic and Slovakia since 1 January 2025, but collection growth may shift material towards open-loop applications, export, energy recovery or disposal if sorting, recycling and offtake do not develop simultaneously.

Sorting is the decisive link between collection and verified value retention. Manual sorting remains essential in the Baltic and Eastern European regions and for assessing garment condition and reuse value throughout Europe. At the same time, material recycling requires more consistent identification of fibre composition, colour, construction, contamination, coatings, elastane and disruptive components such as buttons, zips and trims. A clear regional divide exists in the adoption of advanced sorting technologies. Central Europe demonstrates the highest level of maturity in automated sorting technologies that include optical and AI supported systems. Southern European interviewees reported technology-driven sorting, with participating facilities operating at an average capacity of approximately 27 tonnes per day. By contrast, no NIR-based sorting capacity was identified in the three Baltic countries, while Eastern Europe proposes hybrid manual and NIR sorting as a replication opportunity. Automation should therefore complement, rather than replace, manual value assessment and should only be expanded where its outputs meet defined recycler specifications and contracted demand.

The regional recycling landscapes show substantial differences in technological and industrial maturity. Finland and Sweden have the most developed recycling ecosystems in the Nordic region, while Denmark is developing chemical-recycling capacity and Norway remains more dependent on collection through charitable organisations and export. Nevertheless, the closure of Finland's national sorting hub at the end of 2025 and the closure of Sweden's high-capacity sorting operation show that technical infrastructure is not viable without secure demand, predictable feedstock and sustainable financing.

Central Europe combines strong capabilities in textile sorting, mechanical recycling, process innovation and recycling technologies. France and Germany are particularly strong in machinery and fibre preparation, while Belgium contributes specialised sorting, process innovation and preparation technology, and the Netherlands combines operational sorting and recycling with process innovation. However, recycling capacity should not

automatically be considered closed-loop textile-to-textile recycling. Most recycled textiles are currently used in nonwovens, insulation materials, automotive applications, geotextiles and similar products. According to CEN/TS 18272-1:2026, discarded textiles or textile fibres can only be considered closed loop when they are transformed into a textile product again. Therefore, recycling should only be classified as closed loop when the recycled outputs and their subsequent use in textile products can be verified. High-value fibre-to-fibre recycling remains limited, as a large share of recycled textiles continues to be diverted to open-loop or non-woven applications, which are often perceived by stakeholders as lower-value pathways, instead of being recycled back into fibres suitable for yarn spinning and the production of new textile products.

Southern Europe also has established mechanical recycling and preprocessing, particularly for cotton-rich production and post-consumer waste. Interviewed facilities generally reported capacities of approximately 1,000 to 4,000 tonnes per year, and approximately 60% of the reported technologies were classified as TRL 9. Mechanical routes produce recycled yarns, nonwovens and insulation, while chemical preprocessing and chemical recycling remain more limited, especially in Portugal. Spain showed a more diversified recycling landscape than Portugal in the interviews. Contamination, blended fibres, elastane, finishing chemicals, non-textile components, processing costs and quality loss remain important barriers to marketable outputs.

Eastern Europe has functioning mechanical-recycling outlets but remains concentrated mainly on technical and open-loop applications. The Czech Republic has a broader industrial base and more extensive mapped infrastructure than Slovakia, although the available Czech waste figures use different scopes and cannot form a consistent time series. Almost 23,000 tonnes were reported as separately collected by Czech municipalities in 2024, while broader estimates of total Czech textile waste ranged from 120,000 to 140,000 tonnes per year in a 2026 national source and from 120,000 to 200,000 tonnes per year in a 2024 EPR study. Slovakia reported just under 11,000 tonnes of separately collected household clothing and textiles in 2024, together with nominal preparation-for-reuse capacity of 54,400 tonnes per year and nominal mechanical material-recovery capacity of 11,890 tonnes per year. These capacities are not equivalent to verified throughput and may include imported or non-household feedstock. A Slovak government evaluation of June 2026 concluded that a functional textile system had not yet been achieved and that data was insufficient to evaluate actual reused or recycled tonnage.

The Baltic region has the largest structural recycling gap. No commercial-scale post-consumer fibre-to-fibre or chemical-recycling capacity was identified in Estonia, Latvia or Lithuania. Existing activity is mainly small-scale mechanical downcycling of production or industrial waste into nonwovens, wiping materials, filling or packaging. The relatively small, combined population, comparatively low domestic textile consumption in Latvia and Estonia, variable feedstock purity and the lack of industrial preprocessing constrain country-level investment. Cross-border aggregation is therefore considered essential to achieve viable recycling volumes. Compared with Central Europe and the Nordic region, the Baltic states have less recycling infrastructure but stronger specialised manual sorting and an established second-hand value chain. This creates an opportunity to move beyond the region’s current role as an import, sorting and re-export hub by expanding preparation for reuse, repair, remanufacturing and higher-value material preparation.

