Re_fashion

Technical monitoring of optical sorting, recognition and disassembly technologies for textiles at European scale

Summary

April 2023

Terra

Experts en solutions circulaires

SUMMARY

Introduction

This study was carried out by Terra between June and December 2022 and its main objective was to update the study carried out in 2019.

This study aimed at:

- Establishing a state of the art of technologies used for **textile materials recognition and sorting**;
- Supplying an overview of the stakeholders and projects working on this topic in Europe and to consolidate feedback.

In order to cover all steps from **characterisation to material preparation for recycling**, a section on **disassembly technologies** has been added to this new version.

This summary has two major sections:

1. A first section on material sorting.
2. A second section on disassembly.

Each section first addresses the concepts and the state of the art, then provides an overview of the stakeholders and projects identified in Europe.

It should be noted that other stakeholders and projects exist throughout the world but this study focuses on Europe.

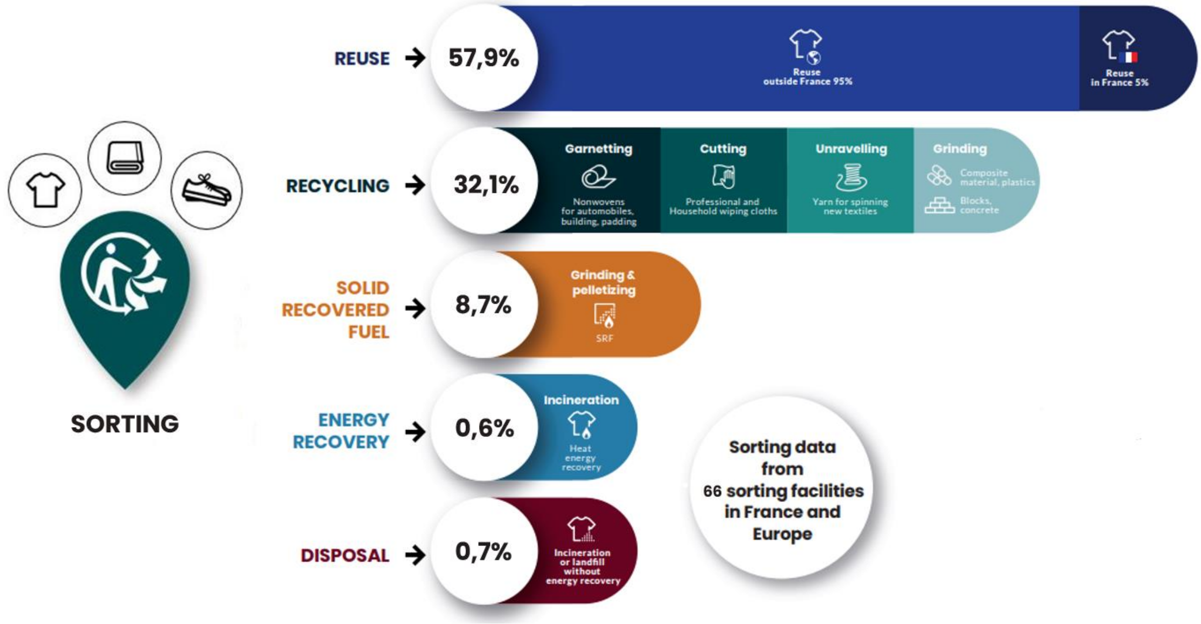
Material sorting

State of the art of textile materials recognition and sorting technologies

Background

Collected post-consumer textiles are manually sorted so to determine their **reuse** potential. The **reused** portion accounts for 58% of sorted CHF (clothing, household linen and footwear). The fraction that cannot be reused is either:

- Recovered in the form of materials (wipes, nonwovens, etc.).
- Or recovered in the form of energy. Less than 1% of CHF are disposed of.



The second life of textiles and footwear after sorting (Source: *2021 Refashion Activity Report)*

A necessity to develop recycling

The **quantity of collected textiles is increasing** but the **reusable portion is decreasing**.

This trend is continuing at a European level for various reasons:

- Decline in the quality of clothing placed on the market (with an increase of entry-level products with a questionable commercial and emotional value).
- Development of peer-to-peer resale upstream, thereby increasing the amount of wear and tear in products later collected in textile collection points.
- The obligation of separate collection of textiles, even non-reusable ones, in Europe by 2025.

Export of textiles for recycling or reuse may also get more limited in the future.

It is therefore essential to create **new outlets** for non-reusable textiles and to **develop their recycling.**

Material and colour sorting

Textile recycling is still limited. One of the obstacles in its development is the absence of reliable material characterisation methods for the fraction intended for recycling.

The majority of applications that can integrate recycled textile materials **require that different materials be separated upstream.** Textile materials sorting is therefore an **essential brick** in the recycling chain.

For certain types of recycling, **colour sorting** may also be required. For example, to avoid having to dye the recycled material.

Disassembly

Another major obstacle is the need for many recycling processes to obtain textile materials **without any hard points or other disruptors to recycling.**

In parallel to material and colour sorting, disassembly is another key step and is addressed in the second section of this document.

Textile materials

A **multitude of textile materials** exist (see table below). The prerequisite for sorting is therefore to **identify the composition** and chemical structure of these materials.

Fibre types	Examples
Synthetic **polymers**	Polyester, polyamide, acrylic, elastane
Cellulose fibres	Cotton, viscose, linen
Protein-based fibres	Wool, cashmere, silk

The technology that is being sought

To separate textiles, a material **recognition system** is required that is:

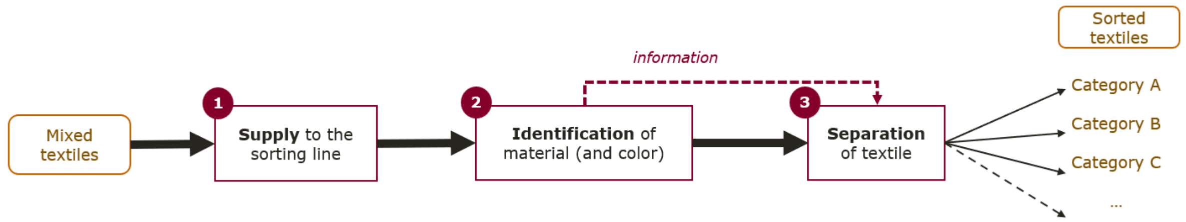
- Reliable.
- Fast.
- Non-destructive.
- Economical.

Sorting materials exclusively by hand (by feel and/or reading labels) does not meet these criteria. Therefore this report focuses on technologies that may be more suitable.

Material sorting is only considered for the textile fraction that has been judged as being non-reusable following an initial manual sorting operation.

Automated sorting

To be able to develop large-scale sorting for recycling purposes, a certain level of **automation** is necessary.



The major stages in material sorting

Material sorting can be divided into three major stages:

1. **Supplying** the textile sorting line.
2. The **identification** of materials and colour (using NIR spectrometry, RFID, etc.)
3. Physical **separation** of textiles on the basis of the classification made at the identification stage.

These stages may be to a greater or lesser extent automated.

The identification stage is presented in further detail below.

Types of sorting machines

Today two major types of sorting machines for textiles can be found on the market:

- multi-category sorting,
- two or three category sorting.

Multi-category sorting machines

These machines can be differentiated by the fact that only one identification system can sort a large number of categories (in general 5 to 50) by means of a long conveyor belt system and a lateral pneumatic ejection system.

The main disadvantage is the low sorting throughput (around one item per second).

This type of sorting can also be considered with other separation systems.

