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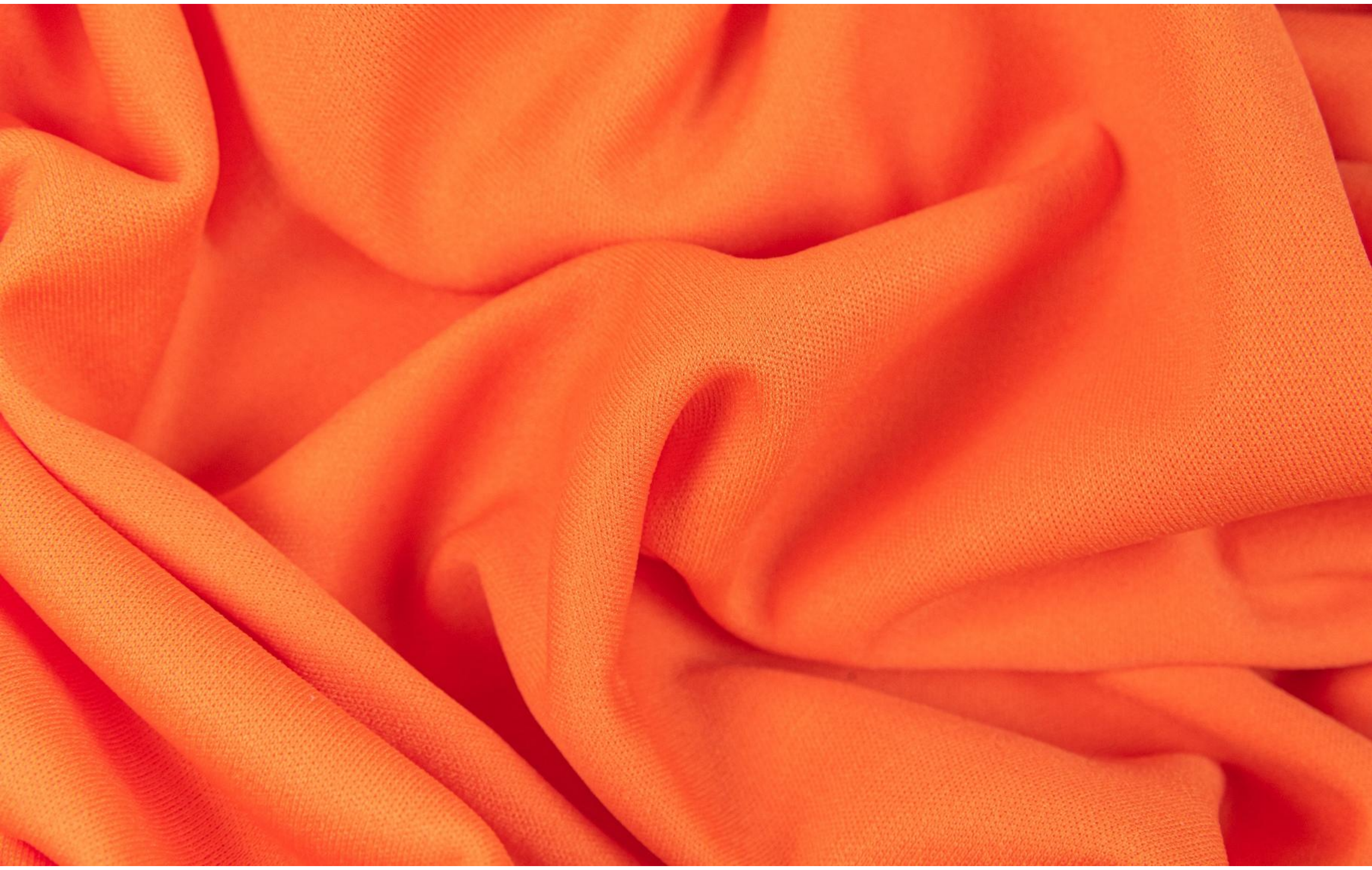
THERMOMECHANICAL RECYCLING OF TEXTILES

September 2025



To promote circularity and reduce the environmental impact of the Textile and Footwear sector, **recycling is a preferred route when repair or reuse are no longer feasible**. Thermomechanical recycling of textiles consists of processing textile waste, primarily made of thermoplastic materials, into new raw materials by melting them, without altering their chemical structure. While similar technologies are already industrialized in other sectors, most notably in the recycling of PET bottles within the packaging industry, this recycling pathway is still at an emerging stage when it comes to post-consumer textile waste.