Reuse remains the most developed higher-value strategy in most regions, but its role and market context differ considerably. In the Baltic states, estimated second-hand consumption amounted to approximately 2,38 kg per capita in Latvia in 2021, 2.7 kg per capita in Lithuania in 2018 and 3.2 kg per capita in Estonia in 2022. Reuse is generally financed through sales, while remanufacturing and recycling remain more dependent on subsidies or grants. In the Nordic region, reuse continues to finance a substantial share of collection and sorting but limited domestic demand and competition from very low-priced new clothing increase dependence on export. In Central Europe, mature social-economy and commercial reuse systems face comparable pressure from declining product quality, saturated second-hand markets and ultra-fast-fashion price competition. In Southern Europe, approximately 36% of the material reported by interviewed collection organisations was routed to reuse after

sorting, compared with 32% to recycling, 29% to export and only 3% to refurbishment or remanufacturing. These Southern European percentages reflect the interviewed operations and should not be interpreted as national or regional mass balances.

EPR maturity also varies significantly. France operates the most developed textile EPR system of the regions assessed, covering collection, sorting, repair, reuse, recycling, research, communication and eco-modulation, although the French experience also demonstrates that EPR does not automatically resolve weak downstream markets. The Netherlands introduced textile EPR in 2023 and is moving from legal establishment towards operational achievement of reuse and recycling targets. Belgium, Germany, Portugal, Spain, the Czech Republic, Slovakia, Lithuania, Estonia and the Nordic countries are at different stages of designing, introducing or expanding textile-specific producer responsibility. Latvia introduced textile EPR in July 2024, but the treatment of imported second-hand goods creates a particular financing issue across the Baltic region because large, imported flows eventually enter national collection systems.

The common replication priority is therefore not the isolated expansion of collection or recycling machinery, but the creation of coordinated regional value chains. Local systems should preserve product quality and prioritise prevention, direct reuse and repair. Regional hubs should provide fine sorting, preparation for reuse, removal of disruptive components, material identification and production of recycler-grade feedstock. Specialised industrial hubs can then process sufficiently large, homogeneous and traceable material streams. This hub-and-spoke approach is particularly relevant to the Nordic and Baltic regions, where national volumes and long transport distances constrain stand-alone systems, to Eastern Europe, where municipal fragmentation and data gaps remain significant, and to Central Europe, where existing specialised capacities could be connected more effectively. Southern Europe similarly requires stronger integration between collection, sorting, recycling and textile manufacturing.

Overall, the five regions possess complementary capabilities. Central Europe provides mature reuse structures, advanced sorting and machinery expertise; the Nordic region contributes recycling innovation and experience with coordinated municipal collection; the Baltic region offers specialised manual sorting, repair and remanufacturing potential; Eastern Europe combines established collection networks with mechanical outlets and social-economy opportunities; and Southern Europe combines textile manufacturing, mechanical recycling and comparatively mature preprocessing. Replication should build on these complementary strengths rather than reproduce complete national value chains in every country.

The principal conclusion across all regions is that increasing collection volumes is not equivalent to increasing circularity. A credible European circular textile ecosystem requires quality-preserving collection, common material and output classifications, transparent mass balances, stable EPR financing covering the full net system cost, protection of existing reuse and social-economy actors, contracted demand for sorted and recycled outputs, and monitoring based on verified outcomes. These outcomes should include product lifetime extension, preparation for reuse, repair, actual recycler inputs and outputs, fibre-to-fibre production, open-loop recovery, exports, energy recovery, disposal and total system cost. Without these conditions, expanded collection risks increasing storage, transport, sorting and residual-treatment costs rather than retaining textile value. The circularity hub will be the major actor to guide the implementation of the blueprint.

4 Steps Towards Circularity

Practical guidance towards textile circularity have been collected below under four stages towards circularity starting from finding motivation and defining and vision and targets, followed by committing, and establishing cooperation and communication, as well as elimination obstacles, and followed by change management phase. Stages adopted and modified from framework by Yang *et al.* (2021), and contents has been brought into textile field and complemented with tExtended learnings, to build practical guidance and steps for circular transition.

4.1 Motivation, Vision and Targets

- Find motivation for change by determining benefits including environmental, social and economic benefits.
- Learn about success stories by following pioneer companies and learn about possibilities by following new developments and projects
- Define your way to implement circularity, for example, by selecting circular strategies most relevant for your activities/business, for example, durability, repair, reuse, remanufacturing, recycling and/or the use of secondary raw materials.
- Determine realistic timeline for implementation of your strategies and note that implement the transition in stages rather than waiting for a complete solution.

4.2 Commit, Cooperate and Communicate

- Allocate sufficient resources for the change
- Circularity happens in value chains, therefore, commit your nearest stakeholders and find suitable partners needed in circularity: identify missing actors, such as collectors, sorters, repair providers, recyclers, technology suppliers and users of secondary materials.
- Engage customers with clear, practical information about care, repair, reuse, collection and return options. Support communication with credible evidence, avoid vague sustainability claims, and make circular choices convenient and attractive.
- Find partners needed for implementation your vision, and establish shared specifications, responsibilities and rules for distributing costs, risks and benefits: Define responsibilities, resources, milestones and measurable targets.
- Communicate the circularity steps takes in practical terms to your stakeholders and provide credible evidence for circularity claims and avoid vague sustainability communication.
- Strengthen the business case by assessing investment, operating and compliance costs and confirming reliable demand before scaling. Use pilots and collaborative demonstrations to test solutions, reduce commercial risk and support informed investment decisions.

