State of the art of recycling solutions for shoe soles in Europe

Specifications of recyclers and machine manufacturers

Re_fashion

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Report written by CETIA & REFASHION, based on the work carried out by CETIA

GLOSSARY

Crosslinking: passage of a polymer from a state where the macromolecules are independent to a state where they are linked by chemical bonds.
Cupsole: any insole moulded to the shape of the shoe, then sewn and/or glued to the upper; sometimes also called a cupped sole.
Recovery[1] : any operation which principal result is that waste is serving a useful purpose in substitution for other substances, materials or products which would have been used for a particular purpose, or that waste is prepared for use for that purpose, including by the waste producer.
Recycling: any recovery operation by which waste, including organic waste, is reprocessed into substances, materials or products for its original function or for other purposes. Energy recovery operations, reprocessing materials that are to be used as fuels and backfilling operations do not qualify as recycling operations.[2]
Rod: A plastic (or elastomer) yarn is a continuous filament or profile produced by extrusion.
Sorting for recycling: second-sort, or finer sorting, of CHF waste, or components thereof, not intended to be reused, according to their material composition and/or colour in accordance with a recycler's material specifications, in order that recycling can be performed without any further sorting being required.
Waste: any substance or object, or more generally any movable property, which the holder discards or intends or is obliged to discard (article L 541-1-1 of the French Environment Code).

ACRONYMS & ABBREVIATIONS

ABS	Acrylonitrile Butadiene Styrene
CHF	Clothing, Household linen and Footwear
EPDM	Ethylene Propylene Diene Monomer
EPR	Extended Producer Responsibility
EVA	Ethylene Vinyl Acetate
MEM	Marketer
NBR	Nitrile Butadiene Rubber
NR	Natural Rubber
PA	Polyamide
PEBA	Polyether block amide
PC	Polycarbonate
PU	Polyurethane
PS	Polystyrene
PVC	Polyvinyl chloride
RRM	Recycling Raw Materials
SBR	Styrene Butadiene Rubber
SBS	Styrene-Butadiene-Styrene
TP/ TPR	Thermoplastic Rubber
TPU	Thermoplastic Polyurethane

[1] https://www.legifrance.gouv.fr/codes/article_lc/LEGIARTI000042176087
[2] https://www.legifrance.gouv.fr/codes/article_lc/LEGIARTI000042176087

1. INTRODUCTION

1.1 Context

Every year in France, around a third of post-consumer textiles (clothing, household linen) and footwear is collected compared to the volume of new products placed on the market. The tonnages of post-consumer textiles and footwear collected are set to increase in the near future throughout Europe, with the legal obligation since January 1st, 2025 for the separate collection of post-consumer CHF in all member states. The French 2023-2028 EPR CHF specifications impose a 60% collection target of all products placed on the market by 2028.

In 2023, the market for clothing, household linen and footwear (CHF) in France represented around 833,000 tonnes, of which 148 675 of footwear. In the same year, 268,161 tonnes of post-consumer CHF were collected and 187,510 tonnes sorted. 32.5% of sorted post-consumer CHF, the vast majority of which was textiles (clothing, household linen), was non-reusable but could be recycled[3]. Currently, the prime recovery solution for non-rewearable footwear is Solid Recovered Fuel (SRF), in the absence of existing industrial recycling solutions. On the one hand, these figures underline the need to raise public awareness of the need to dispose of post-consumer CHF at voluntary drop-off points, whatever their condition, so that they can be directed towards the most suitable recovery route. On the other hand, they demonstrate the need to speed up the development of industrial recycling solutions for non-reusable post-consumer CHF in France and Europe, notably for footwear.

The sole represents 40% to 50% of a shoe's total weight and is often made up of fewer components than the upper. This is why the main footwear recycling initiatives focus on shoe soles. However, the presence of multi-material soles, the diversity of the formulations used, and the difficulties linked to material identification make their recycling still complex. For footwear preparation for recycling, two main approaches co-exist: complete grinding of footwear followed by separation of their component materials, and (manual or automated) dismantling of the upper and the sole in order to separately recycle one and/or the other. The development of sorting for recycling and preprocessing technologies allows for circular loops to be set up for shoe soles; it is a key element for building efficient, sustainable recycling chains.

1.2 Objective

Refashion has undertaken the realization of an in-depth study of recycling solutions for shoe soles derived from non-rewearable post-consumer footwear in Europe.
The study aims to explore recycling solutions for shoe sole materials for closed loop and open loop applications; energy recovery is excluded. The results of this study are intended to accelerate the recycling of non-rewearable post-consumer footwear in Europe, and to promote a circular economy in the European footwear industry.
This report includes a state-of-the-art review of existing solutions, based on collected information including recyclers' specifications, as well as results from trials carried out on three closed-loop recycling solutions for two sole material types.

It should be noted that the list of recycling solutions' providers is intended to be as exhaustive as possible but will need to be regularly updated.

[3] (Refashion - Activity Report 2023)

2. Sole preparation for recycling

2.1 Shoe construction

There are many different types of footwear on the market: sneakers, boots, pumps, derbies, sandals and more. Each of these shoe models features a variety of materials and manufacturing techniques (cemented, stitched, injected, vulcanized, etc.), but the upper and the sole remain invariable components.
The upper refers to the top part of the shoe, providing support for the foot. Its components vary from model to model, but generally include an outer part (quarters, tongue, claps, etc.), a lining and reinforcements (hard toe, counter, etc.) (see**Erreur ! Source du renvoi introuvable.**). The sole can be designed in different ways, as a single material or more commonly, as a multi-material sole, it is often composed of different elements: an outsole and a midsole (or comfort sole). Other elements may be added depending on the nature of the shoe: a heel, a welt, a shank (to ensure rigidity and support of the arch), or an anti-perforation sole (for example for safety footwear), etc.

The main types of manufacturing are:

- Adhesive

This method consists of attaching the shoe upper and the sole together using adhesives. The surfaces to be bonded are first prepared to increase their adhesion. The adhesive is then applied evenly to the two parts to be joined, which are then pressed together.

- Stitched (Lateral, Blake, Goodyear, Norwegian, etc.)

The shoe upper and the sole are assembled by stitching. Typically, the upper is first attached to the insole, then an outsole (or "outer sole") is added and sewn to the rest of the shoe.

- Injected

This method uses injection machines to fill moulds representing the imprint of the sole. The uppers are fixed to the carousel stations, while the movable moulds rotate around the injector. The polymer (PVC, TPU, SEBS, PU, etc.) is injected into the mould at high pressure, creating the sole. Single- or dual-density injections can be used to adjust hardness and comfort.

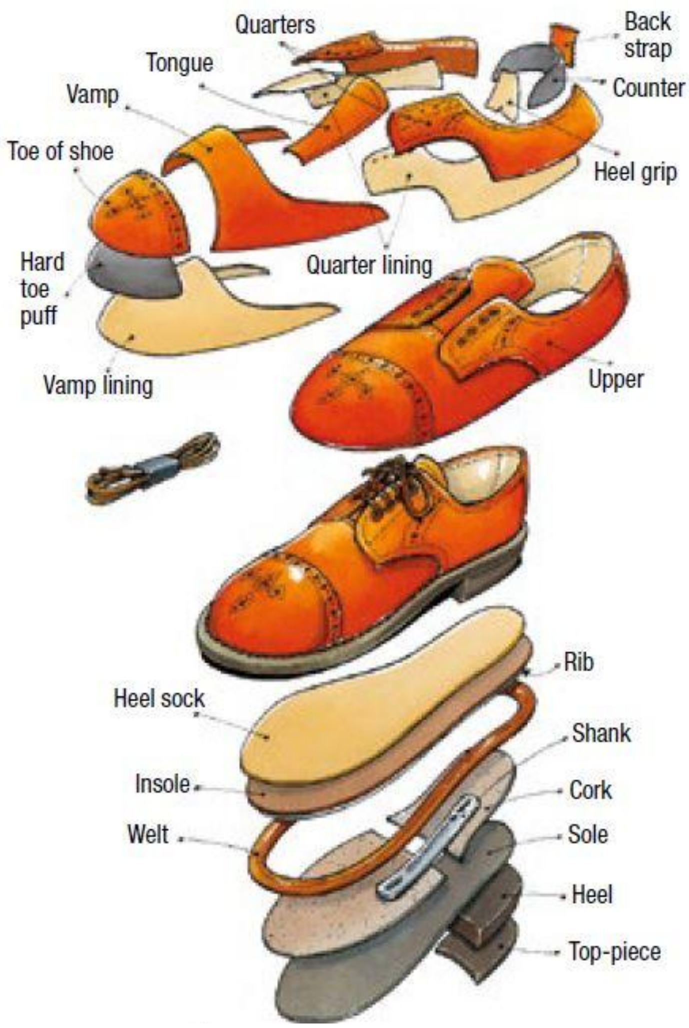

Figure 1: Detailed breakdown of a shoe (Derby model), CTC©

2.2 Footwear preparation for recycling solutions

Two methods currently exist for preparing non-rewearable footwear for recycling:

- **Complete shoe shredding** (or **grinding**), followed by the separation of the various materials using different sorting systems (residual contaminants limit the purity of material streams),
- Manual or automated **shoe upper/sole separation** (dismantling) for separately recycling the sole (mainly) and the upper.

The Refashion mapping of footwear recycling (Figure 2) presents some successful R&D projects and existing initiatives for post-consumer footwear preprocessing and recycling. Today, solutions have evolved and are presented in the following sections. Sorting solutions are also presented, as they are an essential upstream step in the recycling process.