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Sources

This summary note, written and published by Refashion, is part of the continuation of the webinar on thermomechanical recycling organized by Refashion and the European Center for Innovative Textiles (CETI), which is available for replay. Refashion sincerely thanks Manisha Marival, Head of Recycling and Circular Economy at CETI, for her contribution to the discussion. For the past 13 years, CETI has been a center for applied research and innovation working alongside major companies in the textile industry to advance circularity within the sector.

The data on the composition of different textile materials in the non-reusable waste stream from sorting centers is derived from the characterization study of incoming and outgoing streams from sorting facilities (Refashion, 2023).

Definitions & context

Legislative framework for recycling

Recycling offers a significant potential for sourcing new materials by reusing existing ones instead of disposing of them, thereby recovering recycled raw materials (RRM). In an era of climate change and resource scarcity, recycling is essential to improve our environmental footprint and preserve natural resources.

The Environmental Code positions recycling just below reuse in the waste treatment hierarchy. The EU textile strategy, presented in April 2022[1], emphasizes the use of recycled and recyclable materials, encouraging industries to adopt more sustainable practices. Additionally, the 2018 revision of the EU Waste Framework Directive (2008/98/EC) requires all EU member states to establish systems for the separate collection of textiles, household linen and footwear as of January 1st, 2025. Since clothing, household linen and footwear collection inevitably generates non-reusable textile flows, the framework directive reinforces the importance of recycling in waste management and the transition to a circular economy.

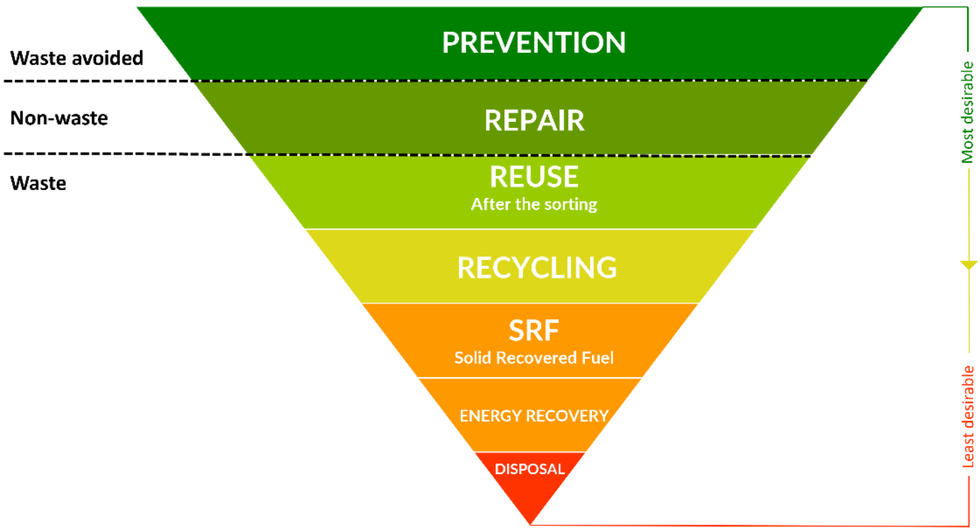


Figure 1: Waste treatment hierarchy

In France, the [French law on fighting waste and on the circular economy]() (AGEC) of 2020 sets objectives and requirements in terms of recycling.