4.3 Eliminate Obstacles

- Map obstacles related to materials, technology, infrastructure, logistics, regulation, economics, skills, data and consumer behaviour, and prioritise barriers according to their impact and whether the company can address them alone or needs partners.
- Circularity requires coordinated changes in product design, material quality, data, infrastructure, regulation, financing, skills, partnerships and demand. It is beneficial to take systemic view of elimination of obstacles, not trying to address obstacles separately.
- Foster digital transparency and traceability
- Find support, for example, via circularity hubs or an ecosystem coordinator to connect companies, public authorities, research organisations and service providers.
- In waste valorisation and recycling business, avoid investing in too large capacity before reliable feedstock and downstream demand have been confirmed. Make alternative plans for sourcing and/or next steps processing of materials.

4.4 Manage the Change

- Implement the transition in stages rather than waiting for a complete solution, continuous incentivisation of stakeholders may be needed to keep up with the transition in long-term
- Collect and utilize data in change management and in circular business; Agree beforehand on common data formats and secure methods for sharing information across the value chain.
- Engage customers with clear, practical information about their possibilities and options in circularity, for example, about textile care, repair, reuse, collection and return options. Support communication with credible evidence, avoid vague sustainability claims, and make circular choices convenient and attractive.

5 Summary and Conclusions

This report translates the tExtended vision of a knowledge-based circular textile ecosystem into guidance for regional implementation. The Blueprint describes a collaborative and data-driven system in which products and materials are kept at their highest feasible value through durable design, responsible production and use, reuse, repair, remanufacturing and recycling. The Conceptual Framework and its Textendifier implementation complement this vision by providing a structured method for matching textile waste characteristics with technically feasible circular strategies while considering economic, environmental and circularity impacts.

The regional studies show that Europe already has many of the capabilities needed for textile circularity, but these capabilities are unevenly distributed and are not yet connected into stable value chains. Across all regions, separate collection is increasing faster than the capacity and demand for sorting, reuse and recycling. Reuse remains the principal higher-value route, while fibre-to-fibre recycling is still limited and much recycled material is directed to nonwoven or other open-loop applications. Technical capacity alone does not guarantee circular outcomes: investments can fail when feedstock quality, financing, operational responsibilities and markets for outputs are not secured.

The key conclusion is that increasing collection volumes is not equivalent to increasing circularity. Regional implementation should begin with quality-preserving collection and prioritise prevention, direct reuse, repair and preparation for reuse before recycling. Sorting must combine manual assessment of product value with reliable identification of material composition and disruptive components. Recycling capacity should be expanded only when suitable feedstock, verified outputs and committed demand are available. Common definitions, transparent mass balances and outcome-based monitoring are needed to distinguish genuine value retention from transfer to exports, low-value applications, energy recovery or disposal.

Replication should therefore build on complementary regional strengths rather than attempt to establish complete national value chains in every country. A hub-and-spoke model can connect local collection, reuse and repair with regional fine sorting and preparation, and with specialised industrial recycling facilities serving sufficiently large and homogeneous material streams. Circularity hubs or ecosystem coordinators can align public authorities, producer responsibility organisations, companies, research and education organisations, reuse actors, recyclers and users of secondary materials. They can also support shared specifications, data practices, investment planning and cross-border cooperation.

Effective implementation requires stable financing across the full system. Extended producer responsibility can provide an important framework, but it should cover the actual costs of quality-preserving collection, logistics, sorting, preparation for reuse, repair, recycling, residual treatment, data management and communication. Eco-modulated fees and other incentives should reward durability, repairability, safe materials, disassembly and realistic recyclability. At the same time, existing charitable and social-economy actors should be integrated into future systems, and investments should be coordinated with market development and reliable demand for reused products and secondary raw materials.

The practical guidance in this report emphasises a staged transition: establish a shared motivation, vision and measurable targets; commit resources and partners; identify and remove systemic obstacles; and manage change using reliable data, transparent communication and continuous learning. Regional actors should start with realistic priorities and pilots, evaluate environmental, economic and circularity outcomes together, and scale only solutions that demonstrate both technical feasibility and a credible business and governance model. Implemented in this way, the tExtended Blueprint and Conceptual Framework provide a common direction and a flexible basis for developing regionally appropriate circular textile ecosystems across Europe.

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Appendix 1 Textile Waste Routing in Textendifier

Textendifier provides information about circular strategies in the textile industry to support you in making circular and sustainable solutions related to your textile and textile waste business. Textendifier is also a software tool designed to explore textile waste streams and their optimal circular utilization strategies. Textendifier has been developed by the European Commission funded in project tExtended. The main goal of the tool is to onboard especially new European circular ecosystem actors and ultimately minimize the unused textile waste in Europe.