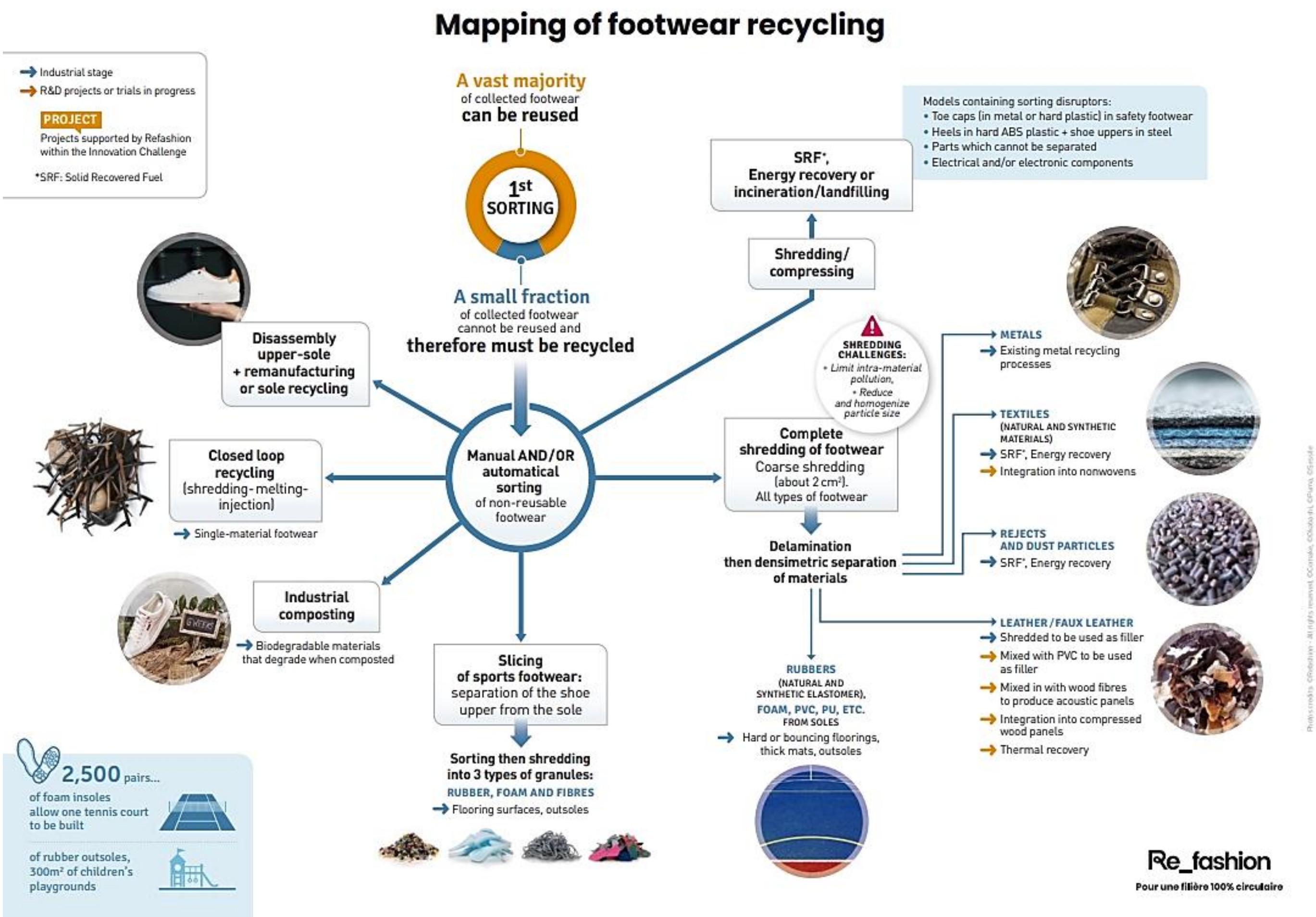

Figure 2 : **Mapping of post-consumer footwear recycling solutions - Refashion**

2.2.1 Grinding solutions

For over 30 years, **Nike Grind** has been recycling its unsold shoes, prototypes and defective footwear, as well as post-consumer footwear collected via its Reuse-A-Shoe program set up since the 90s[4]. After donation, used shoes are shipped from their collection point in the USA or Belgium (for European markets) to be transformed into Nike Grind materials. The whole shoes are shredded and six types of materials are extracted: rubber, TPU and EVA from the outsole, PU foam from the midsole, and fabric and leather from the upper. The extracted materials are then sold to various companies to be recycled in a variety of ways: shoe soles, sports field floors, protective phone cases, etc. Collaborations with Amorim Cork Solution and Muratto have enabled the incorporation of recycled EVA into cork to create floor underlays, wall coverings and other decorative projects.[5,6]

SOEX developed an automated solution for preparing non-rewearable post-consumer footwear for recycling as part of the Footwear Recycling project funded by Refashion in 2012 and 2014. In 2018, after five years of development, the company inaugurated Europe's first dedicated footwear shredding line, capable of processing 1 to 2 tons of post-consumer footwear a day. The SOEX process takes place in five stages. First, shoes are completely shredded, then a magnet extracts ferrous metals, while a delaminating mill separates the remaining materials, extracting non-ferrous metals and textiles. The rest is then sorted by an aeraulic separator which sorts rubber[7], leather and foams based on their density. This solution separates and extracts rubber, leather and foams in the form of shreds, metals and textiles in the form of fluff.[8,9]

The 8 Impact is a company based in Saint-Remy (01), France, specializing in the transformation of elastomers from post-consumer goods, including non-rewearable post-consumer footwear. The 8 Impact focuses on footwear containing materials that can be extracted and recovered as recycling raw materials (RRM). Thanks to their patented 8-stage process, The 8 Impact is capable of extracting and separating various materials (rubber, EVA foam and textile "fluff") up to a purity level of 98%. The 8 Impact won the Refashion 2021 Innovation Challenge with their project aiming at building a demonstrator using EVA (elastomeric polymer) derived from the recycling of sneakers' outsoles to make underlay for parquet flooring.[10]

Fast Feet Grinded is a Netherlands-based company specializing in footwear recycling. The Fast Feet Grinded process shreds shoes, separating out components such as foam, rubber, textiles (in the form of small pieces or fluff) and leather. Sorting footwear by type and brand is carried out prior to the sorting process to achieve a purity rate of extracted materials of around 90%. Fast Feet Grinded then works with various partners to create new products from these recovered and recycled materials, including sports flooring, picnic tables and furniture. In October 2024, the company also collaborated with Asics to create a new shoe model featuring recycled footwear elements: NEOCURVE ™.[11]

[4] https://www.nikegrind.com/about/
[5] https://amorimcorkcomposites.com/en-us/nikegrind/
[6] https://www.muratto.com/en/references
[7] The term "rubber" is commonly used, but the correct term is "elastomer".
[8] https://www.soex.de/en/services/recycling/
[9] https://pro.refashion.fr/eco-design/sites/default/files/fichiers/Experimentation%20Assessment%20of%20Air-Soex%20Project.pdf
[10] https://recycle.refashion.fr/wp-content/uploads/2025/01/Guide_dapprentissage_Projet_The8Impact2024.pdf
[11] NOT TOTAL RUBBISH | ASICS Global - The Official Corporate Website for ASICS and Its Affiliates

2.2.2 Upper/sole separation solutions

CETIA is a technology platform based in Hendaye (64), France, specialized in preprocessing clothing and footwear for recycling. Since 2023, its Re_SHOES pilot line can automatically separate shoe soles from uppers, by tearing or waterjet cutting depending on the type of shoe assembly. Tearing is used for cemented assemblies, while waterjet cutting is used for other assembly types. Soles are then sorted according to their material composition using a NIR sensor.

IDELAM is a Franco-Swiss company based in Pessac (33), France, specialized in the development of innovative recycling and waste treatment processes. Its technology is based on a CNRS patent, using a supercritical fluid delamination process. As part of the Refashion 2019 Innovation Challenge, IDELAM implemented its solution to dismantle components from various footwear types. The company is also a winner of the Refashion 2024 Challenge Innovation for the follow-up project which aims at assessing the recyclability of materials resulting from the various shoe components' separation process, and at optimizing this process for the technology's upcoming industrialization.

RESCOLL is a company specializing in the research and development of advanced materials and innovative processes, based in Pessac (33), France. Among its many innovations, INDAR technology stands out for its ability to make structural adhesives reversible. This technology takes the form of a primer which, when activated by heat, enables shoe components to be separated easily. A concrete application example of the INDAR technology is the collaboration between RESCOLL and the ERAM footwear brand that began as part of the Design For Repair project, winner of the Refashion 2016 Innovation Challenge. This collaboration aimed at integrating the reversible bonding technology into footwear manufacturing, to improve their repairability and durability.[12]

ReValorem, based in Charleville-Mézières (08), France, is a company specialized in the reuse, recovery, and recycling of unsold textile and footwear items from the luxury industry. After composition analysis in laboratory, each item is manually dismantled. The different elements are sorted by customer source, composition and colour, then transformed into shreds ready for processing into RRM.

2.2.3 Sorting solutions

Once footwear has been preprocessed using grinding or upper/sole separation solutions, it is also necessary to sort the different materials. Sorting materials is essential for recycling, since the various recycling processes (see section 3.2) have their own specific constraints and cannot handle all materials. Sorting materials will have a major influence on the quality of the RRM and the recycled product.

There are two main types of sorting solution:
- Aeraulic and magnetic solutions, often used as part of grinding solutions;
- Near infrared (NIR) spectroscopy solutions, mainly used for upper/sole separation.

Aeraulic and magnetic solutions are based on exploiting the physical properties of materials to separate them. Initially, magnets are used to remove ferrous metals, an eddy current separator to remove non-ferrous materials, and then aeraulic separation solutions are employed. These separation solutions make use of differences in the density of the objects to be sorted: it is the air resistance to the movement of the objects to be sorted that is used. This enables the separation of low-density objects (carried in the air stream) from high-density objects. The limitations of these separation solutions derive directly from the physical properties of the materials. As shown in the following graph, some of the materials used in shoe soles have very similar or even equivalent densities, making the separation of the materials very complex.

[12] https://pro.refashion.fr/sites/default/files/fichiers/6_2017_Roads-Innovation_GB_BD.pdf

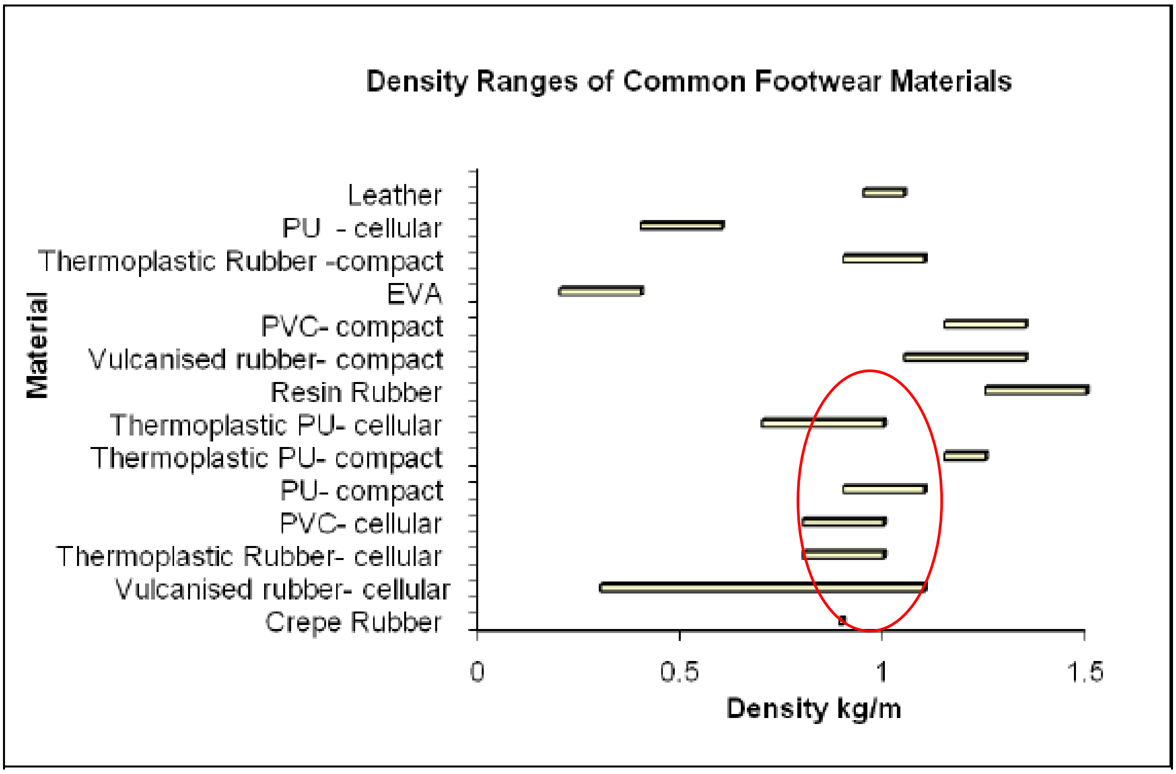

Figure 3: Density range of materials commonly used in footwear[13]

Spectroscopic solutions (NIR sensors, hyperspectral cameras) are used to identify sole materials. These solutions may come in the form of scanners, such as those from Matoha (PlasTell, see Figure 4) or Plas'tri, which allow multiple measurements to be taken on a same sample to identify the different materials, or automated sorting equipment, such as Picvisa's EcoFlake[14] line or Plas'tri's line (Figure 5). However, one of the limitations of spectroscopic detection tools lies in their inability to detect materials containing carbon black pigments.