[1] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_2013

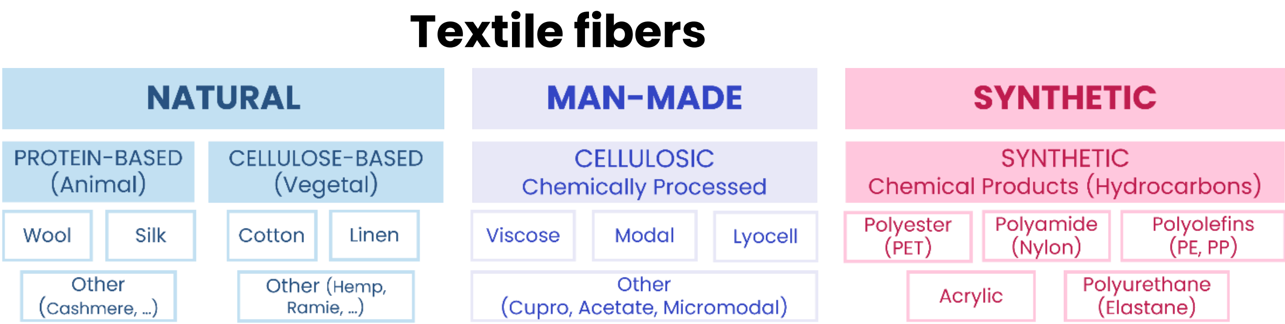


Figure 2: Classification of fibers used in textiles

Various types of fibers are used for textiles (clothing, household linen) manufacturing, and they are having an impact on possible recycling processes (Figure 2). **A distinction is made between natural fibers and man-made fibers, which can be derived either from natural resources (man-made cellulosic fibers) or from petrochemical sources (synthetic fibers).** These fibers are processed into yarn through spinning techniques, which vary depending on the fiber type, before being woven or knitted into textiles.

The three textile recycling pathways

Recycling, as defined by the European Commission in Directive 2008/98/EC, means « *any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes* ». This definition includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials intended to be used as fuels or for backfilling operations.

There are three main recycling pathways for textiles. These routes are complementary and help process a larger share of non-reusable textile waste:

Mechanical	**Thermomechanical**	**Chemical**
Encompasses all **mechanical treatments** (cutting, tearing/garnetting, unravelling, and grinding/shredding) used to convert textile waste into new raw materials. For more details, explore our [report on mechanical recycling.]()	Designed for synthetic textiles made **from thermoplastics**, this process involves shredding, densifying, and extruding the material to produce new granules.	Involves breaking down textile materials into their **basic components** (monomers or polymers) using chemical processes such as dissolution or depolymerization. For more details, explore our [report on chemical recycling.]()

For more details, explore [our three webinars]() on each recycling pathway.

Thermomechanical recycling processes

Thermomechanical recycling is intended for predominantly synthetic textiles made of thermoplastic fibers. It combines mechanical processes, such as shredding and densification, with thermal processes, such as extrusion, pelletizing, and compounding, to produce Recycled Raw Materials (RRM) in the form of pellets or compounds. These pellets can then be used for melt-spinning new synthetic textile fibers or in plastics manufacturing across various sectors depending on the material's properties.

Thermoplastic fibers

Thermoplastics are a family of plastics (polymers), alongside thermosets and elastomers, and are the most widely used polymers. They are processed without any chemical reaction through injection, extrusion or thermoforming, while retaining their chemical properties. During these processes, thermoplastics soften when heated - above each polymer-specific transition temperature - and solidify again upon cooling in a **reversible** manner. This characteristic makes thermoplastics comparatively easier to recycle. In apparel, polyester and polyamides are the most common thermoplastic fibers.

On the other hand, **thermosets** undergo an **irreversible** polymerization reaction. Once cooled, they reach a solid state that can no longer be re-melted, making their recycling much more complex. Some polyurethanes, for example, may exist in thermoset form.

Exploring further:

Polymer chemistry

Thermoplastic polymers can be divided into two main types: **amorphous**, such as polycarbonate (PC) and polystyrene (PS), and **semi-crystalline**, such as polypropylene, polyamide and polyester or polyethylene terephthalate (PET).

Amorphous polymers have a random, disordered chain structure, whereas semi-crystalline polymers contain both highly ordered crystalline regions and disordered amorphous regions. The more crystalline regions a polymer has, the stiffer it is. Conversely, a polymer with more amorphous regions will be more flexible.

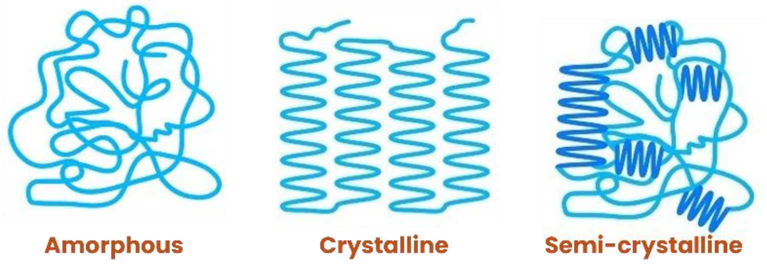


Figure 3: Types of chemical structures of polymers
Source: Polymer Crystallization by Thermal Analysis (mt.com)

Glass transition Temperature (Tg)

This is the temperature at which an amorphous polymer changes from a hard, glassy state to a soft, rubbery state, or vice versa. It is a key indicator of the polymer's mechanical properties.