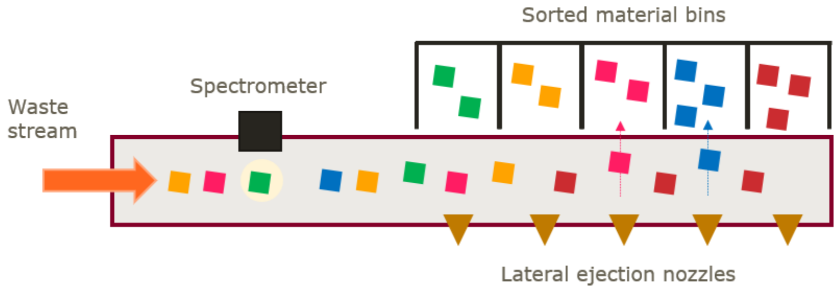


Diagram of a "multi-category" sorting machine

Two or three category sorting machines

This type of machine can only sort into 2 to 3 categories. However, the sorting throughput is much higher with faster conveyor belts and with the possibility of having several items side by side on the belt.

To be able to sort into a greater number of categories, several sorting machines must be combined.

This is the type of equipment that can be found, for example, in packaging sorting centres (10 to 20 machines per sorting centre).

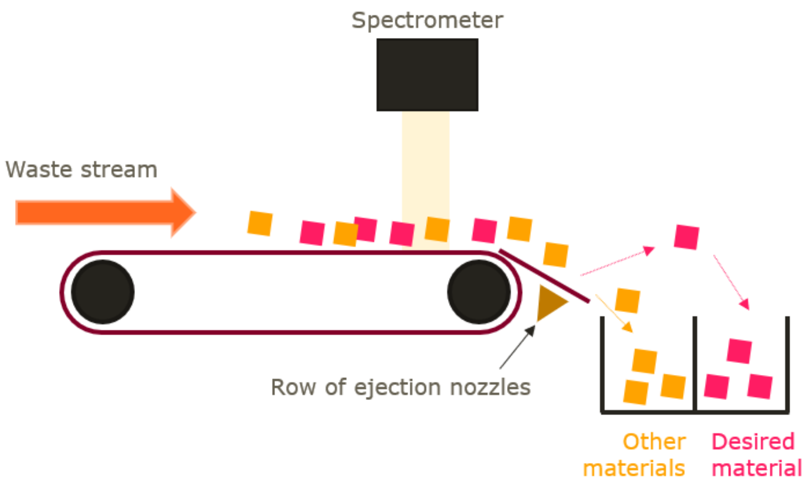


Diagram of a two-category sorting machine

Full garments or clippings

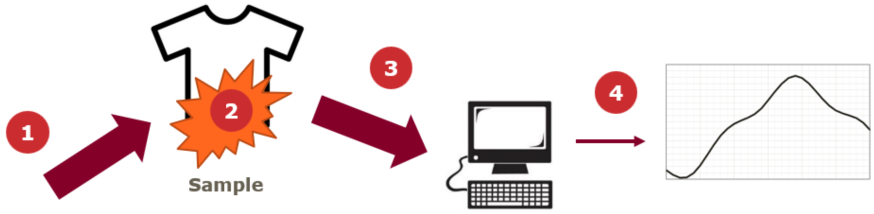
Regardless of the machine type, sorting textiles by material may be carried out on full garments or clippings (cut pieces of textiles).

Material recognition

Most of the equipment enabling textile material recognition is based on the **spectroscopy principle**.

Spectroscopy, user guide

A **spectrometer** is an equipment that can analyse a sample's composition.



How spectroscopy works

It works as follows:

1. The sample to be analysed is exposed to an electromagnetic wave.
2. The wave and the sample's chemical structure interact (molecule, atom, bonds, etc.).
3. The wave is measured after having interacted with the sample.
4. A spectrum is produced.

The spectrum represents the sample's chemical signature.

Therefore, by comparing the spectrum of an item's unknown composition with a reference spectra database containing pre-recorded samples, the composition of the analysed item can be determined.

Sorting categories

During the development of a new material recognition system, it is necessary to have a **library** of reference material **samples** (here textiles).

These samples:

- Correspond to the desired sorting categories.
- Serve in constituting the reference spectra database.

Note that a spectrum depends on the material but also on the sensor that is used. So, a single material scanned with two different spectrometer models will not provide the same spectrum. This is why it is useful for spectrometer suppliers to have physical samples of textile materials.

A **sorting category** may correspond to:

- A pure material (e.g. 100% cotton).
- A blend of materials (e.g. 50/50 cotton/polyester).
- A family of materials that are close (e.g. cellulosic fibres).

ZOOM on the Refashion Textile Materials Library

To speed up the development of material recognition technologies for textiles[1], in 2021 Refashion decided to create a textile materials reference library:

- It contains 409 samples divided into 25 material composition categories.
- Each sample has been certified by a specialist laboratory.
- 10 identical copies have been created and made available to the sector's stakeholders.

Finding textile samples with a known and reliable material composition is one of the obstacles encountered by material identification technology developers.

[1] See page 45 in the 2021 Refashion Activity Report (available here)

> Laboratory tests performed on the samples sourced from retail showed that for 20 to 50% of cases*, the composition marked on the label was incorrect.
>
> **according to the item (fabric, garment) and as defined in EU Regulation n°1007/2011* (different material or difference >3%)

In summary

In summary, the **performance** of an automated materials recognition system depends on:

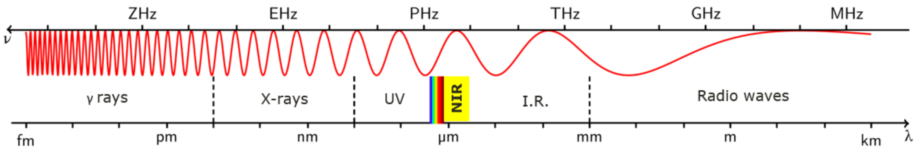
- the **quality of the measuring equipment** (*hardware*): optical system, light source, resolution, reproducibility of the spectra, etc.
- the **reference database** (*library*): number and representativeness of materials available in the database.
- **classification algorithm** (*software*): model used, configuration, etc.

If one of these points is lacking, the effectiveness of material recognition may not be good.

Near infrared (NIR)

Spectroscopy using near infrared wavelengths is the most commonly used technology for textile materials recognition.

This is commonly called **NIR**, near-infrared.



Electromagnetic spectrum domains (Source: Wikipedia)

A technology already used in Europe...

All main projects and stakeholders identified in Europe that are working on textile material sorting (see following section) use this technology for material recognition.

... and suitable for textiles

It is indeed suited to the chemical composition of textiles because the different materials **can be clearly differentiated** using near-infrared.

... and for waste sorting

Near-infrared has been used for several decades for sorting packaging, plastics and cardboard.

Materials used in textiles are chemically **close,** for example**, to those of packaging.** To illustrate this, polyester is found in PET bottles and paper and cardboard are made from cellulose as is cotton.

Automated sorting technologies based on near-infrared are therefore **totally compatible with** waste **sorting operating conditions**.

... and relatively inexpensive

Compared to other spectroscopic technologies, near-infrared remains relatively inexpensive.