Figure 4: PlasTell Desktop - Matoha[15]

Figure 5: Sorting line using a hyperspectral camera - Plas'tri[16]

It should also be added that footwear is usually pre-sorted by type, or even by brand, prior to the preprocessing phase, in order to mitigate the limitations of the various sorting technologies.

[13] https://www.researchgate.net/profile/Shahin-Rahimifard/publication/284678958_Development_of_an_Economically_Sustainable_Recycling_Process_for_the_Footwear_Sector/links/5bf3f7d54585150b2bc3d5af/Development-of-an-Economically-Sustainable-Recycling-Process-for-the-Footwear-Sector.pdf
[14] https://picvisa.com/optical-sorting/ecoflake/
[15] Plastics identification device - PlasTell | Matoha
[16] https://www.plastri.fr/produits.html

In the case of grinding solutions, this mainly involves sorting by brand, by type of footwear (sneakers, sports shoes, boots, etc.) or even by type of sole, thereby limiting the variety of materials present in the feedstock, and thus improving the purity of output RRMs.

For upper/sole separation solutions, sorting footwear by type of manufacture is performed, so that shoes can be directed to the most suitable dismantling processes. This sorting ensures that following processes run smoothly with a higher throughput.

3. Shoe sole recycling

3.1 Main materials examined

Thanks to the work carried out as part of the development of the Refashion footwear materials Library, the main materials used in shoe soles (outsoles and comfort soles) have been identified:

Table 1: Main materials used in footwear soles

Thermoplastics	Rubber	Thermosets / Cross-linked thermoplastics	Other
TPU and expanded TPU	SBR	PU	Leather
SBS and SEBS	NR/IR and SBR blend	Expanded EVA	
PVC	EPDM		
ABS	NBR		
PC			
PA			

Sole materials can be classified into four categories according to their physicochemical properties:

A **thermoplastic** is a polymer that becomes malleable or liquid when heated and solidifies on cooling. This process is reversible and can be repeated several times without any significant degradation in the material's mechanical or chemical properties. Thermoplastic materials can be recycled by extrusion, equivalent to mechanical recycling in the plastics sector or thermomechanical recycling in the textiles sector.

Rubber is a type of polymer with elastic properties (elastomer or gum), which means it can stretch under tension and return to its original shape when released. Rubber is characterized by high flexibility and excellent resistance to permanent deformation. Once vulcanized (for example with sulphur or peroxide), rubber undergoes a cross-linking process similar to that of thermosets, meaning that it can no longer be melted or re-moulded by heat. This vulcanization process improves rubber's durability, wear resistance and thermal stability.

A **thermoset** is a polymer which, once hardened by a cross-linking process, can no longer be melted or remoulded by heat. Unlike thermoplastics, this curing process is irreversible, giving thermosets high thermal stability and chemical resistance. For this family of polymers, it is therefore impossible to melt the material and use a mechanical recycling process. Once shredded, however, the material can be used as a filler in a matrix.

Finally, a **cross-linked thermoplastic** is a polymer that has undergone a cross-linking process, creating chemical bonds between polymer chains, improving its thermal stability, chemical resistance and mechanical properties. Unlike thermosets, cross-linked thermoplastics retain a certain capacity to deform under heat but cannot be completely melted and therefore mechanically recycled.

3.2 Recycling processes

Recycling processes vary according to the materials to be treated and the intended applications. Similarly, the mechanical properties of RRMs will depend on the input materials used. These processes are described below:

Grinding / shredding: In a recycling context, this is a mechanical process designed to break down items into smaller pieces, such as pellets or flakes. This facilitates further processing, such as melting, chemical regeneration or the manufacture of new plastic products. The choice of the shredding technology depends on the material type, the desired output requirements and other considerations specific to the recycling process. Shredding is a step upstream of all other recycling processes, but it can also be used on its own to enable direct use of shreds in open-loop applications.

Micronization: Micronization is a mechanical process which reduces the particles of a material to a micron size. The resulting powder can be used as a filler in new products. The reduction in size increases the specific surface area of the particles, enabling better interaction between the particles and the matrix in which they are incorporated. There are two micronization processes: atmospheric micronization (at room temperature) and cryogenic micronization (under liquid nitrogen). The latter enables finer, more controlled micronization, though it comes with a higher economic and environmental cost.

Extrusion / Mechanical recycling: Thermoplastics can be recycled by extrusion, thanks to their ability to be re-melted after shaping. The material is first shredded (between 5mm and 10mm), then inserted into an extruder where shreds are mixed, melted, sheared and homogenized, before emerging in the form of a rod which is then ground to form recycled material pellets. Due to the recycling process' thermomechanical effects, mechanical properties are degraded. The material must therefore be mixed with a certain percentage of virgin material to be reused in similar applications. The percentage of incorporated recycled materials varies according to the type of material, the quality of the sorting performed upstream, and the cleanliness of the sorted feedstock. It is also possible to use the recycled material as is, if its mechanical properties meet the target specifications.

Devulcanization: During processing, rubber undergoes an irreversible chemical reaction when "heated", known as "vulcanization". This process forms bonds between the rubber's polymer chains, making it more elastic and resistant. Once vulcanized, it cannot be softened or reshaped by heat. Devulcanization is the process by which these crosslinks are broken, converting vulcanized rubber back into a processable material. Various processes are available:

- **Mechanical devulcanization**: This process uses mechanical forces, such as shearing or grinding, to break the chemical bonds in vulcanized rubber.
- **Chemical devulcanization**: This process uses chemical agents to break the sulphur bonds in vulcanized rubber. Commonly used chemical agents include peroxides, acids and bases.
- **Thermal devulcanization**: This process involves heating vulcanized rubber to high temperatures to break down its chemical bonds.
- **Thermomechanical devulcanization**: This process combines heat and mechanical forces to break down the chemical bonds in vulcanized rubber.

Decrosslinking: Following the same principle as devulcanization, in this case for PU and EVA, decrosslinking involves breaking the crosslinks that make these materials infusible, so that they can be reprocessed, reshaped or recombined with other materials to create new products.

Formulation: Formulation here refers to the process of incorporating RRM, for example by extrusion (referred to as **compounding**) or devulcanization, into a new material for use in a final product. The aim of this process is to optimize the material's properties by precisely mixing recycled components with virgin materials, in order to obtain characteristics that meet the desired specifications.

Recycling processes are essential for transforming waste into RRM that can be used in new products. Each process has specific advantages and limitations, influencing the quality and properties of the recycled materials. Grinding and micronization processes can handle all types of materials, while extrusion, devulcanization and de-crosslinking processes are specific to certain materials (see Figure 6). The quantities of regenerated materials that can be reincorporated into a final product depend on the expected mechanical properties. For this reason, **trials must be carried out to optimize processes and maximize the reincorporation of RRM**.

Recycling process	Grinding	Micronization	Extrusion Compounding *(TP)*	Devulcanization *(Rubber)*	Decrosslinking *(EVA)*
Input					
1st grinding step					
Additional step					
Output				Strip, rod, or powder	Strip, rod, or powder

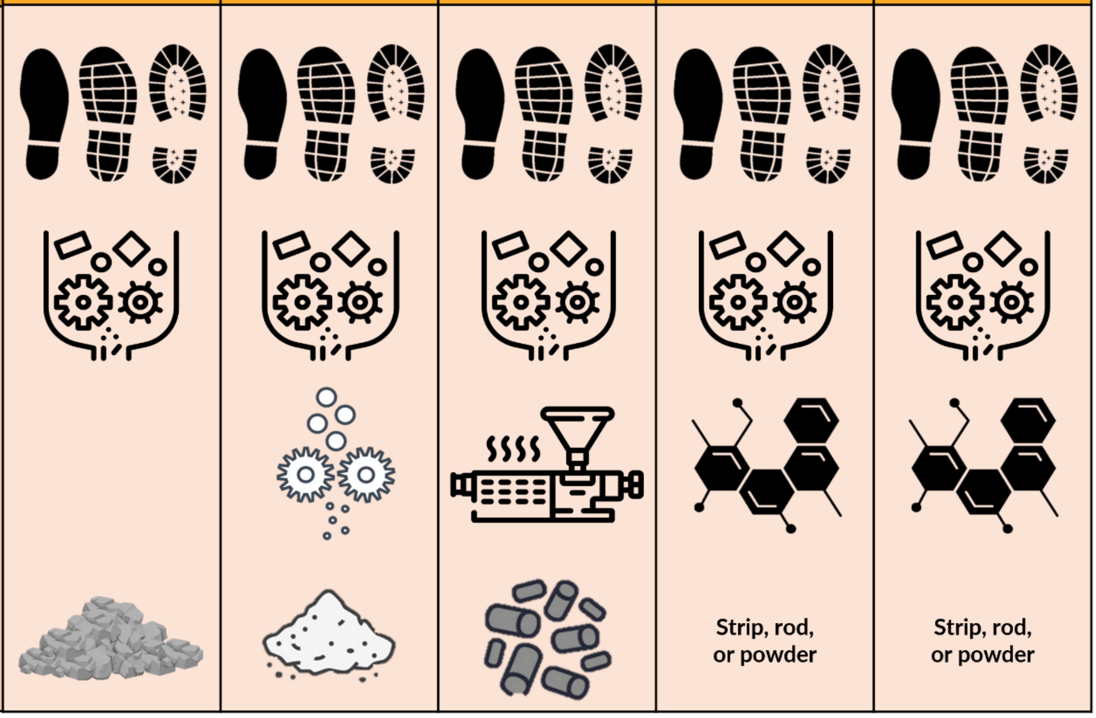

Figure 6: Recycling processes for shoe soles and RRM outputs

3.3 Recycling solutions

This state of the art of recycling solutions for shoe soles in France and Europe has been conducted based on information collected at the end of 2023 and 2024.
The companies presented below are classified into four categories:

Technical centre / Innovation centre: Any technological research structure that supports an industrial sector (e.g. plastics and rubber). These centres are often equipped with pilot or semi-industrial scale machines, enabling them to be more flexible in terms of required material quantities to carry out feasibility trials. Costs associated with these trials are not representative of the industrial market.

Recycler: In the scope of this study, any industrialist carrying out grinding, extrusion, devulcanization or micronization operations, preparing RRM ready for incorporation.

Recycled material incorporator: Any company using recycled materials to create a new material substituting all or part of the virgin material. This can be for their initial purpose (closed loop) or for other purposes (open loop).

Machine manufacturer: Any company specializing in the design, production and sale of machines and equipment used to recycle materials.

The study of sole recycling solutions in Europe allowed to identify 26 stakeholders, 19 of whom provided details of their recycling/conversion processes and materials specifications.
These include:

- 2 technical centres,
- 5 recyclers,
- 7 recyclers / recycled material incorporators,
- 3 recycled material incorporators,
- 2 machine manufacturers.

Please note: this overview of recycling solutions for shoe soles in France and Europe constitutes an initial census and is meant to be regularly updated and expanded.

3.3.1 Technical centres

3.3.1.1 Elanova – France (94)

Identity sheet
Centre for rubber valorisation

Competences:

- Grinding
- Micronization
- Devulcanization
- Formulation
- Formatting
- Characterization

Processed materials:

- All rubber types

Elanova, formerly the "Centre français du caoutchouc et des polymères" (CFCP), is a technical centre dedicated to rubber valorisation. Its purpose is to defend the interests of companies and support the development of the rubber industry in France and Europe. The centre groups together several entities, including Elanova lab (formerly LRCCP), the technical centre for the rubber and polymers sector. Elanova lab actively contributes to the development of the industry through its research and development projects aimed at meeting the challenges of the circular economy.
As the rubber expertise centre, Elanova lab offers services for the recycling of rubber soles: micronization, devulcanization (by third parties), formulation, formatting and characterization.