This appendix contains slightly edited educational information available in Textendifier tools user interface.

Accelerating circular textile economy in Europe

The sustainability issues related to textile production and increasing accumulation of textile waste is a global challenge. In the EU, textile value chain has been identified as one of the key product value chains with an urgent need and a strong potential for sustainable and circular transition. EU's vision for future circular textile ecosystem is described in 'Strategy for Sustainable and Circular Textiles' (EC, 2022). This strategy also creates a framework and outlines actions for how to get there by 2030. The EU has also addressed textiles within waste legislation by implementing mandatory separate collection of textile waste in 2025. See Figure 1.1 below.



Figure 1.1 EU vision of Circular textile ecosystem 2030. Adopted from 'EC Strategy for sustainable and circular textiles'.

Transforming the current linear value system into circular one requires adoption of new kinds of strategies and economic principles. R-strategies introduced by Potting et al., can be applied in textile production and use phase, and include also end-of-life strategies such as recycling or incineration (Figure 1.2). However, the current system still lacks solutions for effective collection and sorting of discarded textiles, for increasing the reuse of products and materials, as well as to valorise and recycle a significant part of textile waste fractions.

The circular strategies in Textendifier's focus include reuse, remanufacturing, and recycling. Since textile waste is extremely versatile, a range of recycling options are needed to effectively deal with it. Several processing steps are needed and, thus, costs, environmental, and other impacts vary depending on the recycling method.

This makes it challenging to select the most optimal circular strategy. Furthermore, many of the strategies, especially textile recycling related, are still in development stage or available only in specific geographical regions. This adds complexity to choosing the right circular strategy or understanding the properties of circulated materials. Textendifier is designed to address this complexity, making the decision making easier.

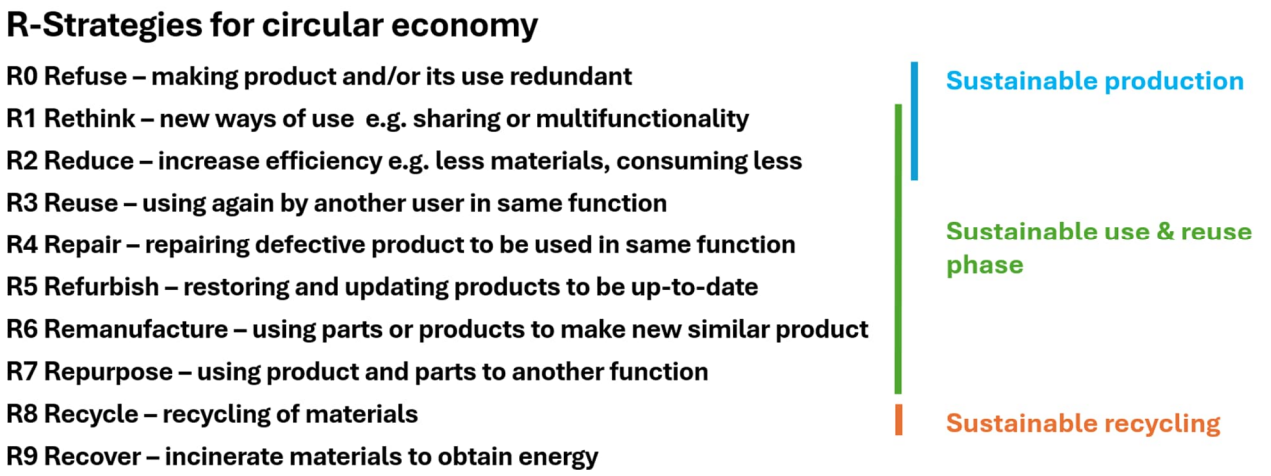


Figure 1.2 R-strategies adopted from Potting et al. (2017).

Overview of Circular Strategies

Textile use and reuse phase

Prolonging textile life cycles is one of the key objectives of this tool. For simplicity, some of the R-strategies affecting the use phase have been grouped under the same strategy. In the extension of product lifetime, the tool is considering 1) Reuse, 2) Preparing for reuse, and 3) Remanufacturing.

Reuse refers to using of textile product within its original purpose. The reuse sector is well established in Europe, with various actors involved including commercial for-profit actors, non-profit reuse centres, and charity organizations. In the EU waste hierarchy reusable products are not considered as waste. However, depending on the collecting method, for example, if reusable products are returned to the same collection point as non-reusable textiles they need to achieve End-of-Waste status to be considered products.

Preparing for reuse is term adopted from the EU waste hierarchy referring to activities that can make damaged product (waste) reusable (non-waste) again. In Textendifier Repair and Refurbish R-strategies are included into ‘Preparing for reuse’ strategy, since the product remains mostly the same.

Remanufacturing in Textendifier refers to processes that use parts of old textile products for making new textile or other products. Related to R-strategies this means that Remanufacture (making new textile products) and Repurpose (manufacturing of other types of new products) activities have been combined.