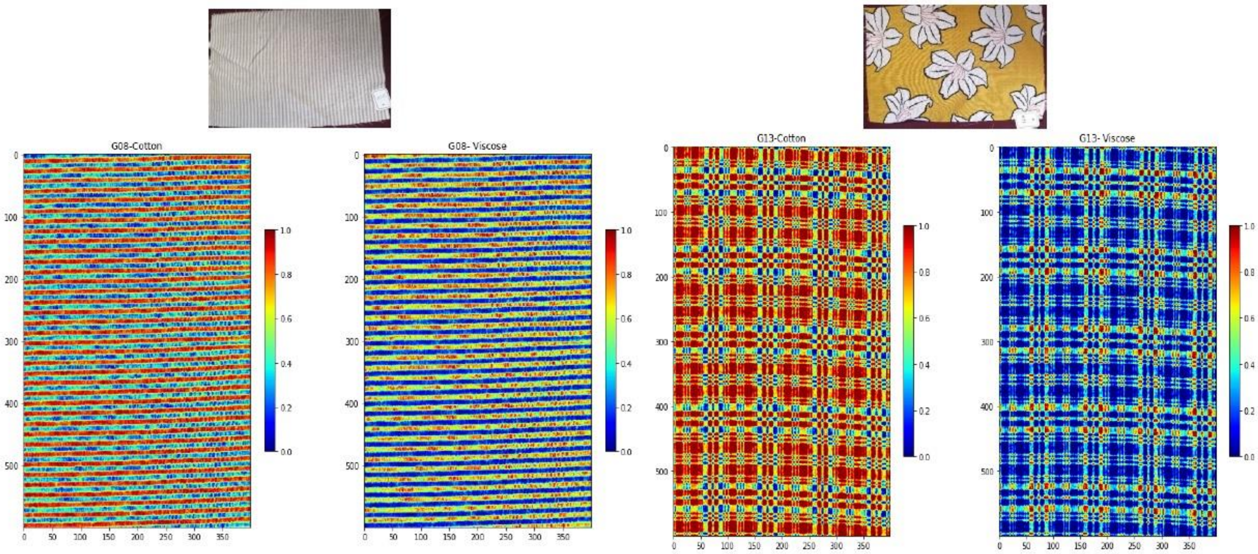
Type of NIR equipment	Price (order of magnitude)
Spectrometer	€2-20 K
Optical sorting machine only	€150-200 K

Hyperspectral imaging

If standard spectrometry measures a spectrum at one point only, it is also possible to use hyperspectral imaging.

A hyperspectral camera will measure a material's spectrum at several points over the whole item so to create a 2D image of the material's composition.

Compared to a single point measurement, the advantage is that different types of fibres can be detected in textiles that do not have a uniform composition on one side, as well as for overlapping items, as long as one part of the items appears in the image. This equipment is however more expensive.



Example of hyperspectral imaging (Source: Plateforme d'Imagerie Multi Spectrale (PIMS) – CEA DNAQ)

Operational feedback on textiles

Since the first study in 2019, the number of stakeholders and projects working on textile materials recognition with near-infrared technologies has significantly increased.

A few automated textile sorting lines are already in operation in Europe and many stakeholders are testing or are using manual spectrometers too.

Even if the limitations of NIR technology that had then been identified remain overall identical, more feedback is now available. These limitations are described below.

Pure and blended materials

Good results are obtained for the identification of **pure materials** (100% cotton, 100% polyester, etc.).

However, the **identification of blends** is by definition more **complex** and there are thousands of different blends in textiles.

Most **two-material blends** may correctly be identified using near-infrared provided that they are included in the textile database.

When **determining the exact percentage** of each material in a blend, **a margin of error to a lesser or greater extent** will exist depending on the blend, on the spectrometer used or on the textile's structure (see other limitations below).

It is unlikely that blends with more than two materials may be correctly detected.

Even if blends are not identified, it is important that these are not recognised as a pure material in order to prevent a sorted stream from being polluted. Today this is a limiting factor for some equipment.

Surface detection

The main technological limitation of **near-infrared spectroscopy** is the fact that it **only analyses a material's surface**. Pieces having a non-uniform 3D structure risk being wrongly identified.

This is typically the case with "double layered" garments or for some blends where one material is more concentrated on the surface than another.

Some coatings or thread or weave structures may also have an influence on the material's identification.

Materials in low proportions

The fact that a material is present in **very low proportions** (a few percent) within a blend **complicates its identification.** This is very frequently the case with **elastane** in textiles, which rarely exceeds 5% of the blend.

Some stakeholders indicate being able to detect elastane under certain conditions. Good detection depends on the percentage of elastane but above all on the textile's structure (surface detection). If the elastane thread is covered by another material, it will be difficult to detect it. The material to which it is attached and the thickness of the material can also play a role.

Close materials

Some materials are **chemically** very **close.** A classic example is that of **cotton and viscose**, as both are cellulose-based.

Although it is more complicated, cotton and viscose can be differentiated by NIR. However, viscose/cotton blends pose more problems. Still very few stakeholders have worked on other materials close to cotton such as linen.

In the case of polyamide, it might also be possible to differentiate PA6 from PA6.6.

Dark colours and pigments

Regarding colours, some **dark pigments** (e.g. carbon black) may **hinder or make material detection impossible** by totally or partially absorbing near-infrared waves. This can be observed with black textiles but also with mottle grey or other colours.

However, compared to plastics, this type of phenomenon is less frequent in textiles. Some black materials can indeed be clearly identified using NIR. This can be explained by the use of different pigments.

Various treatment processes

The treatment processes that some textile materials have undergone during their manufacture could potentially have an impact on their recognition in near-infrared.

An analogy can be drawn between some functional treatment processes (e.g. coatings, waterproofing) and the problems of blends with a low proportion material or related to surface detection.

Sorting quality

Lastly, the question regarding the **level of quality of the** sorted **fraction** and the **tolerated impurity ratio** is crucial because sorting is a **trade-off between the quantity and the quality** of the sorted fraction.

The level of impurities tolerated in the sorted fraction **depends on its outlet** and targeted application. Work on the level of sorting quality is therefore carried out in partnership with recycling / preparation / integration operators of the sorted materials, considering their specifications.

Other types of spectroscopy

Apart from near-infrared, **other spectroscopy**-based recognition **methods** exist.

In general, these methods are however **more costly and more complicated** to use in the industry with yet **little R&D on textiles**. Here are a few examples.

MIR

Mid-infrared (or MIR) is an infrared range that is a little further from the visible range than NIR. It is currently used to sort black plastics, in particular in the WEEE sector. In theory, it could also be used for textiles but no projects have been identified.

Raman spectroscopy

Raman spectroscopy uses wavelengths in the same area as infrared but is based on physical differences (Raman effect) and uses a laser as a light source.

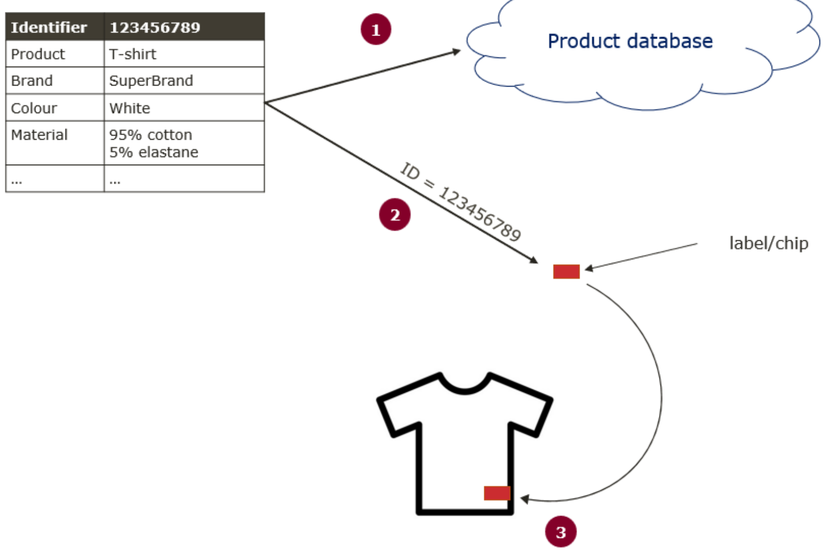
In theory, it could be used for textile materials and could also be more accurate than NIR. However, this technology is still very little used in industrial waste sorting processes. The CRTX.ai project is researching its application for textiles.

Recognition by a digital identifier

Another way to identify a material is to attach information to the product during its manufacturing or when it is sold. This is, for example, the labelling principle.

By implementing information and communication tools, labelling systems can be improved by using a database and a unique identification number.

Product placement onto the market



The principle

When a product is placed onto the market, a **product information file** which includes all information about it is created and **saved in a database.** An identifier is allocated to each product enabling its file to be retrieved in the database.