Processed materials	Proposed service	Minimum quantity	Input material quality	Input material format	Output format
All rubber types	Micronization	Project-dependent	Simple sole: clean, with no special constraints	Shredded soles, in the form of pellets	Micronized materials
			Complex sole: clean and disassembled (no metals)*		
NR, SBR, EPDM	Devulcanization	40 kg	Simple sole: clean, with no special constraints	Shredded soles, in the form of pellets	Extruded rod
			Complex sole: clean and disassembled (no metals, no textiles)*		
All rubber types	Formulation	300g	Clean material	Micronized or devulcanized material	Depending on customer needs
All rubber types	Incorporation: Compression, injection or extrusion	Project-dependent	Depending on target application	Raw blends, micronized /devulcanized blends reintegrated into a matrix	Formatted vulcanized or micronized rubber

**The presence of different elastomers in a same piece doesn't pose a problem for micronization and devulcanization.*

Contact:
Anne Lasri - Chemical research engineer - anne.lasri@elanova.fr

3.3.1.2 IPC - France (01)

Identity sheet
Industrial technical centre dedicated to plastics processing and composites

Competences:
- Grinding
- Sorting
- Extrusion
- Injection

Processed materials:
- All thermoplastics

IPC (Centre Technique Industriel de la Plasturgie et des Composites) is the technical centre dedicated to innovation in plastics and composite materials in France.
Through its expertise, IPC actively guides industrial companies in research, development and technology transfer, focusing on environmentally friendly solutions.
IPC has a number of expertise platforms, notably DIS30, dedicated to the development of sustainable plastic and composite solutions, thanks to a wide range of pilot and industrial-scale equipment: grinding, washing, sorting, extrusion and injection equipment. IPC thereby offers services for recycling thermoplastic soles.

Processed materials	Proposed service	Minimum quantity	Input material quality	Input material format	Output format
	Sorting on NIR machine (Mistral Connect from Pellenc ST)	-	Shreds greater than 30mm	Soles or shreds	Waste sorted by polymer type
All types of thermoplastics	Sorting by flotation	-	-	Shreds	Sorted materials
	Triboelectric sorting	20kg	2 to 3 materials maximum *(for efficient sorting)*	Shreds between 2 and 8mm	Sorted materials
	Grinding (knife mill, single-shaft mill, slow-speed mill)	5 kg	No metals *(ok for small, eyelet-type inserts)*	Whole soles	Calibrated shreds from 8mm to 50mm as required
	Washing (friction washing, with possibility of temperature rise up to 90° and integration of detergents)	5 kg	Shreds from 6mm to 20mm	Shreds	Clean and dried shreds
	Extrusion (single-screw extruder, twin-screw extruder)	5 kg	Clean, homogenized and filtered material	Shreds from 5mm to 12mm	Standard sized pellets or micro-granules

Contact:
Guillaume MESSIN - Business Developer - guillaume.messin@ct-ipc.com

3.3.2 Recyclers

3.3.2.1 J. Allcock & Sons Ltd - England (Manchester)

Identity sheet
Recycler

Competences:
- Micronization
- Devulcanization

Processed materials:
- All rubber types

J. Allcock & Sons is a material supplier, recycler and manufacturer for the polymer industries. Founded in 1924, the company specializes in rubber and silicones; it claims over 50 years' experience in rubber. Offering comprehensive recycling services, it collects vulcanized rubber waste, shreds it to required specifications and offers it in a variety of formats. Its services help to reduce the quantity of vulcanized rubber waste as well as demonstrate economic and technical benefits.

Processed materials	Proposed service	Minimum R&D quantity	Minimum production quantity	Input material quality	Input material format	Output format
All rubber types	Micronization	20 kg	15/20 tonnes	Clean sorted material. Hardness>55 ShA No metals	Whole soles	Micronized rubber
	Devulcanization	100 kg	15/20 tonnes	Only sulphur-crosslinked, clean, sorted material. Hardness>55 ShA	Whole soles	Devulcanized rubber

J. Allcock & Sons offers micronization trials with 20 kg of soles and devulcanization trials with 100 kg of soles. A minimum of 15 tonnes is required for any production trial.

Figure 7 : Devulcanized rubber[17]

Contact:
Andrew Rushton - Managing Director - enquiries@allcocks.co.uk

[17] http://www.allcocks.co.uk/en/devulcanisation.htm

3.3.2.2 MicroPolymers - France (71)

Identity sheet
Recycler

Competences:

- Grinding
- Atmospheric micronization
- Cryogenic micronization

Processed materials:

- All types of materials

MicroPolymers specializes in the production of polymer powders by micronization. MicroPolymers has a range of machines for grinding, atmospheric and cryogenic micronization. MicroPolymers has already carried out production on sole materials. Trials can be carried out to define the best process to use for larger-scale production.

Processed materials	Proposed service	Minimum quantity	Input material quality	Input material format	Output format
All sole materials	Grinding	10 kg	Clean material. No metals	Whole or shredded soles	Calibrated shreds as required
	Atmospheric micronization				Micronized material
	Cryogenic micronization				

Contact:
Alain Maubert - Sales director France - a.maubert@micropolymers.fr

3.3.2.3 RubberLink (Bolflex) - Portugal (Felgueiras)

Identity sheet
Recycler

Competences:

- Collection
- Grinding
- Devulcanization
- Extrusion

Processed materials:

- All rubber types
- SBS
- EVA

RubberLink is a subsidiary of Portuguese rubber sole manufacturer Bolflex. It was founded in 2013 with the aim of recovering rubber waste from the footwear sole industry. It is approved as a General Waste Operator by the Portuguese Environment Agency, for the global management of rubber waste.
Rubberlink has a processing capacity of 4,000 tons a year, recycling various types of rubber: tire by-products, waste from the footwear industry and materials from post-consumer footwear.

Processed materials	Proposed service	Minimum production quantity	Input material quality	Input material format	Output format
All materials	Grinding	500kg	No metals	Whole shoes or soles	Calibrated shreds
Rubber, EVA	Micronization	500kg	Sorted material, No metals	Ground materials	Powder
Rubber	Devulcanization	500kg	No materials other than rubber, no metals	Ground materials	Devulcanization material sheet, powder

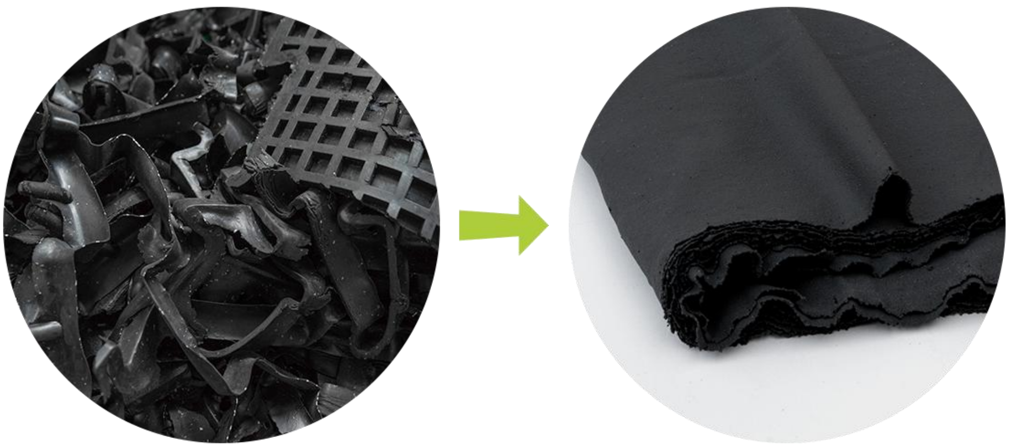

Figure 8 : Rubber recycling with RubberLink[18]

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Luís Miguel Ferreira - Sales - miguel@bolflex.pt

[18] www.rubberlink.pt

3.3.2.4 Rubber Conversion - Italy (Verona)

Identity sheet
Recycler

Competences:
- Devulcanization

Processed materials:
- Rubber (NR, SBR and NBR)

Rubber Conversion Srl is a B2B technology company that has developed its rubber devulcanization technology, implemented in a large-scale, fully operational production site located in Verona, Italy. The innovative SME **manufactures various ranges of sustainable rubber mixing (SRC) from end-of-life rubbers and offers a Rubber Devulcanization Service (RDS)** in various rubber manufacturing sectors for post-production and post-consumer waste (tire manufacturers, automotive manufacturers, rubber goods producers, as well as companies in the footwear and leisure goods sectors).

Rubber Conversion fosters strong collaborations with collectors and recyclers to "close the loop" by devulcanizing materials used as raw materials in new blends. **The company has already recycled post-consumer rubber soles from major brands, using devulcanization to produce blends containing up to 50% RRM**, all of which are GRS-certified and awarded the EcoVadis GOLD sustainability rating.

Processed materials	Proposed service	Minimum R&D quantity	Minimum production quantity	Input material quality	Input material format	Output format
Sulphur-vulcanized rubber (NR, SBR and NBR)	Devulcanization	10 kg	400 kg	Clean powder, free textile content (tolerance < 0.35%), free metal content (tolerance < 0.1%), tolerance other impurities < 2%	Ground soles, grain size between 400 and 600 microns	Flakes

Rubber Conversion offers laboratory-scale devulcanization tests using 10 kg of rubber soles. For production tests, a minimum of 1 tonne of ground rubber soles is required.


Figure 9 : Devulcanized rubber - Rubber Conversion

Contact:
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3.3.2.5 The 8 Impact - France (01)

Identity sheet
Recycler

Competences:
- Grinding
- Densimetric sorting
- Micronization
- Devulcanization

Processed materials:
- All types of materials

The 8 Impact, based in Saint-Remy (01), specializes in the regeneration of elastomers from post-consumer goods, including post-consumer sneakers.

Following a preliminary sorting by shoe type, their patented 8-stage mechanical process uses densimetric separation (without any water) to extract and separate the various shoe materials (rubber, EVA, textile "fluff", metallic hard points), up to a purity level of 98%. EVA and rubber can then be transformed into RRM of various sizes thanks to its different equipment: grinding, micronization, devulcanization.

Processed materials	Proposed service	Minimum R&D quantity	Minimum production quantity	Input material quality	Input material format	Output format
All sole materials	Grinding and densimetric sorting	5 kg for laboratory trials	To be defined following R&D trials	Sorting by type of footwear required upstream*	Whole soles	Granules from 1 to 6 mm
	Micronization				Shreds from 1 to 6 mm	Powder
	Devulcanization				Shreds from 1 to 6 mm	Devulcanized rubber rod

** The 8 Impact provides the required sorting specifications*

Figure 10 : Shoe sole shreds - The 8 Impact

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3.3.3 Recyclers/Incorporators

3.3.3.1 AER Caoutchouc / French Plymouth - France (67)

Identity sheet
Recycler, Incorporator

Competences:
- Rubber grinding
- Devulcanization
- Reformulation

Processed materials:
- All rubber types
- PU

AER Caoutchouc, in partnership with Plymouth Française since 2021, is positioning itself as a distributor of recycled rubber products, focusing its efforts on thermomechanical devulcanization. This patented process, without any chemical additives, valorises rubber scraps while preserving elastomer properties. Tests need to be carried out to define the mechanical properties of materials recycled from soles.
Processed materials can be reincorporated into the initial compound or used in new blends.
AER/Plymouth is committed to recycling various types of rubber (e.g. natural rubber and SBR) and PU. In 2023, they partnered with the footwear retailer Courir in an end-of-life footwear recycling program, *Recycle Your Ex Sneakers.* [19]

Processed materials	Proposed service	Minimum quantity	Input material quality	Input material format	Output format
All rubber types, PU	Devulcanization	300 kg	Ideally sorted by elastomer family. Clean material (no sand, no stones, no metal parts)	Whole soles or shoes	Devulcanized rubber strip or powder, depending on elastomer and/or sole formulation

The commercial offer includes trials to assess the feasibility of processing the material to be recycled.