Textile recycling

There are a wide range of textile recycling technologies. Within Textendifier we consider four main types of recycling: 1) fibre mechanical recycling, 2) chemical recycling via dissolution (polymer level), 3) thermo-mechanical recycling (also polymer level), and 4) chemical recycling via depolymerization (monomer level). Fibre mechanical recycling requires the least processing but does not improve the fibre quality. The more the

fibre structure is modified, the more processing is needed, but also improvement of fibre and even polymer quality is made possible.

Fibre mechanical recycling refers to a method, where textile structures (fabrics and yarns) are dismantled back to separate fibres by mechanical processing. The resulting fibres can be used for spinning of new yarns, if the fibre length is long enough, and shorter fibres can be used for other applications including nonwoven materials and composites. The process can be applied to monomaterials (composed of one fibre type only) or fibre blends.

Chemical recycling on polymer level is carried out by dissolution of fibres into polymer solution. Polymers are chain-like molecules forming the fibre structure. Polymer solution can be used to spin new fibres or to make other products such as films. This method in typically used for cellulose-based fibres like cotton. Cellulose is a natural polymer, but also some synthetic polymers like acrylic can be recycled this way as well. Solvents used in the dissolution are usually fibre type specific, so often the technology is designed for specific monomaterials only. It is, however, also possible to use this kind of process as a separation technology for multimaterial textiles, where one component of the blend is dissolved, and another can be separated from the solution. Most chemical recycling processes are still using primarily monomaterials and are capable of removing only traces of blended fibres.

Thermo-mechanical recycling refers to the process of melting fibres. Polymer melt can be used to make new fibres or other products. The method is applicable to many synthetic fibres like polyester and polyamide, which are thermo-plastic. Thermo-plasticity refers to a property of plastics to soften while heated and rehardening on cooling without significant change in properties. Since each plastic material has specific melting temperature and melting behaviour, these methods are usually fibre type specific and may need process adjustment depending on the presence of additives and contaminants affecting the melting behaviour, especially when aiming for production of new textile fibres. There are, however, also processes for blends result in in materials that can be used in non-textile applications. In such cases, blended fibres a melted in similar temperature and the new material obtained upon cooling is a plastic mixture. Alternatively, when one fibre in the blend melts and another stays in fibre form, a composite material is obtained.

Chemical recycling via depolymerization refers to a method where also chain-like polymer structure is broken into its building blocks, monomers. These polymers can be then built back to polymers via re-polymerization. The formed polymeric materials are like new, virgin material and can be used to make fibres or other products. Depolymerization processes are suitable for synthetic (plastic) fibres such as polyester and polyamide. They are typically fibre type specific, and it should be noted that the process and obtained monomers vary even within the same fibre type, as there are chemically different polyesters and polyamides. Depolymerization processes have been developed mainly for PET - polyethylene terephthalate (the most common polyester) and polyamide-6 (one of the two most common polyamides). Depending on the process, also separation of other fibres and contaminants may be possible.

Incineration refers to combusting waste for energy (heat) recovery. It is the last step in the EU waste hierarchy, and according to the EU Waste Directive, waste suitable for energy recovery that cannot be reused on recycled, must be incinerated instead of landfilling. However, EC textile strategy emphasizes that there is a need to minimize incineration and landfilling. Nevertheless currently, incineration is the dominant and more established textile waste management strategy compared to reuse and recycling. Incineration is included in the optimization for transparency reasons and to allow the user to understand the differences to truly circular strategies.

Optimizing Circular Strategies

Circular strategies included to Textendifier

- Reuse
- Preparing for reuse
- Remanufacturing, repurposing
- Fibre mechanical recycling for spinning – yarn aimed to be used in textile manufacturing
- Fibre mechanical recycling to nonwovens and other products
- Chemical recycling for cellulosics via dissolution
- Thermo-mechanical recycling to fibres
- Thermo-mechanical recycling to other products
- Chemical recycling of synthetics via depolymerization
- Incineration - optionally to open loop recycling

Circular strategies and related technologies have different requirements and conditions on the textile waste characteristics that they can process. The most important requirements and criteria are explained below per circular strategy.

Reuse, Preparing for reuse, and Remanufacturing

Within the waste hierarchy, reuse and preparing for reuse should be prioritized over recycling. This priority requirement may also be applicable to remanufacturing, as it is an alternative that allows for the avoidance of recycling. These activities do not usually require lots of resources such as chemicals, energy, water etc., but they can be quite labour intensive and, thus, more expensive.

For reuse, textile products need to be at least checked, priced, and made available for buyers in stores or online platforms. If there are small defects, need for washing, or products are outdated but can be refurbished to attract buyers, activities in this route may include repairing, cleaning, removal or covering of stains, adding decorations, making small modifications etc. And after these steps, products are priced and made available for buyers.

In remanufacturing, materials are recovered from old products, and new products are designed and made from the recovered materials. Production is typically much more complicated compared to normal textile manufacturing and is usually made by artisans.