The **product identifier** is marked **on a label** (in the form of a bar code, QR code) or saved **in a chip** (RFID, NFC) which is incorporated into the product.

Bar codes and QR codes

A bar code will code numerical or alphanumerical information (generally an identifier) in the form of bars and spaces.

00000 00001

A **QR code** is a type of 2D bar code.

The bar code or QR code is read by optical readers or cameras. These technologies are well mastered and not costly.

RFID

RFID (Radio Frequency Identification) is based on **radio labels** comprised of:

- a chip in which information is **stored** (e.g. identifier).
- an aerial that reads the information at **a distance.**

RFID labels used in clothing are essentially passive labels (an external signal must be sent to read them).

Distance reading depends on the RFID standard used and can be a few meters away.

Today, RFID labels are increasingly used in the clothing sector for logistical, shop inventory or anti-theft purposes.
Several forms exist to discretely include them into clothing: classic labels, thread, buttons, etc.

NFC

NFC (Near Field Communication) is a RFID derivative. It can be found in most modern smartphones for example.

The distance for reading is quite short (ten or so centimetres).

Use in textile sorting

The use of these technologies for textile material and colour sorting requires that **useful information to the product's end-of-service life** is given in the product file as soon as it enters the market.

For example:

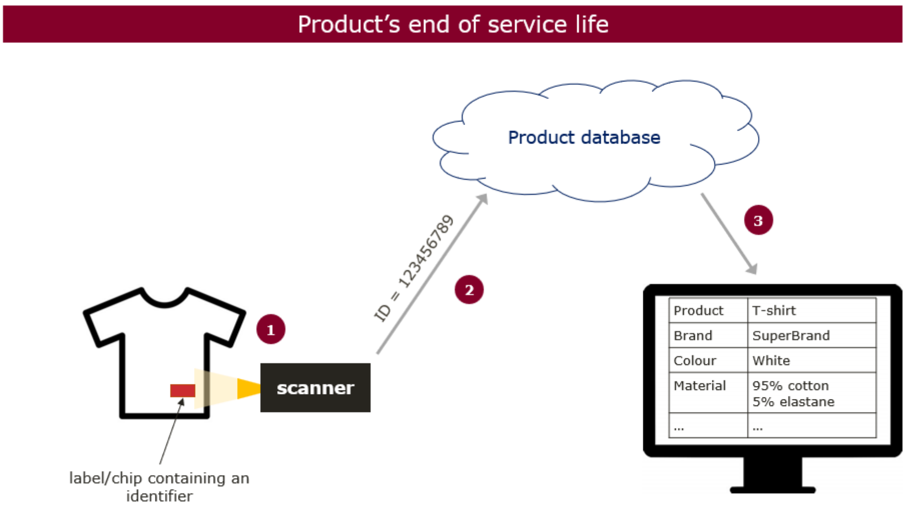
- material composition,
- colour and type of dye,
- presence of disruptors to recycling,
- etc.

At the end of the product's service life, the sorting operator reading its label or chip can recover the product identifier, search the database and obtain all product information.

This method not being based on physical interaction, it **does not have the limitations of NIR** (surface detection, blend, pigment, etc.).

In addition to the material composition, a large quantity of information can also be conveyed such as, for example, useful information on disassembly or even sorting for reuse.

In the case of RFID, **automation** can **easily** be **implemented** because reading is undertaken at a distance. A RFID reader could then substitute or be added to a spectrometer in an automated sorting machine.



What are the limitations?

Whatever the format considered, this method is based on a different model because the information must be included in the product when it is placed onto the market.

This presents **several limitations**:

- **standardisation** of information: between retailers and sorting operators, between brands, etc.
- **large scale adoption** by brands,

- reliability of the product information (case of labels today),
- database management,
- risk of no label or chip at the product's end-of-service life,
- not applicable to items already on the market (historical feedstock).

So QR code or RFID? Even if the general principle is the same, the question about the most suitable label to use arises.

With the RFID chip, the process can easily be automated whereas the label needs to be found in order to read the QR code. The RFID chip can also be discretely incorporated into a garment so to maximise the chances that it will still be present and legible at the end of service life.

However, questions arise on whether or not a RFID label could be a disruptor to recycling. Lastly, the social acceptability on the generalised use of RFID chips in garments is not guaranteed.

Perspectives Given the amount of textiles already on the market and the timelapse between the product being put on the market and its end-of-service life, this solution can only be considered on a **mid- to long-term** basis for textile sorting.

The deployment of this type of labels linked to a digital product file could however accelerate in the coming years with the European Commission aiming to implement a **digital product passport** for some products such as textiles.

Other possible markers Other marking techniques for products or materials exist. Here are a few examples:

- DNA markers,
- 3D markers,
- fluorescent markers,
- microparticles, etc.

The size of the information that is possible to place on the product in this way would however be too limited for a unique identifier or a detailed material composition.

It seems that their use for textile materials sorting is not being considered in the short or medium term.

Additional technologies

Other technologies could come and complement material sorting using near-infrared (or other).

Colour sorting In technical terms there are no specific problems in **colour sorting because** colour can be identified by a simple camera. The problem lies more in the classification of colours and shades to be sorted.

Artificial intelligence The use of robots calling upon "artificial intelligence" for waste sorting is in full development. This equipment, based on standard cameras, **recognises objects and shapes (but not materials).** Stakeholders are starting to work on application to textiles.

This type of technologies can be a complement to material sorting to **detect some types of garments**:

- Undesirable items on a material sorting line (e.g. double layered jacket, etc.).
- Or, on the contrary, items that require specific sorting (e.g. T-shirt, jeans).

Metal sorting Metal sorting systems are widely used in the recycling sector.

Type of metal	Sorting equipment
Ferrous metals	Magnetic separator / Overband
Non-ferrous metals	Machine using induction technology / Eddy current separator

For textiles, such systems can identify and separate any **metallic hard points** in textile streams.

Recognition of problematic substances

Some **substances** found in collected textiles may currently be **prohibited in certain applications** (e.g. REACH) and must therefore be removed from the sorted stream.

This is the case for example for bromine in the plastics industry. To identify **brominated plastics**, X-ray fluorescence or spark (arc atomic emission) spectrometry can, for example, be used.

The use of such technologies could be considered for textile recycling processes that are subject to such regulations.

Conclusions on material identification and sorting

Textile material sorting using near-infrared spectrometry was still in development 3 years ago. It is now **being used at operational level throughout Europe** with several automated lines in operation.

During the search carried out for this study, we were able to see that the interest for the subject is much greater, both from equipment suppliers and from their potential users. The number of stakeholders involved has greatly increased and they appear to be more mature.

An emergence of many projects using near-infrared spectrometry for textile sorting should be seen over the next few years. Indeed, even if some limitations exist and will continue to exist with this technology (e.g. surface detection), it is currently **the most mature technology in the recognition** of post-consumer non-reusable **textiles**.

The sector appears to be approaching a tipping point towards industrialisation and a large-scale deployment of material sorting, even though many challenges are yet to be overcome and are not only technical (economic model, the existence of markets, etc.).

Automated material sorting machine suppliers

Pellenc ST

Pellenc ST is a French company based in Provence that designs, manufactures and sells waste sorting machines for the waste treatment and recycling industry. Their machines can be found in a large number of packaging sorting centres in France.

They are comprised of:

- a **high-speed conveyor belt** (several meters per second),
- a **spectrometer** scanning waste on the belt widthways,
- **ejection air nozzles** at the end of the belt separating materials into 2 or 3 categories + **reception boxes** to recover the sorted fractions.