Figure 11 : Devulcanized rubber by Plymouth[20]

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- French PLYMOUTH Sales - commercial-recyclage@plymouth.fr

[19] https://www.courir.com/fr/c/recycle-your-ex-sneakers/
[20] https://www.aer-caoutchouc.com/process-recyclage-caoutchouc-broyage-devulcanisation/

3.3.3.2 Amorim Cork Solution - Portugal (Santa Maria da Feira)

Identity sheet
Recycler, Incorporator

Competences:

- Grinding
- Mixing

Processed materials:

- EVA

Amorim Cork Solution (ACS) manufactures cork products for various sectors: aerospace, flooring, construction, footwear, sealing, etc.
In particular, it provides a "circular" range made from cork and incorporating waste from various materials: PU foam, EVA and rubber. These are post-production wastes from the automotive and footwear industries.
A collaboration with Nike Grind enabled the reincorporation of EVA with cork to create parquet underlays.[21]

Processed materials	Proposed service	Minimum R&D quantity	Minimum production quantity	Input material quality	Input material format	Output format
EVA	Blending with cork	10 kg	To be defined following R&D trials	Clean feedstock	Whole soles	Roll

Amorim Cork Composites has an innovation department dedicated to R&D. A trial phase is necessary to test the various properties of the incoming materials, to determine potential applications and the percentage of material that can be incorporated. For this, 10 kg are required.

Figure 12 : Flooring underlay made with Nike Grind EVA

Contact:
Francisco da Silva - Global Product Manager - francisco.silva@amorim.com

[21] https://amorimcorkcomposites.com/en-us/nikegrind/

3.3.3.3 Authentic Material - France (31)

Identity sheet
Recycler, Incorporator

Competences:

- Grinding / micronization
- Formulation

Processed materials:

- Leather

Authentic Material, based in Toulouse since its creation in 2016, is a company specializing in the recycling of natural material waste (mainly leather). The company has developed an innovative natural processing technology to transform these scrap materials (quality defects, deadstock, offcuts...) into reusable materials.
Thanks to processes based on grinding and thermo-compression, pure or composite materials are transformed into 100% natural blocks (Phoenix) or mixed with bio-sourced thermoplastics (Qilin). These new materials offer new creative possibilities, such as reinforcements, accessories, jewellery...

Processed materials	Proposed service	Minimum R&D quantity	Minimum production quantity	Input material quality	Input material format	Output format
Leather	Thermo-compression	50 kg	To be defined following R&D trials	Clean, sorted material (no glue)	Whole soles	Thermo-compression plate
	Mixing with a bio-sourced thermoplastic	50 kg	To be defined following R&D trials	Clean, sorted material	Shreds from 5mm to 10mm	Injection pellets

Authentic Material is proposing an initial pre-study phase to demonstrate the feasibility of recycling 50kg of waste.

Figure 13 : PHOENIX materials (left) and QILIN black leather compounds (right)[22]

Contact:
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[22] https://www.authentic-material.com/en

3.3.3.4 ESO RECYCLING – Italy (Tolentino)

Identity sheet
Recycler, Incorporator

Competences:
- Grinding and sorting
- Thermo-compression

Processed materials:
- All materials

ESO Recycling is an Italian company specialized in materials recycling and recovery from multiple industries. Its expertise lies in grinding, sorting and thermo-compression technologies that enable to transform waste into recycled raw materials and innovative products.
ESO Recycling processes a wide range of items, including footwear, tennis balls, bicycle tyres, personal protective equipment (PPE), as well as post-consumer and pre-consumer waste, production scraps, unsold stock and prototypes from the fashion and luxury goods industries.

The footwear recycling process begins with sorting followed by complete grinding of the shoes. Ground materials are then sorted using air and magnetic systems to separate the different shoe materials: rubber, textiles, plastic, leather, ferrous and non-ferrous metals.

Thermo-compression or moulding solutions are used to form finished products. ESO Recycling can then produce a variety of products such as playground and athletics track surfaces, thermal and acoustic insulation panels, fashion accessories and innovative furnishing solutions (via a partnership with a furniture company).

Processed materials	Proposed service	Minimum production quantity	Input material quality	Input material format	Output format
All materials	Grinding and sorting, thermo-compression	2 tonnes	Post-consumer footwear	Whole shoes	Plates or finished products

Figure 14 : ESO Recycling© recycling plant

Figure 15 : ESO Recycling© recycling process

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3.3.3.5 INDCO - France (38)

Identity sheet
Recycler

Competences:
- Grinding
- Extrusion
- Colour
- Injection

Processed materials:
- All thermoplastics

INDCO is a company specialized in the recycling of thermoplastic materials since 1970.
It has a wide range of machines for grinding a variety of plastic materials. In addition to grinding, INDCO also focuses on the regeneration of ground materials. The company has an on-site laboratory to characterize its recycled materials.

Processed materials	Proposed service	Minimum quantity	Input material quality	Input material format	Output format
Thermoplastics	Grinding	3 tonnes	Clean *(no metals, as little soil as possible)* and sorted materials	Dismantled shoe soles	Graded shreds
	Extrusion	3 tonnes	Clean *(no metals, as little soil as possible)* and sorted materials	Shreds from 5 mm to 10 mm	Injection pellets

INDCO offers grinding and extrusion services adapted to thermoplastic soles, enabling large quantities to be processed. Thanks to the acquisition of ARC company, INDCO also has expertise in dyeing. Moreover, the company offers waste buy-back and sales services.

Figure 16 : INDCO site in Villard-Bonnot[23]

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[23] https://www.linkedin.com/company/indco/

3.3.3.6 TerraCycle - France, United Kingdom

Identity sheet
Recycler, Incorporator

Competences:
- Setting up collection, preparation, processing and recycling solutions via a network of partners

Processed materials:
- All types of materials

TerraCycle is a recycler of "non-recyclable" or "difficult-to-recycle" waste. TerraCycle is present in 20 countries worldwide, including 12 in Europe, notably France and the UK.

TerraCycle works with various service providers to set up recycling chains adapted to the needs of its customers and to the different products to be recycled. TerraCycle also sets up sorting and massification processes.

Custom material specifications according to customer

In 2024, the Asics brand teamed up with TerraCycle for a closed-loop recycling program for their Nimbus Mirai™ model in France and the Netherlands. Users can return their used pair of shoes to TerraCycle using a prepaid label. The pair is then disassembled by separating the upper from the sole. The sole, made of "FF BLAST™ PLUS ECO" foam, is mechanically recycled while the polyester upper is washed, dried, ground and micronized before being pelletized and spun. The recycled materials are then returned to Asics to produce new pairs of Nimbus Murai™.

Figure 17: Dismantled Asics Nimbus Murai™

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Marie Lethellier - Global Vice President, Operations - marie.lethellier@terracycle.com

3.3.3.7 Viriam - Italy (Mantova)

Identity sheet
Recycler, Incorporator

Competences:
- Formulation / compounding
- Micronization

Processed materials:
- Expanded EVA
- TPU

Viriam is an Italian company founded in 2019 specialized in the recovery of plastic materials.
Via a collaboration with Italian sole manufacturers, Viriam has developed a process enabling the integration of up to 50% post-production micronized EVA into virgin materials, without degrading the material's technical properties. This innovation is the result of a micronization process combined with additives and binding agents.
Viriam is currently testing post-consumer waste, with the aim of reincorporating 50% recycled EVA into new materials.

Processed materials	Proposed service	Minimum R&D quantity	Minimum production quantity	Input material quality	Input material format	Output format
EVA, TPU	Micronization / formulation	10-15kg	10/15 tonnes	Materials as clean as possible, no metals	Shredded or whole soles	Injection pellets

Viriam proposes an initial feasibility study to determine the percentage of recycled material that can be incorporated and to characterize the new material properties. These tests require 10 to 15 kg of preferably ground material.

Figure 18 : Soles produced in using recycled EVA by Viriam

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3.3.4 Incorporators

3.3.4.1 Elastever - France (49)

ELASTEVER

Identity sheet
Incorporator

Competences:
- Micronization
- Formulation

Processed materials:
- All rubber types
- Other sole materials under study

Elastever specializes in the creation of thermoplastic elastomers incorporating over 70% of recycled materials from the recycling of used tyres. Thanks to an advanced formulation, Elastever produces thermoplastic elastomer pellets that are fully compatible with standard industrial processes such as extrusion, injection and plastic moulding. By collecting, micronizing and mechanically recycling end-of-life tyres, Elastever offers a range of products that can be used in diverse sectors, including sealing gaskets and protective applications (buffers, shock-proof additives for plastics). Their process is adapted to rubber soles, on which tests have already been carried out.

Materials processed	Proposed service	Minimum quantity R&D	Minimum quantity prod	Input material quality	Input material format	Output format
All rubber types Other materials on request	Micronization *(equipment currently being acquired)*	To be defined	10/15 tonnes	Clean materials *(no sand, stones, metals, etc.)* Sorting by colour is an advantage	Whole or shredded soles	Micronized rubber
	Formulation and extrusion	20 kg	10/15 tonnes	Micronized materials <300 µm	Micronized rubber + injection pellets	Injection pellets

An initial study phase is necessary to evaluate the percentage of incorporable materials and to characterize the new material's mechanical properties. Elastever can also carry out trials on materials with economic potential, other than rubber.

Figure 19 : Compound produced from tire rubber

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3.3.4.2 Stonegom - France (63)

Identity sheet
Incorporator

Competences:
- Mixing for the production of various types of floorings

Processed materials:
- All rubber types
- Other sole materials under study

Stonegom is a manufacturer of innovative, durable floor coverings for a variety of applications (outdoor floorings, parking lots, cycle paths, sports fields, school playgrounds...). The company aims to integrate recycled materials into its floor coverings.
Its patented flooring is composed of a natural material, pozzolana (a volcanic rock sourced from the Auvergne region), recycled materials (such as used tyres, soles) and a specific binder to bind all materials together. The result is a material with acoustic, draining and resistant properties. A lifecycle analysis completed by a critical review enabled to qualify this flooring as a high-performance environmental solution, particularly in terms of CO_2 emissions.

Processed materials	Proposed service	Minimum quantity	Input material quality	Input material format	Output format
All rubber types	Conversion to flooring	Depends on project size	No washing required. No metals	Whole soles	Mix of rubber soles, pozzolana and binding agent

Stonegom offers tailor-made projects. For example, the company worked with the Pévèle-Carembault municipalities community and the recycler The 8 Impact to create a cycle path in Pont-à-Marcq, using pozzolan, used tyres and sneakers.

Figure 20 : Cycle path created by Stonegom in collaboration with The 8 Impact and the Pévèle-Carembault municipalities community[24]

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[24] https://stonegom-coating.com

3.3.4.3 The Good Plastic - Netherlands (Almere)

Identity sheet
Incorporator

Competences:

- Thermo-compression

Processed materials:

- All types of materials

The Good Plastic Company is a polystyrene (PS) waste treatment and processing company. After grinding of materials, The Good Plastic produces thermo-compressed plates. The rigid material, known as Polygood, can be painted, engraved, drilled or cut to size, just like wooden panels which it can substitute. It is also possible to incorporate other types of plastic waste in small quantities into these panels, by grinding and mixing them with PS waste which then acts as a binding agent. The percentage of added plastic waste must be validated by trials to ensure the technical quality and the recyclability of the panels.