Intrinsic Viscosity (IV)

Intrinsic viscosity is a measure of the molecular weight of polymers and reflects the material's melting point, its crystallinity and its tensile strength. For bottle production, high–molecular weight PET with an IV of about 0.8 is required, whereas for textiles, polyester with an IV of 0.6 may be sufficient. Viscosity is strongly influenced by temperature: in general, polymers' viscosity decreases as temperature increases. This reduction makes their processing easier and allows their use in textile manufacturing.

Steps in thermomechanical recycling

To direct textiles towards recycling, it is essential to know their composition in order to select the most suitable method depending on the fiber types and the intended application. In the case of thermomechanical recycling, some materials may disturb the processing, particularly natural cellulosic fibers (which can degrade or burn at high temperatures) and surface coatings or finishes (see Table 1 below). Their removal upstream and the selection of monomaterial, thermoplastic fiber textiles, ensures both recycling efficiency and quality, while minimizing any risks of contamination or of process malfunctions.

Table 1: Classification of suitable materials and disruptors for thermomechanical recycling

Materials suitable for thermomechanical recycling	**Disruptors[2]**
Polyester **Polyamide** **Polypropylene** **Thermoplastic polyurethane**	- Metallic-plastic yarns - Thermolactyl fibers (chlorofibers) - Dyes - Garments with coatings/finishes (PU, PVC) - Dirt, moisture, odors - Complex blends (more than two materials, any material <5%, elastane >5%) - Electronic and electrical components - Aesthetic elements (flocking/prints) - Hard metallic and thermoplastic components

*This list is **non-exhaustive**. The complete list of textile recycling facilitators and disruptors is detailed in the " Study on recycling disruptors and facilitators in Clothing, Household linen and Footwear " 2025 report published on the Refashion website.*

Once textiles have been sorted and preprocessed for recycling, the thermomechanical recycling process includes the following steps:

Figure 4: Steps of the thermomechanical recycling process

[2] Study on the factors disrupting and facilitating textile and household linen recycling, Refashion, 2014

Grinding

Grinding involves reducing the size of textiles by shredding them into short fibers of a few centimeters or millimeters, or into powder, using a shredder (or grinder).

Densification

Densification involves conveying shredded textiles into a drum where they are agglomerated and compacted. This process is carried out either by heating the thermoplastic to its melting point - typically through blade friction to avoid overheating and weakening the material, or by applying high pressure. This step increases the density of the shredded material, helping to eliminate static electricity, facilitating feeding into the extruder, and achieving a **sufficient viscosity index** for the subsequent extrusion stage. At this point, agglomerates of fused fibers are obtained.

Extrusion/Granulation

The third step consists of extruding the melted thermoplastic material into granules (pellets), which are cooled at the exit of the spinneret to solidify.

Compounding

When processing a new waste stream, it is necessary to perform characterization tests on the pellets to measure their rheological properties and intrinsic viscosity. These results help determine whether a compounding step is required.

Compounding is therefore the extrusion–granulation process during which shredded and densified textiles can be mixed with virgin thermoplastic material, and one or more additives are incorporated. This step produces compounds (pellets) with mechanical, thermal, or aesthetic properties tailored to the intended application (e.g., antistatic, UV-resistant, antioxidant, dye, pigment, etc.).

Non-exhaustive list of European stakeholders in thermomechanical recycling:

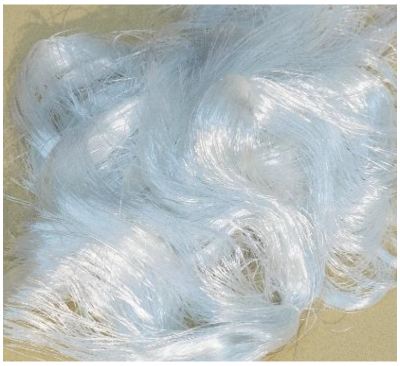
Ceti TRANSFORMATIVE TEXTILES CETI	Cycl-add Cycl'Add	mapea Mapea	muovi AU FIL DU RECYCLAGE Muovi

Applications of thermomechanical recycling

At the end of the thermomechanical recycling process, different applications are possible depending on the properties of the pellets. These include closed-loop ones, where the recycled material is reincorporated into products of the apparel sector, and open-loop ones, where it is reincorporated into products of other sectors (furniture, sports and leisure, plastics, etc.). These outlets are complementary and help manage the diversity of post-consumer textile waste.