Country	France
Technology	NIR + colours
Equipment type	**Mistral+ CONNECT**: two or three category automated sorting machine.
Link with textiles	After having undertaken initial trials on textiles in 2013, the company has recently offered its sorting technology to some textile sorting centres.
Contact	Site: https://www.pellencst.com Contact: Marc Minassian (Sales Director France) m.minassian@pellencst.com
Illustration	 *Mistral+ CONNECT sorting machine*

Picvisa

Picvisa is a Spanish company based in the Barcelona region.

Picvisa offers both a multi-category machine based on the same principle as the Fibersort from Valvan and two/three category type machines like those of Pellenc ST and TOMRA.

Country	Spain
Technology	NIR + colours
Equipment type	**Ecopick:** robotic arm **Ecopack**: Two or three category sorting machine **Ecosort Textil**: automated sorting line with lateral blowing
Link with textiles	Picvisa has been working for 7 years on identifying used textiles in waste sorting centres.
Contact	Site: https://picvisa.com/en/ Contact: Silvia Gregorini (Business Developer). sgregorini@picvisa.com

Illustration	 *Ecosort Textil sorting line*

TOMRA

TOMRA is one of the world leaders in optical sorting technologies for waste recycling.

TOMRA optical sorting machines **work in a similar way to those of Pellenc ST.**

TOMRA has a French subsidiary located near Montpellier and several test centres throughout the world for the testing of its equipment, including one in Germany near Koblenz.

Country	Norway/Germany
Technology	NIR + colours
Equipment type	**Autosort**: Two or three category sorting machine
Link with textiles	Equipment used in the Sysav factory in Malmö, Sweden.
Contact	Site: https://www.tomra.com/en/solutions/waste-metal-recycling/applications/textiles Contact: Louisa Hoyes Louisa.Hoyes@tomra.com
Illustration	 *Autosort automated sorting machine*

Valvan

Valvan is a Belgian machinery manufacturer specialized in baling and semi-automatic sorting machines (for reuse) for textiles.

Over the last years, they have been developing the Fibersort, an optical sorting machine for textile material.

The Fibersort is comprised of:

- robots that feed a long conveyor belt (optional),
- a spectrometer at the start of the belt with single point scanning of the material,
- sorting bins placed along the belt with lateral blowers.

Country	Belgium
Technology	NIR + colours
Equipment type	**Manual Fibersort**: sorting table with sensor and screen **Semi-automatic Fibersort**: automated sorting line with manual feed

	Integrated Fibersort: completely automated and integrated sorting line with upstream and/or downstream steps.
Link with textiles	Valvan's Fibersort is used in several textile sorting centres in Europe.
Contact	Site: https://www.fibersort.com/en/ Contact: Jean-François Gryspeert jfg@valvan.com
Illustration	 *Sensor and conveyor belt with lateral nozzles in the Fibersort line*

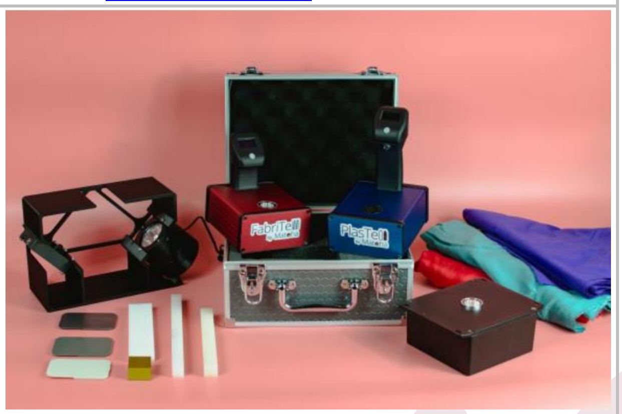
Other potential suppliers

In addition to the above-mentioned suppliers, there are other suppliers producing optical sorting machines for waste packaging or plastics. Some are working in-house on adapting their sorting machines to textiles and should propose commercial offers in the near future.

Handheld spectrometer suppliers

Matoha

Matoha is a London start-up established in 2017. It designs and manufactures **handheld spectrometers for plastics and textiles.** The textile spectrometers were first marketed in 2021.

Country	United Kingdom	Matoha – What will you scan next?
Technology	NIR	
Equipment type	**FabriTell**: handheld spectrometer **Matoha Bench**: spectrometer that can be integrated in a sorting table **Matoha handheld**: ultra-portable spectrometer **Sensing module**: OEM module	
Link with textiles	Matoha spectrometers are used in several European sorting centres and have been used in Refashion's household textiles characterisation campaign.	
Contact	Site: https://matoha.com/ Contact: hello@matoha.com	
Illustration	 *Sensing module, FabriTell and PlasTell handheld spectrometers and Matoha Bench*	

Senorics

Senorics is a start-up created in 2017 in Dresden, Germany. Senorics started to focus on textile identification 2 years ago.

Sensorics offers a handheld spectrometer as well as an OEM version[2].

Country	Germany	SENORICS
Technology	NIR	
Equipment type	**SenoCorder Solid**: handheld spectrometer **SenoSence**: OEM module[2]	
Link with textiles	Collaboration with a few sorting centres	
Contact	Site: https://www.senorics.com/ Contact: Hannah Szynal hannah.szynal@senorics.com	
Illustration	 *Handheld Senocorder spectrometer*	 *SenoSence OEM module*

Spectral Engines

Spectral Engines is a German sensor designer and manufacturer founded in 2014 in Finland. The company's technologies result from research at VTT (a Finnish research institute).

Spectral Engines manufactures OEM sensors for other companies that integrate or assemble them. For textiles, they also offer a turnkey spectrometer with a textile database.

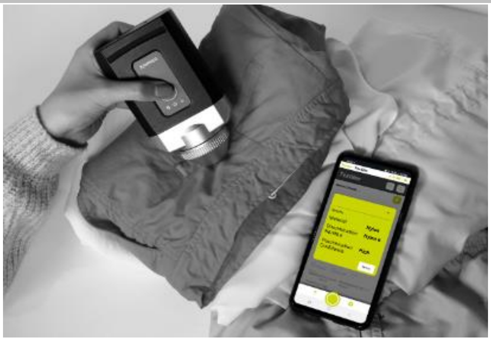
Country	Germany	SPECTRAL ENGINES MEMBER OF THE NYNOMIC GROUP
Technology	NIR	
Equipment type	**Nirone Scanner**: handheld spectrometer **Nirone Sensor**: sensor	
Link with textiles	Technology used by LSJH for textiles sorting tests in Finland.	
Contact	Site: https://www.spectralengines.com/ Contact: Laurent Greulich l.greulich@photinnov.fr	
Illustration	 *Nirone spectrometer*	 *Nirone sensor*

[2] OEM : "Original Equipment Manufacturer" means that the sensor can be integrated in products from another manufacturer.

TrinamiX

TrinamiX is a subsidiary of the BASF group, located in Germany and created in 2015. The company also has offices in China, Japan, South Korea and the United States. TrinamiX operates in **infrared detection** as well as in 3D detection.

The textile module offer is very recent: it was officially launched at the end of 2022.

Country	Germany
Technology	NIR
Equipment type	Handheld spectrometer + development of a semi-automated solution for integration in a sorting table
Link with textiles	TrinamiX already works with the plastics recycling industry and has recently developed offers for textiles.
Contact	Site: https://trinamixsensing.com/textiles Contact: Daniela Kolodziej daniela.kolodziej@trinamix.de
Illustration	 *TrinamiX handheld spectrometer*

Other companies

In the study published in 2020, a handheld spectrometer by the company **Iosys** called mIRoGun had been identified. However, no evolution of this instrument has been observed.

It should be noted that the French company **Plas'tri** that started marketing their plastics spectrometer at the beginning of 2022, has started to show an interest in textiles.

Sorting tables

Sorting tables are variants of manual spectrometers. These are generally constituted of a table with an integrated **sensor** and a **screen** enabling the sorting operator to read the material recognised by the sensor. Several **sorting bins** are added to these tables depending on the number of categories to be sorted.