Processed materials	Proposed service	Minimum R&D quantity	Minimum production quantity	Input material quality	Input material format	Output format
All sole materials	Thermo-compression	30 kg	Depends on R&D trial	Clean materials	Shreds from 5 mm to 10 mm	Plate (1400 mm x 2800 mm)

An initial R&D phase is necessary to ensure the proper integration of the sole material, check the properties of the plate and assess the percentage of material that can be integrated.

Figure 21 : Nike display using Polygood material[25]

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[25] https://polygood.com/projects/nike/

3.3.5 Machine manufacturers

3.3.5.1 Maris - Italy (Turin)

Identity sheet
Machine manufacturer

Competences:
- Extrusion
- Decrosslinking
- Devulcanization

Processed materials:
- All rubber types
- Expanded EVA
- All thermoplastics

Maris is a manufacturer of co-rotating twin-screw extruders for compounding and pelletizing materials, as well as for recycling polymers and rubbers.
Maris has been selling extruders for devulcanization processes for 15 years and carries out tests on many rubber types, including shoe soles, used tyres and technical rubbers. According to the company, devulcanized materials can be reused in the same original application, mixed with up to 50% virgin rubber depending on the field of application, while retaining the desired mechanical properties.
The company has recently designed and tested a new recycling process for cross-linked foams, including EVA from footwear soles and cross-linked and expanded polymers for insulation applications.

Processed materials	Proposed service	Minimum R&D quantity	Machine speed	Input material quality	Input material format	Output format
All rubber types	Devulcanization	25 kg	Two machines from 10 kg/h to 1000 kg/h	Clean materials (<5% impurities, no metals)	Ground materials ~5 mm	Rubber strip
Expanded EVA and expanded crosslinked polymers (XLPE)	Decrosslinking					Strip of decrosslinked material
All thermoplastics	Extrusion					Rod or injection pellets

Maris has a technological centre where trials can be carried out. By adjusting machine parameters such as temperature or screw rotation speed, Maris aims to obtain a material which characteristics meet its customers' specifications.

Figure 22: Maris recycling process integration diagram (source mariscorp.com)

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3.3.5.2 REP International – France (69)

Identity sheet
Machine manufacturer

Competences:
- Injection
- Compression
- Devulcanization

Processed materials:
- All rubber types

REP INTERNATIONAL specializes in the design and manufacture of rubber injection moulding machines. Beyond equipment supply, the company offers comprehensive industrial solutions tailored to the specific needs of its customers. In particular, the company has developed the HSR model, a thermomechanical devulcanization machine. HSR (High Shear Regeneration) technology is designed to devulcanize rubber waste, facilitating its reintegration into the production chain.
REP claims a thermomechanical process, with no chemical additives, no modification of formula elements and applicable to all rubber types.

Processed materials	Proposed service	Minimum R&D quantity	Machine speed	Input material quality	Input material format	Output format
All rubber types	Devulcanization	10 kg	8 kg/h to 16 kg/h	Clean materials *(no sand, no stones, etc.)*	Ground materials between 5 mm and 10 mm	Devulcanized powder

REP International offers feasibility trials to assess the feedstock recyclability using their process. These trials are carried out on their small-capacity machine and require 10 kg of ground materials.

Figure 23 : Devulcanization machine[26]

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[26] https://www.repinjection.com/rubber-devulcanization-2/hsm-devulcanization-machine

3.4 Overview of shoe sole recycling stakeholders

UNITED KINGDOM

3	J. Allock & Sons Ltd – Manchester
13	TerraCycle – Londres

FRANCE

1	Elanova (94)
2	IPC (01)
4	MicroPolymers (71)
7	The 8 Impact (01)
8	AER Coutchouc (67)
10	Authentic Material (31)
12	INDCO (38)
15	Elastever (49)
16	Stonegom (63)
19	REP International (69)

PORTUGAL

5	Rubberlink (Bolflex) – Felgueiras
9	Amorim Cork Composites – Santa Maria da Feira

NETHERLANDS

17	The Good Plastic – Almere

ITALY

6	Rubber Conversion – Verona
14	Viriam – Mantova
11	ESO Recycling – Riccione
18	Maris – Turin

Légende :

- Technical center
- Recycler
- Recycler & Incorporator
- Incorporator
- Machine manufacturer

Figure 24 : Map of shoe sole recycling stakeholders in Europe

Company	Country	Type of company	Proposed service	Expanded EVA	TPU	SBR	SBR+NR blends	PU	PVC	SEBS/SBS	ABS	Leather	EPDM	NBR	Minimum quantity (R&D or production) (kg)
Elanova	France	Technical centre	Micronization			•	•						•	•	Project-dependent
			Devulcanization			•	•						•		40
			Formulation			•	•						•	•	300
			Transformation			•	•						•	•	Project-dependent
IPC	France	Technical centre	NIR sorting		•				•	•	•				-
			Sorting by flotation		•				•	•	•				-
			Triboelectric sorting		•				•	•	•				20
			Grinding		•				•	•	•				5
			Washing		•				•	•	•				5
			Extrusion		•				•	•	•				5
J. Allcock & Sons Ltd	United Kingdom	Recycler	Micronization			•	•						•	•	20
			Devulcanization			•	•						•	•	100
MicroPolymers	France	Recycler	Micronization (cryogenic and atmospheric)	•	•	•	•	•	•	•	•	•	•	•	10
Rubberlink (BOLFLEX)	Portugal	Recycler	Grinding			•	•			•			•	•	500
			Micronization			•	•						•	•	500
			Devulcanization			•	•						•	•	500
Rubber Conversion	Italy	Recycler	Devulcanization			•	•							•	10
The 8 Impact	France	Recycler	Micronization			•	•						•	•	5
			Devulcanization			•	•						•	•	5
			Grinding	•	•	•	•			•			•	•	5

Company	Country	Type of company	Proposed service	Expanded EVA	TPU	SBR	SBR+NR blends	PU	PVC	SEBS/SBS	ABS	Leather	EPDM	NBR	Minimum quantity (R&D or production) (kg)
AER Caoutchouc Plymouth	France	Recycler Incorporator	Thermomechanical devulcanization			•	•	•					•	•	300
Amorim Cork Composite	Portugal	Recycler Incorporator	Mixing / Formulation	•											10
Authentic Material	France	Recycler Incorporator	Thermo-compression									•			50
			Thermoplastic formulation									•			50
ESO Recycling	Italy	Recycler Incorporator	Grinding and sorting, thermo-compression	•	•	•	•	•	•	•	•	•	•	•	2000
INDCO	France	Recycler Incorporator	Grinding		•				•	•	•				3000
			Extrusion		•				•	•	•				3000
TerraCycle	International	Recycler Incorporator	*Custom via partners*	•	•	•	•	•	•	•	•	•	•	•	Project-dependent
Viriam	Italy	Recycler Incorporator	Micronization + formulation	•	•										10
Elastever	France	Incorporator	Micronization			•	•						•	•	-
			Extrusion			•	•						•	•	20
Stonegom	France	Incorporator	Grinding and mixing			•	•						•	•	Project-dependent
The Good Plastic	Netherlands	Incorporator	Thermo-compression	•	•	•	•	•	•	•	•		•	•	30
Maris	Italy	Machine manufacturer	Devulcanization			•	•						•	•	25
			Extrusion		•				•	•	•				25
			Decrosslinking	•											25
REP international	France	Machine manufacturer	Devulcanization			•									10

Table 2: Summary of companies offering recycling solutions for shoe sole materials

3.5 Other identified companies

Other companies have been identified as recyclers of shoe sole materials. These are listed below:

- **Aloft - Portugal (Canidelo)**

Aloft, a company based in Canidelo, Portugal, specializes in the manufacture of footwear, particularly shoe soles. As part of its activities, Aloft recycles its production offcuts, but also wishes to develop the recycling of other waste streams via its rubber micronization solution.

- **Le Pavé® / SAS Minimum - Aubervilliers (93)**

Le Pavé® an eco-construction material made from recycled plastic waste. It is produced by SAS Minimum, a company based in Île-de-France. Le Pavé® is available in panels of different sizes and thicknesses and is used in various building and design projects. The company is thus able to valorise different types of plastics: PE, PP, PS, ABS, PET. Trials have already been performed to develop panels incorporating EVA shreds from footwear.

- **Muratto - Portugal (Vila Nova de Gaia)**

Figure 25: Muratto wall covering made from Nike Grind EVA

Muratto is a Portuguese company that uses natural or recycled raw materials to develop and manufacture products for wall coverings, acoustic panels and interior decoration.
A collaboration between Nike Grind and Muratto led to the development of a product that can be used as wall covering or for other decorative projects, incorporating over 75% EVA derived from ground sneakers into cork.

- **Playtop - United Kingdom (Newark-On-Trent)**

Playtop is a UK-based company that has been manufacturing playground equipment from end-of-life tyres since 1977. Its recycling process consists in grinding tyres, breaking them down into single components: rubber pellets, metallic yarn and a small percentage of textiles. In 2008, Playtop signed a partnership with Nike, obtaining exclusive rights to incorporate rubber granules from recycled Nike and other footwear into their EPDM, under the Playtop brand with Nike Grind.

Figure 26: Playtop basketball court made from Nike Grind rubber

- **Vamas - Italy (San Miniato)**

Vamas is an Italian manufacturer of shoe soles for the luxury goods industry, offering a range of materials: TPU, PU, PEBA and leather, with recycled and bio-sourced material versions for PU and TPU. In 2024, Vamas teamed up with ReValorem for closed-loop recycling trials of TPU soles.[27]

3.6 Projects

Several projects aiming at improving footwear recyclability through dismantling and recycling have emerged in recent years in Europe.

ReProcessShoe is a German-Polish project run in collaboration by three entities: PFI Germany (Prüf - und Forschungsinstitut Pirmasens e.V.) and the Ł-ITEE. (Lukasiewicz Research Network - Institute for Sustainable Technologies) and OIBS (Polish National Chamber of the Leather Industry). The aim of the project is to implement a solution for dismantling footwear and separating its various components in the purest possible way. A first solution has been developed to separate by mechanical cutting the shoe upper and sole as well as the toe caps of safety footwear.

As part of the European **LIFE Re Shoes** project led by the Italian brand SCARPA, Rubber Conversion's devulcanization technology is used to create new rubber shoe soles, including plates for toe and heel reinforcements as well as new rubber outsoles, all derived from post-consumer footwear. The aim of this project is to establish a circular standard within the footwear sector by effectively managing end-of-life footwear. By implementing an end-to-end approach that includes collection, dismantling, sorting and recycling, a new SCARPA premium shoe model will be developed through circular design that reuses materials from old footwear. The project will end in February 2026.

BioShoes4All is an initiative from the Portuguese footwear industry aiming to reduce the environmental footprint of footwear production, notably through the production of new materials. One of the project's workstreams running until the end of 2025 aims at developing the recycling of the cluster's production offcuts and initiating post-consumer footwear recycling.

[27] https://www.linkedin.com/feed/update/urn:li:activity:7198720268956053505/

4. Recycling trials

As part of the study, recycling trials of materials derived from post-consumer shoe soles have been carried out to evaluate the closed-loop incorporation of the recycled materials.
The choice of materials to recycle was made based on the materials present in collected waste streams.
Recyclers' specifications accepting small quantities were prioritized to conduct these trials.
On this basis, three scenarios were selected:

1. Extrusion / injection of SBS thermoplastic soles
2. Micronization of rubber soles
3. Devulcanization of rubber soles

4.1 Extrusion / injection – SBS soles

The first recycling trial targets extrusion and injection of SBS (also known as TR or TPR) soles.