Closed-loop

Spinning



The thermoplastic pellets obtained after recycling can be spun to produce synthetic fibers. Melt spinning involves extruding the molten polymer to produce continuous filaments, which are then cooled at the spinneret exit, stretched and wound onto bobbins to form yarns.

The advantage of this incorporation route is that it produces high-quality yarns; it is visually impossible to distinguish that these yarns are made with recycled pellets, giving them strong aesthetic appeal. To achieve these characteristics, it is necessary to use high purity feedstock at the start of the recycling process.

Primary textile feedstock for this application: polyester, polyamide, polyolefin textiles (100% pure fiber textiles)

Non-exhaustive list of European stakeholders:

Ain Fibres | Antex | Aquafil | CETI | Fulgar

Nurel

Open-loop

Plastics industry

Plastic pellets can be used to manufacture various plastic products by injection molding or extrusion, such as automotive parts, construction equipment, pallets, sports equipment, or furniture items.

Currently, the use of recycled textiles in the production of compounds for plastics industry is below 500 tons per year, but it could reach 8 kt/year within 5 to 7 years.[3]

Primary textile feedstock for this application: 100% polyester textiles, 100% polyamide textiles, cotton/polyester or polyester/polyamide blends incorporated into polymer matrices.

Non-exhaustive list of European stakeholders:

IPC   Mapea   Plaxtil

Figure 5: R-Shape® sports cups made from 100% polyester non-reusable post-consumer jerseys (NOLT – 2020 Innovation Challenge Winner)

[3] Potentiel de recyclage des textiles non réutilisables, ADEME, September 2023

Challenges of thermomechanical recycling

Thermomechanical recycling, although it presents some interesting potential for synthetic textiles, faces several obstacles.

1. **Economic challenges:**

The cost of post-consumer recycled plastic pellets or recycled yarn generally remains higher than those made of virgin materials. This price difference is due to the complexity of sorting and preprocessing stages, still mostly performed manually, as well as the costs of recycling operations with high energy requirements. Increasing processed volumes could help reduce these costs. In addition, the development of a complete recycling value chain in France and in Europe remains a challenge, as most textile transformation steps — particularly spinning — are still outsourced in Asia, which limits the incorporation of post-consumer recycled materials into local production chains.

2. **Technical challenges:**

Although thermomechanical recycling has been used for several years in the plastics packaging sector, it still faces several technical barriers for its industrial-scale application to post-consumer textiles.

The main obstacle lies in the **quality requirements of input materials**: only **textiles made from thermoplastic fibers** can be effectively processed. The presence of any contaminants or incompatible polymer blends can not only compromise the quality of the final recycled product but can also damage processing equipment. Filters are being developed to remove any contaminants and impurities at the machine inlet, but significant R&D progress is still required to secure this recycling pathway.

In cases of polymer blends, it is necessary to ensure that their melting temperatures are close and that the coexistence of both polymers in the final recycled product is compatible with the target properties.

Furthermore, even for a single thermoplastic fiber, the textile industry uses a wide range of **polymer grades** with varying properties depending on the manufacturer. This leads to high variability within the post-consumer feedstock, making it difficult to produce recycled raw materials (RRM) with consistent quality. In addition, it is challenging to predict how dyes will behave at high temperatures, as dye compositions are also highly variable.

Another challenge lies in **maintaining material properties**, particularly the polymer's **viscosity index**, its mechanical strength and thermal resistance. Excessive exposure to high temperatures can degrade these mechanical properties. The **moisture** content of post-consumer textiles also represents a critical issue. Excessive humidity can provoke counterproductive fiber agglomeration, reduce viscosity, and in some cases even prevent material extrusion.