For continuous operation, sorting tables are more ergonomic than handheld spectrometers. The sorting operator only needs to **pass a textile item in front of the sensor**. The separation of textiles from the stream remains manual.

The models of sorting tables identified in this study are described in the table below.

Comparison of automated material sorting or identification equipment

Automated sorting machine

Supplier	Equipment	Multicategory or two/three category sorting	Possibility of automated (robotic) feeding	Material identification technology	Sensor type	Colour sorting	Recognised materials (supplier claims)	Capacity/velocity (data in t/h depend on the sorted stream and on the manufacturer)	Type of ejection at end of the line	Supplier nationality	Test centre available	Sorting of clippings or of full garments	Examples of equipped sorting centres
Pellenc ST	**Mistral+ CONNECT**	two/three category	Yes	NIR	Hyper-spectral	Yes	(contact manufacturer)	NC	Ejection nozzles at the end of the conveyor belt	France	Pertuis (France)	Both	NC
Picvisa	**Ecopick**	4 categories	Yes	NIR	Hyper-spectral	Yes	Cotton, viscose, wool, polyester, cotton/polyester, polyamide, wool/polyamide, wool/polyester, silk, acetate, acrylic, polyurethane.	1 m/s + 1 item/s	Robotic arm	Spain	Calaf (Spain)	Both	Coleo Recycling
	Ecopack	two/three category						3 m/s + 1.8 to 2 t/h	Ejection nozzles at the end of the conveyor belt				
	Ecosort Textil	multi-category						1 to 2 item/s	Lateral ejection				
TOMRA	**Autosort**	two/three category	Yes	NIR	Hyper-spectral	Yes	Cotton, polyester, cotton/polyester, wool, acrylic, polyamide, viscose.	NC	Ejection nozzles at the end of the conveyor belt	Norway	Mülheim-Kärlich (Germany)	Both	Sysav factory in Malmö, Sweden (Stadler design)
Valvan	**Fibersort**	multi-category	Yes	NIR	Single point	Yes	Wool, cotton, polyester, viscose, acrylic and polyamide	0.7m/s + 1 item/s. 1 200 kg/h (hyp: 3 textile items/kg of flow)	Lateral ejection	Belgium	Construction of a test line (SCIRT project)	Both	• Salvation Army (United Kingdom) • Wieland Textiles (the Netherlands) • CETIA at Hendaye, France (2023)

Sorting tables

Supplier	Equipment	Material identification technology	Sensor type	Colour sorting	Recognised materials (supplier claims)	Supplier nationality
Valvan	**Manual Fibersort**	NIR	Single point	No	Wool, cotton, polyester, viscose, acrylic and nylon	Belgium
Matoha	**Matoha bench**	NIR	Single point	No	Cotton, wool, polyester, polyamide, acrylic, viscose, silk, elastane, acetate and any blend of 2 of these materials.	United Kingdom

Handheld spectrometers

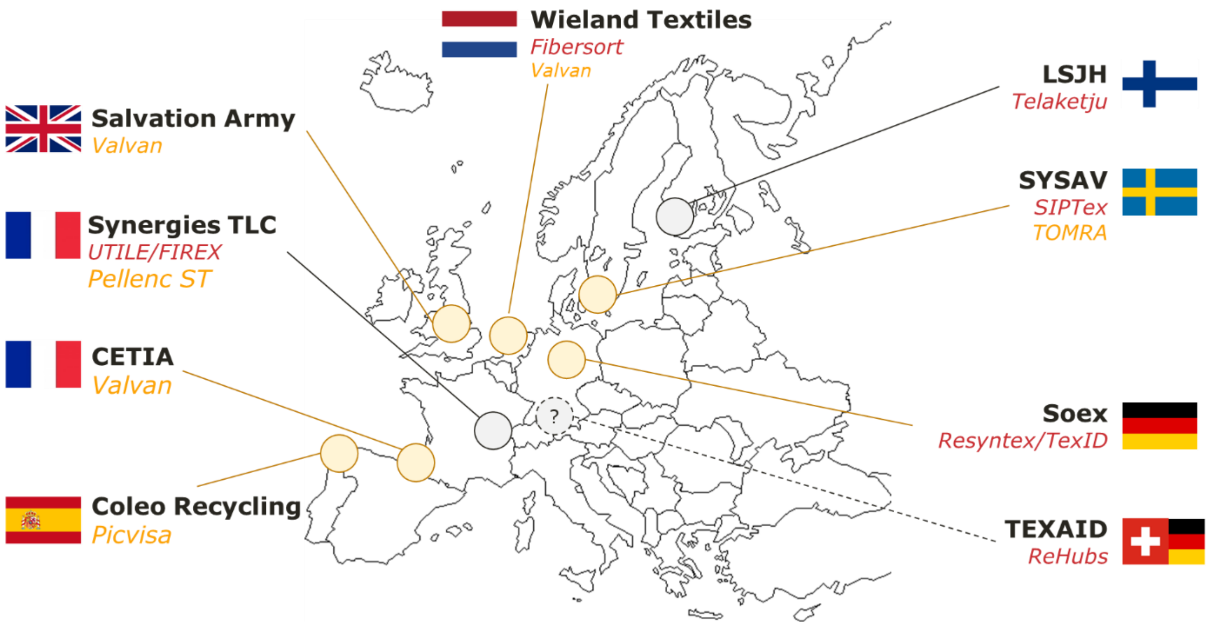
Supplier	Equipment	Material identification technology	Sensor type	Identification of colours	Recognised materials (supplier claims)	Measurement time	Computer software/handheld application	Can be used off-line	Battery operation	Suppliernationality	Size and weight of appliance	Examples of use
Matoha	**FabriTell**	NIR	Single point	No	Cotton, wool, PET, PA, acrylic, viscose, silk, elastane, acetate and any blend of 2 of these materials.	< 1 second	Handheld application	Yes	No	United Kingdom	130x130x90 mm for 0.5 kg	• Refashion characterisation campaign • "Sorting for circularity" study by Fashion For Good
Senorics	**SenoCorder Solid**	NIR	Single point	No	NC	6 seconds	Computer software and handheld application	No	Yes	Germany	110x60x50mm	NC
Spectral Engines	**Nirone Scanner**	NIR	Single point	No	Cotton, wool, viscose, elastane, PET, PA, acrylic, modal, silk	A few seconds	Computer software and handheld application	No	Yes	Germany	80x80x28mm	NC
Trinamix	**Trinamix**	NIR	Occasional	No	Wool, cotton, acrylic, PA6 and PA6.6, PET, polypropylene, silk, viscose, sisal Blends based on acrylic, cotton, silk, PET, nylon and wool (only the main material is recognised)	NC	Computer software and handheld application	No	Yes	Germany	152x84x82mm	NC

Existing or planned automated sorting lines

Map of automated lines or planned lines

Several automated sorting lines that are either already in function or in the pipeline have been identified in this study.

This map shows the main lines that have been the focus of a public announcement as well as related operators, projects and suppliers.



Main automated material sorting lines identified in Europe: already existing (yellow) and planned (grey)

Existing automated sorting lines

Coleo Recycling

Country	Spain	coleo.
Techno	NIR + colour	
Supplier	Picvisa	
Development stage	Existing line	
Capacity	5,000 t/year	

Coleo Recycling is a Spanish company that has a textile recyling site in La Coruña. This site is fitted with a Picvisa "Ecosort Textil" sorting line.

Salvation Army

Country	United Kingdom	THE SALVATION ARMY – SALVATION ARMY TRADING COMPANY
Techno	NIR + colour	
Supplier	Fibersort	
Development stage	Existing line	
Capacity	~500 t/year	

The commercial branch of the Salvation Army in the United Kingdom (SATcol) installed a Valvan Fibersort line at the end of 2022 at its Kettering site.