Shoes were dismantled (upper/sole separation) and the soles were sorted by material composition on CETIA's Re_SHOES line (see**Erreur ! Source du renvoi introuvable.**).
The SBS soles were then sent to IPC for grinding, extrusion and injection into test specimens with different recycled material content rates (10%, 30%, 50% and 70%).
Finally, CTC (Centre Technique du Cuir) carried out the characterization of these specimens.

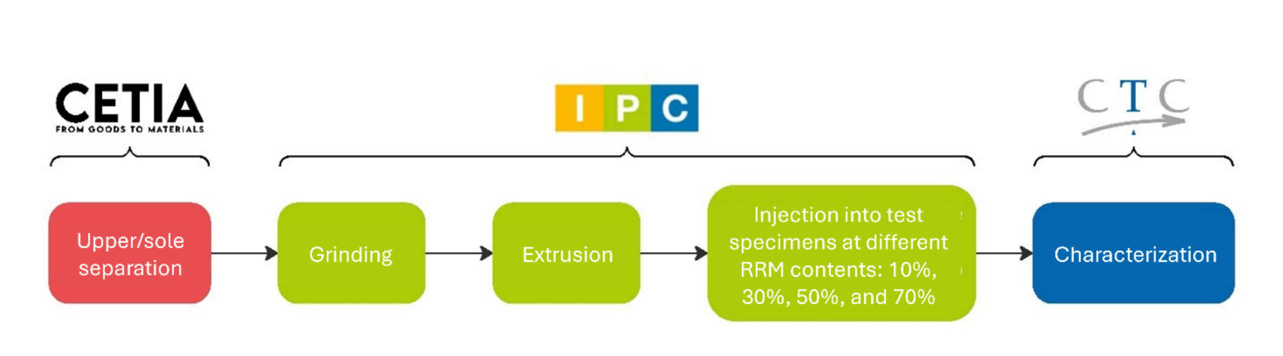

Figure 27 : Chain of stakeholders for the extrusion/injection of SBS soles trial

The initial SBS material batch prepared from post-consumer shoes for the trial was unfortunately lost due to equipment failure at a subcontractor. To address the shortage of SBS material required for the trial, CETIA sourced a batch of defective shoes (primarily pre-consumer sneakers). Eventually, the feedstock consisted of 90% SBS soles from pre-consumer sneakers (around 45kg) and 10% SBS soles from the remaining stock of post-consumer sports shoes (around 5 kg).

Figure 28: Dismantled SBS soles

IPC then worked on the processing, incorporation and formatting operations. The sole pre-treatment phase, i.e. grinding and separation of fine fractions (< 2 mm), was carried out under good conditions with a low level of generated dust (1.8%). Extrusion and injection stages were successfully carried out using conventional injection equipment and stable parameters.
During the extrusion/filtration phase, the filter was changed several times due to the presence of impurities larger than 150 µm in the material. Once dilutions had been made, injection could be carried out; there was no need to modify the parameters during the trial, nor between the different ratio blends.

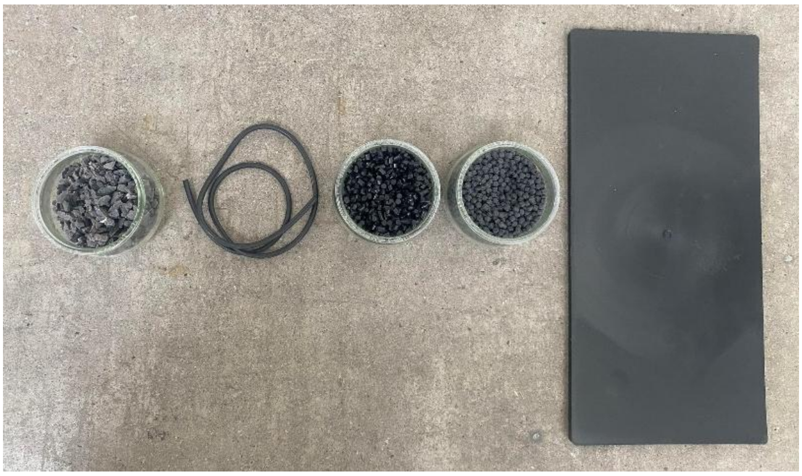

Figure 29 : From left to right: ground material, extrusion rod, recycled pellets, virgin pellets and injected plate containing 50% recycled material

The CTC, a technical centre specialized in footwear, produced test specimens from the plates produced by IPC and carried out the following characterisation tests:

- Abrasion resistance (EN 12770: 1999)
- Flexural strength - 30,000 cycles with an initial 2mm cut (ISO 17707: 2005)
- Tensile strength and elongation at break (EN 12803: 2000)
- Tear strength (EN 12771: 1999)

The results of these tests are shown in Figure 30. The different properties are presented as a variation from the properties of the control sample (0%) using the following formula:

$$Variation(\%) = \left(\frac{sample - control}{control}\right) * 100$$

Figure 30 : Variations in the properties of the material samples incorporating different rates of SBS RRM compared to the properties of the control sample

Characterization results show a real correlation between the proportion of RRM introduced into the new material and the volume loss as well as the flex resistance. The higher the proportion of recycled material, the more these two properties get degraded. Beyond 30%, degradation becomes too significant. Conversely, the elongation at break improves as the RRM content increases.
It is important to highlight that the mechanical properties of the new compounds incorporating the RRM depend on the virgin matrix quality and the incoming sole waste stream. The maximum RRM incorporation rate will therefore be limited following the required properties specified in footwear brands and manufacturers' sole specifications, particularly volume loss.

4.2 Micronization - Rubber soles

The second recycling trial focuses on the micronization of rubber soles.

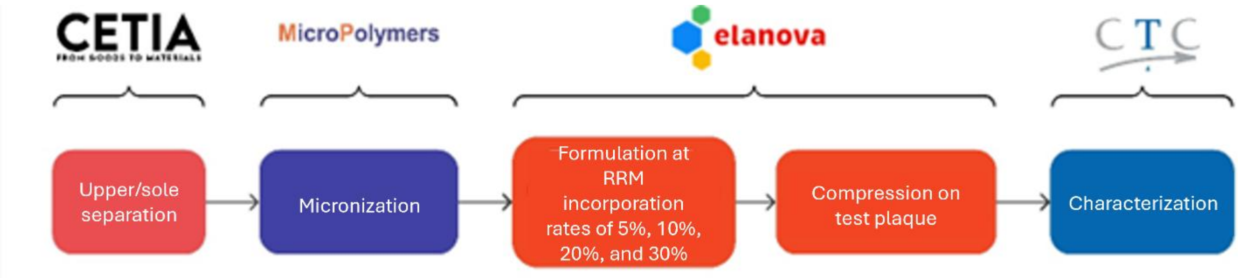

Figure 31: Chain of stakeholders for the micronization of rubber soles

Shoes, mainly post-consumer trainers, sneakers and tennis shoes, were dismantled and their soles were sorted at CETIA (see Appendix 1).

Figure 32: Post consumer rubber soles

Ten kilograms of rubber soles (a mix of different grades) were sent to MicroPolymers for micronization. The feedstock was micronized through successive grinding steps of increasing fineness at ambient temperature. The targeted particle size range was between 200 and 315 µm:

Particle size	Micronized rubber size distribution
> 315 µm	1.8%
Between 200 µm and 315 µm	**93%**
<200 µm	5.2%

Table 3: Micronization test results

Elanova then established the formulation of the new compounds incorporating the micronized RRM at different rates (5%, 10%, 20% and 30%) into a virgin rubber matrix and produced test plates by compression moulding. The following analyses were carried out on the test plates:

- Temperature and power analysis of the five compounds
- Mooney viscosity analysis of the ML (1+4) compounds at 100°C - NF ISO 289-1
- MDR vulcanization kinetics analysis - ISO 6502

The results of these analyses show that the addition of micronized material:

- Increases the viscosity of the compound, requiring more energy and time to obtain a homogeneous mix;
- Increases the Mooney viscosity, but remains entirely acceptable for compression moulding according to Elanova;
- Decreases the cross-linking time but remains within acceptable limits for production conditions, leading to a reduction in production cycle time.

The incorporation of micronized post-consumer rubber therefore requires adjustments in the production process due to changes in viscosity and cross-linking time but remains entirely feasible using standard production equipment.

Figure 33: Micronized rubber (on top) and plates containing different rates of micronized rubber

CTC then carried out the same characterisation tests as for the first trial:

- Abrasion resistance (EN 12770: 1999)
- Flexural strength - 30,000 cycles with an initial 2mm cut (ISO 17707: 2005)
- Tensile strength and elongation at break (EN 12803: 2000)
- Tear strength (EN 12771: 1999)

The results of these tests are compiled in Figure 34. As previously, the different properties are presented as a variation from the properties of the control sample (0%).

Figure 34: Variations in the properties of samples incorporating different rates of micronized rubber compared to the properties of the control sample

In this trial, the volume loss of the new compounds rapidly deteriorates as the recycled material content increases. Beyond 10%, the loss becomes too significant. This result may have multiple causes:

- Lack of extensive sorting of the different rubber grades (SBR, NR, NBR...),
- Absence of a cleaning step to remove any impurities present in post-consumer soles,
- A poorly adapted formulation, with a virgin matrix of basic quality, especially on the volume loss criterion.

On the other hand, tear resistance improves. 20% micronized rubber however appears to be the maximum limit, that also applies to tensile strength.

4.3 Devulcanization – Rubber soles

The third recycling trial involves the devulcanization of rubber soles, carried out by The 8 Impact.

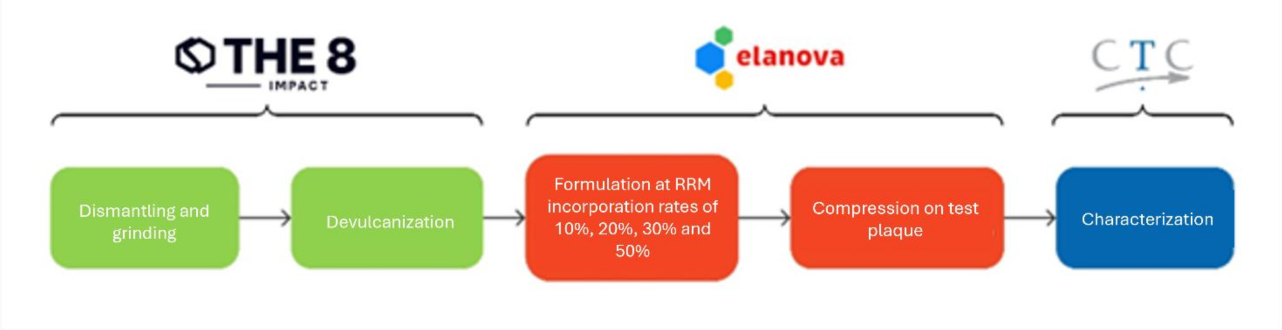

Figure 35: Chain of stakeholders for the devulcanization of rubber soles trial

The shoes used for this trial come from a batch of non-rewearable post-consumer sneakers with Cupsole soles. This batch was sorted for recycling by The 8 Impact and then ground. The 8 Impact then carried out the devulcanization of 20 kg of ground material to obtain 4 kg of devulcanized rubber.

Elanova then formulated the new compounds by incorporating the devulcanized rubber at different rates (10%, 20%, 30% and 50%) into a virgin rubber matrix and produced test plates by compression moulding.