Effect of waste characteristics on the processability of textile waste in these strategies:

- **Waste type:** These strategies are suitable for all kinds of textile products intended for consumer use, if the products are reusable and have market demand. There can even be some uses for Industrial and technical textile waste can in some cases be used, for example, in Remanufacturing.
- **Wear:** Prime quality non-damaged goods class have the highest value in all strategies but especially in Reuse. Small defects may be taken care of in Preparing for reuse, and more damaged or partially worn products may contain some materials suitable for Remanufacturing activities.
- **Cleanliness:** Uncleanliness limits attractiveness in Reuse and Remanufacturing and therefore washing can be considered as a feasible additional process step especially for valuable products. Major impurities and certain contaminations are preventing these strategies.
- **Composition:** Fibre composition does not directly affect reusability. However, certain materials are more valuable and considered more attractive than others.

- **Sorting:** All colours and structures are ok, if products are reusable and attractive. For these strategies sorting usually differs considerably from sorting for recycling: products are sorted, for example, based on product type, as well as targeted gender and age.
- **Disruptors:** Only presence of chemicals limiting the textile use are affecting the utilization in these strategies.

Fibre mechanical recycling

Fibre mechanical recycling refers to a method, where textiles are recycled on fibre level using mainly mechanical processing. First textile products are cut to pieces, which are then processed by shredding and opening steps until textile structures (fabrics and yarns) are dismantled back to separate fibres. This mechanical process is shortening fibres due to cutting and mechanical damages. If secondary fibres obtained from this process have sufficient length (close to 20 mm or above) fibres can be used for spinning of new yarns. Shorter fibres, even dust like side-stream from mechanical recycling, can be used for other applications including nonwoven materials and composites, or used as input material for other textile recycling processes. The processing methods and value of materials destined for textile applications differ from those intended for other uses. Therefore, Textendifier distinguishes between these as separate strategies.

Effect of waste characteristics on the processability of textile waste in these strategies:

- **Waste type:** Ensuring homogeneity of input material is crucial, as various types of textiles require different levels of mechanical processing. Homogeneous post-industrial and pre-consumer waste types are useful input materials due to the possibility to optimize processing and, thus, reduce losses. Household waste tends to yield lower material quality and greater losses during processing.
- **Wear:** Materials with varying degrees of wear may be used. The fibre quality (length and strength) obtained from the process depends on the initial material quality, and some reduction in quality can occur during processing.
- **Cleanliness:** It this method waste is usually processed by mechanical means only, and, therefore, contaminants present in the input material will also be present in output material. Hygiene and safety issues may limit the use of secondary fibres obtained.
- **Composition:** The process can be applied to monomaterials (composed of one fibre type only) or fibre blends. However, monomaterials are usually preferred and lead to a better-quality output. In case of blends, blend ratio of input and output material may be different if one fibre type is damaged more and is partly lost in processing.
- **Sorting:** Sorting based on textile structure gives better outcome in mechanical recycling, as it homogenizes the material batch. Colour sorting is relevant in mechanical recycling since colour remain in fibres. –Mixing all colours leads to greyish output. White colour is particularly attractive as a secondary raw material, as it enables redyeing into any colour.
- **Disruptors:** Some mechanical disruptors may damage recycling machinery. Elastane can accumulate into the device and prevent optimal processing, while coatings and other solid components that are fixed into the textile structure prevent this process. Certain chemicals may cause occupational risks and limit the use of secondary fibres especially in skin-contact applications.

Chemical recycling of cellulosics via dissolution

Chemical recycling on polymer level is carried out by dissolving shredded textile material into a polymer solution. In theory, all processes and solvents used in manufacturing of man-made cellulosic fibres (MMCFs) from pulp (e.g. viscose and lyocell, as well as many emerging technologies) can also be used to recycle of cotton

and other cellulosic fibres. In practise, however, some of the process options are more easily adapted to use textile waste as input material. In most process options, multiple pre-processing steps are needed to improve solubility and removal of unwanted chemicals and contaminants.

After dissolution, cellulosic polymer solution can be used to spin new fibres with processes used to make MMFCs. Also, the quality (length and strength) of these fibres is similar to new, virgin material-based MMCFs. The solution can be used for making other products and materials as well, but since pre-processing and dissolution are similar regardless of the secondary use, these options are covered within Textendifier under one strategy.

Effect of waste characteristics on the processability of textile waste in these strategies:

- **Waste type:** All types of waste are suitable for this process.
- **Wear:** Wear has negligible effect on these processes since processing is similar to the processing of wood base pulp, which has a higher DP (degree of polymerization=longer polymer chains) than cotton, and the reduction of DP is usually needed regardless of the wear.
- **Cleanliness:** Normal uncleanliness does not affect recyclability, but major impurities and contaminants may affect chemical reactions and the process, reducing the quality of the secondary fibres.
- **Composition:** In most process options, input material needs to have a very high cotton content, as the best quality is usually obtained with the purest monomaterials. However, some processes allow use of blends.
- **Sorting:** Sorting by structure is not required. White materials do not require bleaching or have colorants that could affect chemical processes.
- **Disruptors:** Non-cellulosic materials and mechanical disruptors need to be removed.