SYSAV

Country	Sweden	
Techno	NIR + colour	
Supplier	TOMRA	
Development stage	Existing line	
Capacity	24,000 t/year (target)	
Other partners	About twenty partners (SIPTex project): brands (H&M, IKEA, etc.), sorting operator (Boer Group), recycling operator (re:newcell), Refashion, public operators, etc.	

The **SIPTex** project (Swedish Innovation Platform for Textile sorting) is a Swedish project for textile sorting that was undertaken in 3 phases between 2015 and 2022. It was closed end 2022 with the inauguration of **an industrial scale textile automated sorting unit** owned by SYSAV in Malmø (SIPTex 3).

The line is comprised of 4 TOMRA Autosort sorting machines.

SOEX

Country	Germany	
Techno	NIR + colour	
Supplier	NC	
Development stage	Existing line	
Capacity	NC	

Soex has developed a material sorting pilot within the framework of the European project RESYNTEX, between 2015 and 2019.

On this basis, the **TexID** project financed by Refashion enabled a totally automated industrial line to be designed.

After two years of tests at its Wolfen site, Soex installed an **automated sorting line that is fully operational since May 2022.**

CETIA

Country	France	
Techno	NIR + colour	
Supplier	Valvan	
Development stage	Existing line	
Capacity	-	

CETIA is an R&D centre located in the Basque country created by the CETI and ESTIA. Its work focuses on material preparation, sorting and disassembly of clothing and footwear. CETIA notably contributes to textile disassembly projects (SCIRT and TRACE).

CETIA will acquire a Valvan Fibersort line in 2023.

Automated sorting lines projects

LSJH

Country	Finland	
Techno	NIR + colour	
Supplier	NC	
Development stage	Project	
Project leader	LSJH (public waste management operator)	
Projected capacity	NC (planned for 2025)	
Other partners	Local authorities, research institute, universities, collection operators, recycling operators, etc.	

Telaketju is a network of stakeholders and projects which aims at developing a **textile recycling value chain in Finland** since 2017.

Within this context, **LSJH** works on used textile materials sorting and preparation. In 2019, LSJH carried out sorting trials with a spectrometer from Spectral Engines and built a garnetting plant at the end of 2021.

LSJH plans to build an industrial-scale material sorting and recycling factory in Turku in 2025 (announced investment of €20.5). The factory will aim at semi-automatically sorting textiles into different materials, a portion of which will be garnetted on site.

ReHubs

Country	Germany, Belgium, Spain, Finland, Italy.	
Techno	NC	
Supplier	NC	
Development stage	Project	
Projected capacity	50,000 t/year in 2024	
Project leader	Euratex (European Textile Confederation) Texaid (textile collection and sorting operator)	
Other partners	Multiple partners	

ReHubs is a Euratex initiative which objective is to create hubs for processing textile waste and becoming European coordination centres: in Germany, Belgium, Spain, Finland and Italy.

A first plant with a capacity of 50,000 tonnes has been announced for 2024. This project (Sorting 4.0 - « Transform Waste into Feedstock ») will be managed by TEXAID.

Synergies TLC

Country	France	
Techno	NIR	
Supplier	Pellenc ST	
Development stage	Project	
Project leader	Synergies TLC	
Projected capacity	3,000 t/year in 2023 25,000 t/year in 2025	
Other partners	Les Tissages de Charlieu	

Synergies TLC was created by 6 sorting and collection operators to work on material preparation for recycling.

For the past three years, Synergies TLC has worked on material sorting in different projects. The aim is to create **an automated material sorting and disassembly plant.**

The first pilot plant should be operational in 2023 and use Pellenc ST sorting machines. The construction of a **25,000 tonnes capacity plant** has been announced for 2025[3].

Other material recognition sorting projects

CISUTAC

Country	Europe
Techno	NC
Supplier	NC
Project leader	Centexbel
Other partners	Twenty or so partners including TEXAID.
Lien	https://www.cisutac.eu/

CISUTAC (Circular and Sustainable Textiles and Clothing) is a European Union financed project (New Horizons) that aims at creating a circular value chain.

The project includes the development of digital solutions to **improve textiles automated sorting**.

CRTX

Country	Germany
Techno	Raman
Supplier	-
Project leader	circular.fashion
Other partners	Berlin Technical University, Free University of Berlin
Lien	https://crtx.ai/

The **CRTX** project was initiated in 2020 by circular.fashion in collaboration with two Berlin universities which should finish in 2023.

This is a two-part project: one on the **development of Raman spectroscopy** for textiles and the other on image recognition (AI) for sorting for reuse.

Raman spectroscopy tests will evaluate whether or not this technology may be more accurate in recognising textiles than NIR and if it is possible to detect dyestuffs and chemicals commonly found in textiles.

MISTERY

Country	France
Techno	NIR/SWIR
Supplier	-
Project leader	CEA YSPOT
Other partners	Gebetex, Boer Group, Horiba Scientific and Aalto University

[3]Source: IFTH webinar "Instant Tech n°4" 24/01/23

The purpose of the **MISTERY** project (Multispectral OptIcal Sensors for TExtiles RecYcling), financed by Refashion under its 2021 Innovation Challenge, is to develop a new automated sorting solution.

The project uses different **hyperspectral sensors** (NIR, SWIR) to **characterise textiles** intended for recycling and intends to test its effectiveness under real sorting conditions.

SCIRT

Country	Belgium / France / Austria / Germany / Netherlands
Techno	NIR + colour
Supplier	Valvan
Project leader	VITO (research institute)
Other partners	18 partners including CETIA and Valvan
Lien	https://scirt.eu/

The **SCIRT** project (System Circularity & Innovative Recycling of Textiles) is a 3-year European project financed by the EU (Horizon 2020).

The main purpose is to demonstrate the possibility of implementing **a closed loop recycling system** for post-consumption **waste textiles.** Valvan works on the project's sorting aspects.

T-REX

Country	Germany, Austria, Finland, France, Netherlands, Switzerland
Techno	NC
Supplier	NC
Project leader	NC
Other partners	A dozen partners including Veolia, Aalto University and Fashion for Good.
Lien	https://trexproject.eu/

The **T-REX** project (Textile Recycling Excellence) aims at creating a streamlined European close loop sorting and recycling model for household textile waste (polyester; polyamide6 and cellulosic fibres). It is funded by the EU (New Horizon). Veolia will be responsible for sorting.

WhiteCycle

Country	Europe
Techno	NIR
Supplier	IRIS
Project leader	-
Other partners	19 partners including Synergies TLC, Carbios and Michelin
Lien	https://www.whitecycle-project.eu/

The **WhiteCycle** project, co-financed by the EU (New Horizon) aims at creating an industrial solution for recycling complex polyester waste (such as multilayered textiles).

The identification part is managed by a Spanish company, IRIS, specialised in photonic and AI solutions with the Visum HSI system.

Stakeholders and projects on RFID for textile sorting

4RFID

Country	France
Techno	RFID (Radio Frequency Identification)
Supplier	NC
Project leader	Decathlon

The **4RFID** project led by Decathlon and funded by Refashion, aimed at exploring the feasibility of using RFID tags for helping sorting for recycling.

This project's feedback has been positive. A learnings guide for the Textile sector has been published (available here).

circular.fashion

Country	Germany
Techno	RFID/NFC/QR codes
Supplier	-

circular.fashion is a start-up based in Berlin that offers its circularity.ID system to brands. This system is based on **an RFID chip, NFC or QR code incorporated into garments thereby allowing** access to information about them (material, colour, clothing category, etc.).

The identifier can then be read by consumers to access data about the product and/or by a sorting centre at the end of the product's end-of-service life. Circular.fashion works with several partner sorting centres that are testing its system to improve manual sorting (for reuse and for recycling).

Circular.fashion has published a standard on product information (available here).