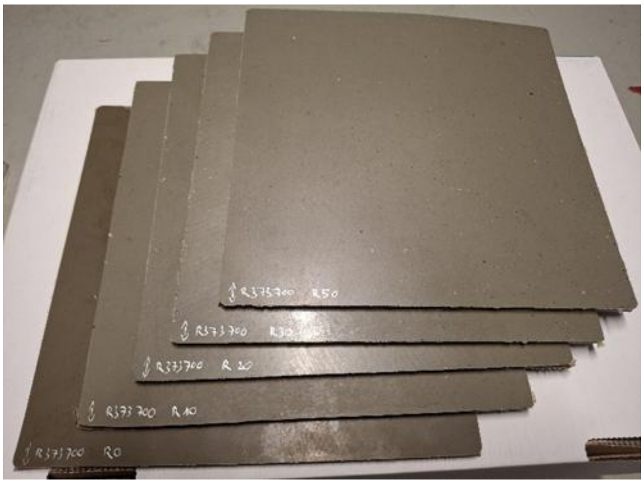

Figure 36: Plates containing different rates of devulcanized materials (Elanova)

Elanova carried out the following analyses on the plates:

- Mooney viscosity analysis of the ML (1+4) compounds at 100°C - NF ISO 289-1
- MDR cross-linking kinetics analysis - ISO 6502

Analysis results show that the addition of devulcanized material:

- Decreases the Mooney viscosity, however without affecting the compression moulding stage;
- Decreases the cross-linking time but remains within acceptable limits for production conditions: the material can be handled without risk of cross-linking before compression moulding. This reduces production cycle time.

It is important to note that the results of these analyses may vary depending on the virgin matrix used. According to Elanova, the decrease in Mooney viscosity is not always observed with regenerated materials; it is also possible to observe the opposite phenomenon.

The CTC then carried out the same characterization tests as for the previous trials:

- Abrasion resistance (EN 12770: 1999)
- Flexural strength - 30,000 cycles with an initial 2mm cut (ISO 17707: 2005)
- Tensile strength and elongation at break (EN 12803: 2000)
- Tear strength (EN 12771: 1999)

The results of these tests are compiled in Figure 37. The different properties are presented as variations from the properties of the control sample (0%).

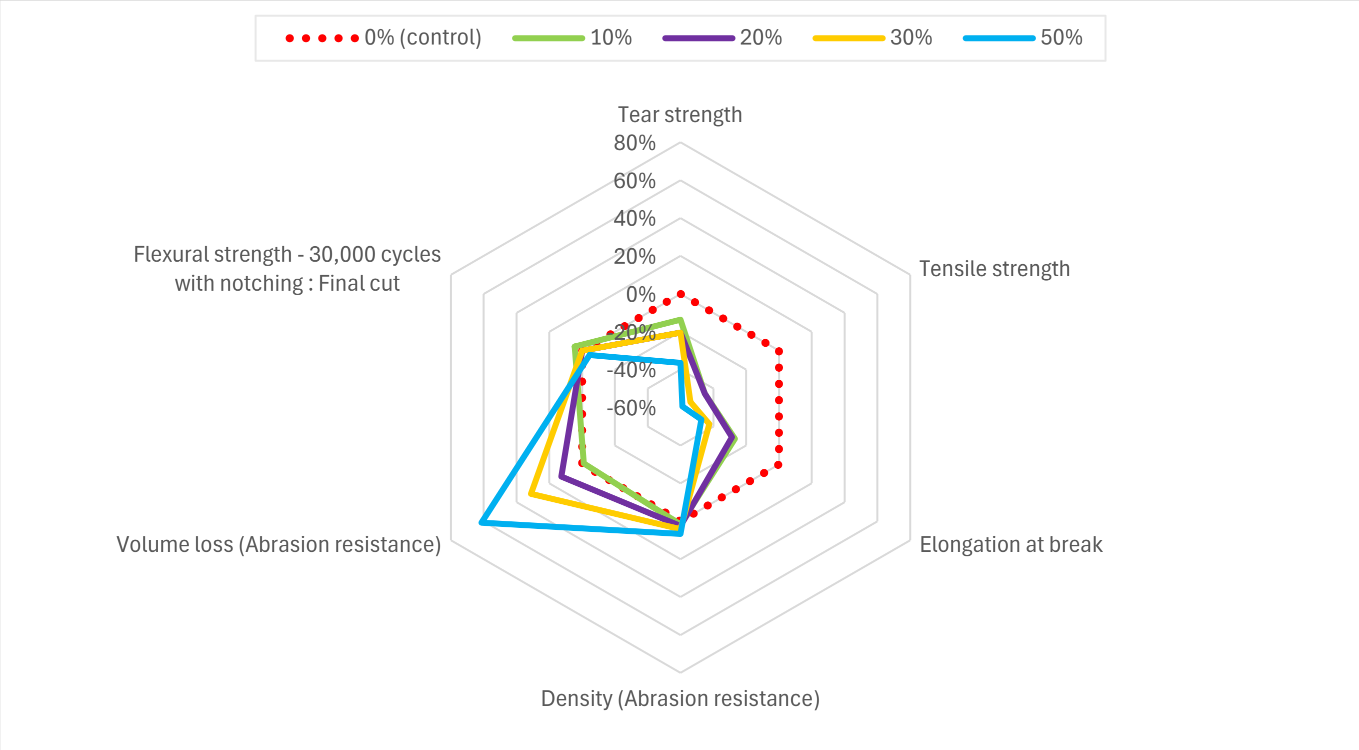

Figure 37: Variations in the properties of samples incorporating different rates of devulcanized rubber compared to the properties of the control sample

In this trial, all the mechanical properties of the newly created materials degrade very rapidly as the proportion of recycled material increases. Beyond 30%, the material becomes too brittle and results in excessive volume loss. Like for the previous trial, this may be due to:

- Lack of extensive sorting of the different rubber grades (SBR, NR, NBR...),
- Absence of a cleaning step to remove any impurities present in post-consumer shoe soles,
- A poorly adapted formulation, with a virgin matrix of too basic quality.

The devulcanization of rubber may allow to achieve a quality of the recycled material equivalent to that of the virgin material. For this, the choice of the blending matrix and the thorough sorting of the incoming rubber waste stream become particularly important.

Trials carried out in the scope of this study - including thermo-mechanical recycling of SBS, micronization and devulcanization of rubber - have demonstrated the feasibility of recycling these materials derived from shoe soles. However, regardless of the recycling process, increasing rates of regenerated material increase volume loss under abrasion, which is the most critical criterion for applications in new shoe soles. A good preparation of the waste stream (material sorting, clean dismantling, potential cleaning *(washing)* step to remove any residual impurities present in the soles) therefore appears essential for recycling post-consumer shoe soles.

5. Summary

In recent years, there have been increasing initiatives and stakeholders in footwear recycling. Indeed, there have been significant advances in footwear preparation for recycling methods, particularly improvements in grinding (shredding) systems and the development of new shoe upper/sole separation techniques. As a result, “cleaner” sole fractions can be recovered, with little to no residual materials from the other shoe components. Since soles can account for up to 50% of a shoe’s weight, they have become a primary target for recycling efforts.

To date, recycling processes for sole materials have mainly focused on production offcuts or unsold footwear (pre-consumer waste).
Most recyclers’ specifications require pure material, free from any contaminants resulting from footwear use, as well as from any hard points and metal. These external disruptors can hinder recycling processes and damage equipment[28], starting with the grinding stage, first step in any sole recycling process.
As for textiles, sorting for recycling is essential to optimize the yield of shoe sole recycling solutions and to improve the quality of produced RRM. Certain technologies such as rubber devulcanization allow to obtain a quality equivalent to that of virgin material but require a highly homogeneous input stream. This necessitates more extensive sorting upstream (by shoe type, sole type, or even by brand) and/or finer material sorting (by rubber grade: SBR, NR, NBR, etc.), which limits the impact on quantities that can be recycled within post-consumer footwear waste streams.

The diversity of materials and potential blends of materials within shoe soles therefore require the use of multiple technologies to process the heterogeneous footwear waste stream. They also imply the need for developing the appropriate tools to sort and prepare homogeneous fractions for recycling. A good preparation of the waste stream (material sorting, clean dismantling, potential cleaning *(washing)* step to remove any residual impurities present in the soles) is essential for recycling post-consumer shoe soles.
In parallel, further experiments are needed to adapt recyclers’ specifications to post-consumer waste streams. The various stakeholders identified in this overview have emphasized the importance of conducting R&D trials before scaling up to larger production runs.

The recycling trials conducted within this study have demonstrated the feasibility of the tested processes on shoe soles feedstock derived from post-consumer footwear waste. They also highlighted that the properties of the resulting recycled materials largely depend on the quality of the incorporation matrix and on the purity of the input stream; these are two essential factors for closed-loop shoe sole recycling.

This state of the art of recycling solutions for shoe soles in Europe serves as an initial foundation to encourage further experiments on recycling shoe soles from post-consumer footwear waste and is meant to be regularly updated and expanded.

[28] Refashion - Study on recycling disruptors and facilitators in Clothing, Household linen and Footwear – February 2025

6. Appendix 1 – Dismantling trial report

CETIA contacted a sorting centre to supply a batch of 300kg of non-rewearable post-consumer footwear, based on the following specifications for their dismantling:

- **Targeted shoes:** sneaker-type shoes with single-material soles;
- **Shoes to exclude:** shoes with multi-material soles (such as running shoes); shoes with black soles.

Multi-material soles have been excluded so as not to add an additional step to the separation of the shoe upper and sole. Black soles have been excluded so that materials can be identified using a near-infrared sensor (Matoha NIR sensor).

The batch of received shoes consisted mainly of trainers, sneakers and tennis shoes (see Figure 38).

Figure 38: Post-consumer shoes received for dismantling

After receipt, an additional sorting step was carried out to allocate the shoes to the different dismantling solutions:

- Shoes passing through CETIA's ripping cell (mostly adhesive-assembled shoes);
- Shoes passing through CETIA's cutting cell (no specifications on assembly types);
- Shoes not compatible with specifications of CETIA's dismantling solutions.

Of the 261 kg of sorted shoes, a 105 kg batch was directed to the ripping system and a 65 kg batch to the cutting system. The out-of-specifications batch consisted mainly of baby/children's shoes, open shoes and a few shoes with black soles.

Figure 39: Out-of-specifications shoes

Of the 105kg batch, 43 kg of clean, contaminant-free soles could be recovered by dismantling by ripping, with the following breakdown:

- 10 kg of SBS soles
- 25 kg rubber soles
- 8 kg of multi-material soles

Figure 40: Rubber soles (left) and thermoplastic soles (right)

Of the 65 kg batch, 12.5 kg of clean, contaminant-free soles could be recovered by dismantling by cutting, with the following breakdown:

- 0.5 kg of SBS soles
- 6.8 kg of rubber soles
- 5.2 kg of multi-material soles

This batch of shoes contains a significant proportion of multi-material soles, which in appearance before cutting, could have been mistaken for single-material soles. Indeed, some dismantled soles may still contain expanded EVA or multiple materials (see Figure 41).

Figure 41: Rubber/EVA/PVC sole (left) and Rubber/EVA sole (right)

The final step involved an additional sorting of the dismantled shoe soles based on their cleanliness, that is the presence of residual contaminants such as textiles after dismantling, or sand, soil, or stones. Some shoe soles had to be discarded to meet the recyclers' specifications.

Summary of recovered material weights:

Prepared batch	Ripping	Cutting	
SBS	10 kg	0.5 kg	*Used for trial 1*
Rubber	25 kg	6.8 kg	*Used for trial 2*
Multi-material	8 kg	5.2 kg	*Discarded*
Total	43 kg	12.5 kg	

7. INDEX OF FIGURES AND TABLES

FIGURES

TABLES