Thermo-mechanical recycling

Thermo-mechanical recycling refers to melting of thermoplastic synthetic fibres like polyester or polyamide to produce new fibres or other products. Typical process steps include removal of hard parts (unless same material as fibres), pre-treatments and pre-processing, compacting of textiles into granulates, extrusion, melt-spinning, after-treatments, fibre finishing, and cutting to stable fibres.

Processes suitable for blends and leading to non-textile applications are somewhat different and, therefore, these options are considered as separate strategies.

Effect of waste characteristics on the processability of textile waste in these strategies:

- **Waste type:** All types of waste are suitable for this process.
- **Wear:** Wear of product has negligible effect of processability, but if also polymers have been worn, recyclability may be affected.
- **Cleanliness:** Normal uncleanliness does not affect recyclability, but major impurities and contaminants may affect the process and/or remain in the melt and consequently reduce quality.
- **Composition:** Exact composition needs to be known, since plastic materials have specific melting temperatures and melting behaviour. Also additives and contaminants affect the melting behaviour.
- **Sorting:** Sorting by structure is not required. Sorting by colour is essential as colours remain in the secondary materials.
- **Disruptors:** Disruptors with the same or compatible composition as fibres may be allowed depending on the process. Volatile chemicals may cause occupations risks, and some chemicals (such as flame retardants) may affect the processability.

Chemical recycling of synthetics via depolymerization

Chemical recycling via depolymerization refers to a method where fibre's polymer structure is broken down and built back together. Typical process steps include hard parts removal, pre-treatments and pre-processing, depolymerization, repolymerization, melt-spinning, after-treatments & fibre finish, and cutting to stable fibres.

Reactions and processes are typically fibre type specific, but their ability to manage blends and contaminants, or even separate fibres, vary. There are several reactions used for the depolymerization of PET (polyethylene terephthalate), such as glycolysis, alcoholysis, and hydrolysis. Polyamide-6 depolymerization is conducted via ring-closing reaction. Each of these main reaction types also includes various process options.

Repolymerization is carried out similarly as in the case of primary materials. Polymers may also be used for other applications than textiles, but since processing is similar regardless of the secondary use, these options are covered by the same strategy.

Effect of waste characteristics on the processability of textile waste in these strategies:

- **Waste type:** All types of wastes are suitable for this process.
- **Wear:** Wear of product has no effect of processability.
- **Cleanliness:** Normal uncleanliness does not affect recyclability, but major impurities and contaminants may affect chemical reactions and the process.
- **Composition:** In most cases needs to be very high content of specific polymer is needed; differences between polyamide-6 and polyamide-66 as well as differences between PET and other polyesters are critical. However, some processes allow use of blends.
- **Sorting:** Sorting by structure is not required. Sorting by colour may be interesting in some processes, that may presence colour.
- **Disruptors:** Disruptors with same or compatible composition as fibres may be allowed depending on the process. Some chemicals may affect the processability.

Implementing Circular Economy

Within circular economy circular strategies should be considered already in design stage. Circular design strategies include approaches like aiming for high durability and longevity, use of secondary (=recycled) raw materials, and/or design for recyclability. Unfortunately, in some cases these approaches may be somewhat contracting also needed some balancing and optimization. For example, blending some polyester into cotton makes textile more durable, but also simultaneously have adverse effect on their recyclability. Most suitable strategy in this case is dependent on the product type.

Although the application of circular strategies is important for developing a circular textile economy, there are currently several barriers to their implementation. This includes, for example, the increased costs associated with developing new circular solutions or utilizing circular materials. There are also technological barriers linked to the lack of reliable technologies to enable circular production, sorting post-consumer waste and recycling as well as the lack of knowledge and skills in utilizing the technologies. This implies as well that the current capacity and resources are not enough to sort recycled products and materials from consumers, when the number of recycled materials increases in the future. Adapting to new circularity requires time and resources for a proper legislation framework to be built.

Finally, consumers attitudes are also often seen as barriers for future circular ecosystemic business models, as the collection of textile products from consumers and their recycling cannot be fully controlled or monitored, and consumers have low awareness and knowledge of the circular products. However, increasing of consumer

awareness and making circular solutions easy and attractive can change consumer attitudes and thus help them to make the transition to more sustainable and circular textile system easier.

ABOUT TEXTENDIFIER

Textendifier provides information about circular strategies in the textile industry to support you in making circular and sustainable solutions related to your textile and textile waste business. Textendifier is also a software tool designed to explore textile waste streams and their optimal circular utilization strategies. Textendifier has been developed by the European Commission funded in project tExtended. The main goal of the tool is to onboard especially new European circular ecosystem actors and ultimately minimize the unused textile waste in Europe.

The Textendifier tool consists of two main steps Waste material selection and Optimization of results:

Waste Material Selection

Describes the key characteristics of the textile waste stream you want to assess. The properties of textile was is key to finding the best use for it.