As with other post-consumer textiles recycling pathways, **technical challenges also arise upstream, starting with material identification and preparation**. Near-infrared (NIR) spectroscopy sorting technologies are more and more advanced but still cannot accurately identify all blended materials. Thermomechanical recycling also requires **color sorting**, even though the final recycled raw material is often re-dyed, typically in darker shades, to widen the range of achievable colors. Several projects are in progress to improve these technologies and deliver better performance in fiber and color sorting. Trim removal is also a critical step, and still primarily performed manually.

3. **Lack of local industrial-scale infrastructure:**

Currently in France, there are a few plastics processing and spinning facilities capable of converting textile waste. However, not all of them can handle post-consumer feedstock due to technical limitations, potential risks to equipment, or a lack of market outlets. To date, the vast majority of recycled polyester yarns comes from PET bottles, a well-known, homogeneous stream that is recycled at industrial scale. Measures are increasingly being implemented to promote closed-loop recycling of PET bottles, so that they are recycled into new bottles rather than into other consumer goods. Some plastics processors are developing ranges of compounds or synthetic yarns incorporating a share of post-consumer textiles, but these products generally account for only a small portion of their overall production. As a result, the production capacity of these facilities could expand, should the demand for recycled raw materials (RRM) derived from post-consumer textiles grow.

4. **Lack of eco-design:**

Another major barrier lies in the lack of eco-design of textile products. Many items are designed and manufactured without considering their recyclability at the end of their lifecycle. The presence of numerous recycling disruptors and blended materials complicates sorting for recycling and trim removal steps.

Summary

Thermomechanical recycling is a pathway that enables the conversion of textile waste, predominantly composed of thermoplastic fibers such as polyester or polyamide (nylon), into pellets that can be reused in new manufacturing processes.

The materials derived from thermomechanical recycling can be reintegrated into multiple industries, currently primarily in open-loop applications (furniture, plastics processing, etc.) and, to a lesser extent, in closed-loop applications (return to original use: apparel). Combining these outlets maximizes the value of recycled materials while meeting the technical requirements of each sector.

However, large-scale development of thermomechanical recycling for textile waste remains constrained by several challenges. This recycling pathway still needs some R&D work, notably to scale technologies up to the industrial level and to secure end markets for recycled materials. One of the main barriers is the need for clean textile feedstock, with well-identified material composition based on thermoplastic fibers. The process is poorly compatible with multiple material blends, which are common in post-consumer textiles. In addition, it is necessary to increase the viscosity of synthetic textiles and ensure low moisture content at machine inlet to minimize fire risks, while also maintaining a viable economic balance.

Furthermore, even if current studies indicate a more favorable environmental footprint for mechanical recycling[4], **the three major recycling pathways - mechanical, chemical, and thermomechanical - are all essential and complementary for establishing a truly circular textile value chain**. To increase volumes of recycled non-reusable textiles, close collaboration across the entire value chain is crucial. Manufacturers, suppliers, brands, recyclers, and consumers must work together to optimize textile material flows, secure feedstock and ensure the success of recycling solutions.

Eco-design also plays a key role in advancing recycling. Designing products with their end-of-life in mind is important to enhance their durability and recyclability. By adopting these principles and continuing collaborative efforts, recycling can become an integrated, sustainable, and effective practice, benefiting both the environment and the economy.

To learn more, explore our best practice guide on textiles design for recycling and our study on recycling disruptors and facilitators in clothing, household linen and footwear.

[4] Study on the technical, regulatory, economic and environmental effectiveness of textile fibres recycling - European Commission, 2021

The Refashion Recycle platform aims to bring together stakeholders of the Textile and Footwear Sector to accelerate the industrialization of the recycling of non-reusable textiles and footwear. Through the organization of workshops and webinars, Refashion builds bridges between companies offering materials and manufacturers who will incorporate them into their production processes.

About Refashion

Refashion is the eco-organization for the Clothing, Household Linen, and Footwear sector in France. It is a private, non-profit company, accredited by public authorities and financed through eco-contributions paid by member brands and retailers. Refashion is responsible for the prevention and the end-of-life management of textile and footwear products sold on the French market.

At the heart of the textile and footwear ecosystem, Refashion is firmly committed to a collective and collaborative approach that mobilizes all stakeholders. With its mission oriented towards future, it works to unite and support every actor in the sector to reduce environmental impacts and generate value. Refashion develops and provides tools, services and resources designed to equip stakeholders with the means to act and implement a more responsible and circular fashion industry.