- Waste type – the origin of the textile waste. Is the post-industrial waste originating from the industrial processes, pre-consumer waste referring to used products e.g. from retailers, or has it been returned by consumers or industrial users after use.
- Wear – the condition of the waste determined by visual inspection. One of the key characteristics impacting the value of textile waste. Post-industrial and pre-consumer textiles are typically not worn in use, but may be damaged, while wear of post-consumer textiles varies widely.
- Cleanliness – The presence of stains, mould, dirt and other contaminants in the waste determined by visual inspection. While some contaminants may prevent utilization of textiles in any other way than incineration, for example, washed textiles containing nonremovable stains from food, grass etc. may not be suitable for reuse, but are perfectly fine for recycling.
- Composition – Material composition very relevant for recycling, since many of the recycling processes are specific to certain fibre types. Reuse is possible regardless of the material composition. However, certain fibre types and compositions are more preferred and thus more valuable.
- Sorting – Textile waste sorting parameters, in this case, are textiles sorted based on colour and/or based on textile structure.
- Disruptors – Presence of materials, chemicals and textile parts that complicate or disrupt the textile waste processing. In Textendifier elastane fibre is considered as disruptor even though it is a fibre.
- Form – Form of the textile waste before processing, for example, products, fabrics, yarns, fibres.

Optimization of Results

The tool proposes optimal circular strategies for utilizing the textile waste and shows the strategy's sustainability impact. This section explains how to read and interpret the results.

Textendifier uses a mathematical method to rank the circular strategies and identify optimal alternatives. The impact scores of the four sustainability factors are first normalized to a score ranging from -1 to 1, which makes it possible to compare, for example, economic value (€) with greenhouse gas emissions (kg CO2eq.). To derive the total sustainability impact, the four normalized sustainability factors are counted together using equal weighting of each factor. This means that none of the sustainability factors is more important than another. Textendifier shows a maximum of the ten most optimal circular strategies for the selected textile waste.

All impact factors are calculated per 1 metric ton of material. Environmental, Economic, and Circularity are positive impacts – the higher the value is, the more positive the circular strategy contribution is. Additionally, the Environmental impact is relative, meaning that it shows improvement in the impacts compared to similar virgin materials. This is done to make the impacts more tangible as the primary objective of circular economy is to minimize the negative impacts of virgin resource use.

To summarize, the total impact score incorporates all four impact factors. It provides a score by which the circular strategies can be compared with each other based on one aggregated score. Unlike the total score, the Economic, Environmental, and Circularity scores are presented in their original, non-normalized form (see Figure 1.3 below.

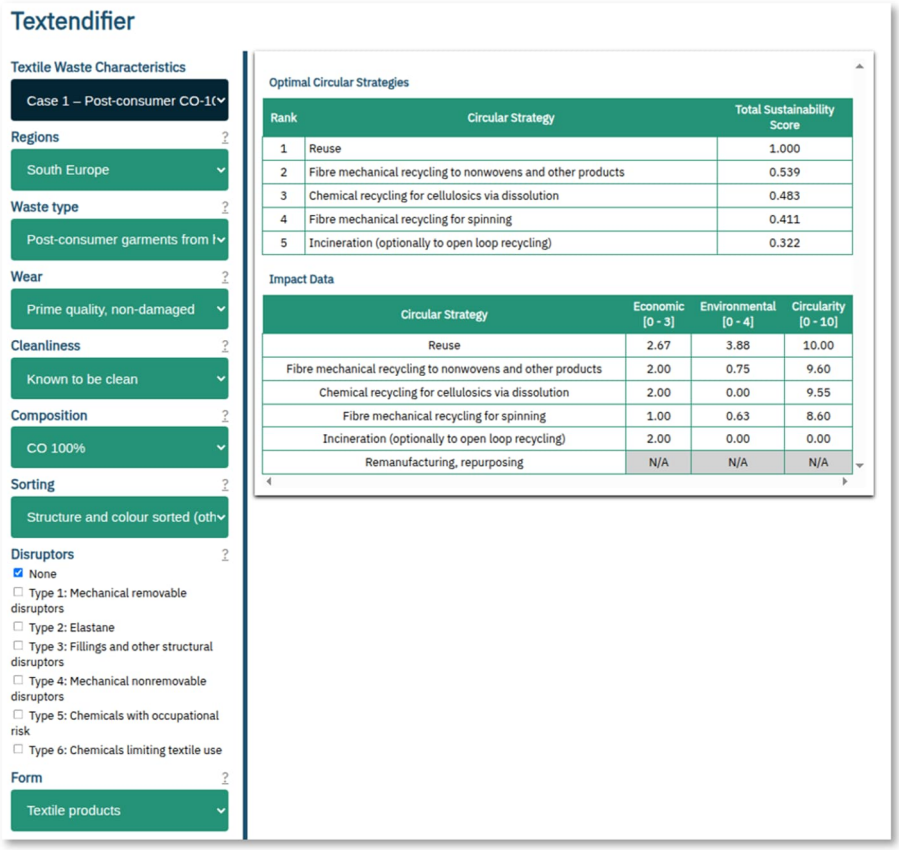


Figure 1.3 An example optimal circularity alternatives based on the textile waste characteristics input.