Disassembly

State of the art of disassembly processes

Background

Disassembly (or trim removal) is a step for **preparing** *(preprocessing)* **textiles** for recycling which consists in **dismantling garments** to remove their **hard points (trims).**

Hard points or recycling disruptors

Hard points **disrupt** textile **recycling.**

These are any elements that are **not made of textile material** or that form a hard point:

- buttons,
- rivets,
- zips,
- etc.

Some can be made of **textile material** but their composition is different from the main fabric:

- label,
- patch,
- lining,
- pocketing fabric,
- etc.

A study by ENSAIT for Refashion (ex Eco TLC) compiled a complete list in 2014 (available here).

The classification of a disruptor depends on the recycling process targeted.

Necessity to develop disassembly

Applications for recycled textile materials require a **certain level of purity**. The level demanded may vary according to the type of recycling but it is generally high, whether this be for mechanical or chemical recycling processes.

Historically, **textiles containing the fewest hard points have been first recycled:**

- cutting wiping cloths from sheets or t-shirts,
- garneting/tearing of pullovers, etc.

To recycle as many non-reusable items as possible and develop new recycling value chains, it is therefore necessary **to increase textiles disassembly capacities**.

Manual disassembly

Manual disassembly consists in **cutting up a textile item** into **several pieces** so to obtain uniform pieces without any disruptors.

An established technique

Manual disassembly has been practised for a very long time, especially for the manufacture of **wiping cloths** from used textiles.

Different tools

Manual disassembly can be carried out using various **tools**:

- manual or electric scissors,
- circular saw,
- band saw,
- puncher/cutters,
- etc.

Quality disassembly ...

Manual cutting allows to achieve **very good disassembly results** by removing all hard points while maximising the remaining textile surface area. It can be adapted to each item (size, shape, location of hard points, etc.).

... but very expensive

The main obstacle to large-scale manual disassembly is that it is **labour-intensive**, very time-consuming hence **expensive**, particularly in Western Europe.

To illustrate this, the majority of used textiles cutting into **wiping cloths** is nowadays **delocalised** to countries where labour cost is less expensive.

The economic equilibrium of manual disassembly of textile items containing many hard points is thus difficult to achieve in France.

Hence the need for automation

To develop large-scale disassembly and develop recycling value chains in Europe, it is **necessary to automate and industrialise the disassembly/trim removal process.**

Examples of automated disassembly techniques are presented here.

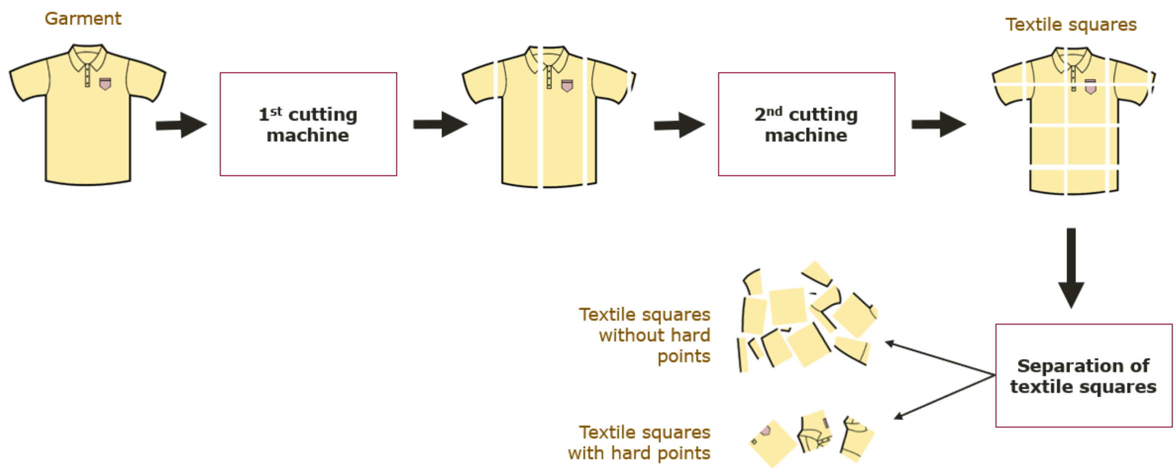
Trim removal on clippings

Several automated disassembly/trim removal techniques require the prior **cutting up of textiles into square pieces (clippings)**.

The principle

These techniques are based on two steps:

1. The **cutting up** of textile articles into clippings: square pieces of textiles with a maximum size defined by the recycler (e.g. 60x60 mm)
2. The **separation** of clippings in two streams:
   - clippings without any hard points: disassembled material,
   - clippings with hard points.



Cutting

Cutting textiles into clippings may be carried out by passing textile items through two **successive cutting machines** placed perpendicularly in order to form square pieces.

Equipment for this step is the same as that found at the beginning of a garnetting line (see below).

Separation

Several techniques may be used to separate the clippings into two streams:

- the **identification** of hard points **using cameras**,
- simple **mechanical separation**.

Visual identification of hard points

Through **cameras** and **image analysing** algorithms, computer vision allows to **detect textile clippings** with or without any hard points.

Once clippings are classified, information is sent to a stream separating device such as those existing in automated sorting machines (e.g. pneumatic ejection, see above).

This is the type of system that has been developed by Valvan (Trimclean).

Mechanical separation

It is also possible to use purely **physical separation** methods based on the **characteristics of hard points** (density, shape, material, etc.).

This is the case for **air separators** that consist in blowing clippings into an air stream.

Lighter pieces are carried along by the air stream whereas **heavier** ones (with hard points) fall. The air flow can travel in **zig zags** to accentuate separation.

In addition to **density**, other characteristics such as the **shape** and **surface** of textile clippings and hard points play a part too.

The air flow is adjusted to obtain a balance between the purity of the disassembled stream and the quantity of material lost.

This type of equipment is common in the recycling industry to separate different materials. This is the system developed by Recuprendra.

More advanced separation

In both cases, other equipment can be added to complete separation, such as **metal separators**:

- **magnets** for ferrous metals
- **Eddy current separators** for non-ferrous metals

Operational feedback

Given that these techniques are still under development or on the verge of being marketed, they are **still difficult to evaluate**.

It appears however that the size of **textile clippings** play an **important role.** Smaller clippings might bring better performance, i.e. less material loss, but would generate shorter fibre length, detrimental to some recycling routes.

Garnetting with hard points removal

In fact, automated hard points removal has existed for the several years **in garnetting/tearing lines.**

Garnetting/tearing

Garnetting/tearing is a **mechanical recycling process** that consists in transforming textiles back **into fibres**. These recycled fibres can then be used to produce nonwovens or make thread again.

The integration of hard points removal in garnetting operations

Garnetting does not necessarily require a hard points removal stage, especially if the processed textiles do not contain any (e.g.: production off-cuts).

However, some tearing lines are designed to treat more complex textile items and **include several mechanical separation stages** for hard points.

The different stages

Hard points removal equipment and techniques vary from one line to another.

However, we often find the following main stages:

1. The **cutting of textiles into clippings** with cutting machines.
2. The use of **pickers** to open and break up textile materials while tearing off hard points.
3. **Garnetting** itself, with the successive drawing of textiles in rotating cylinders equipped with needles or pins in order to refine the resulting fibres.

Mechanical separation systems such as those described above (air separator, density, magnets, etc.) may also be used in different stages of tearing/garnetting lines to separate hard points from textile materials.

Operational feedback

Even if this technique does not remove all types of disruptors (e.g. layers of different materials), it is currently the most **mature automated trim removal method.**

It is already **used on an industrial scale** by many garnetting operators.

The **level** of hard points **removal** for these types of lines seems to have well **progressed** over the last few years.

The garnetting output is in the form of fibres.

Depending on the end application, one could imagine using only a part of the tearing/garnetting line to obtain a coarser, "pre-garnetted" cleaned material.

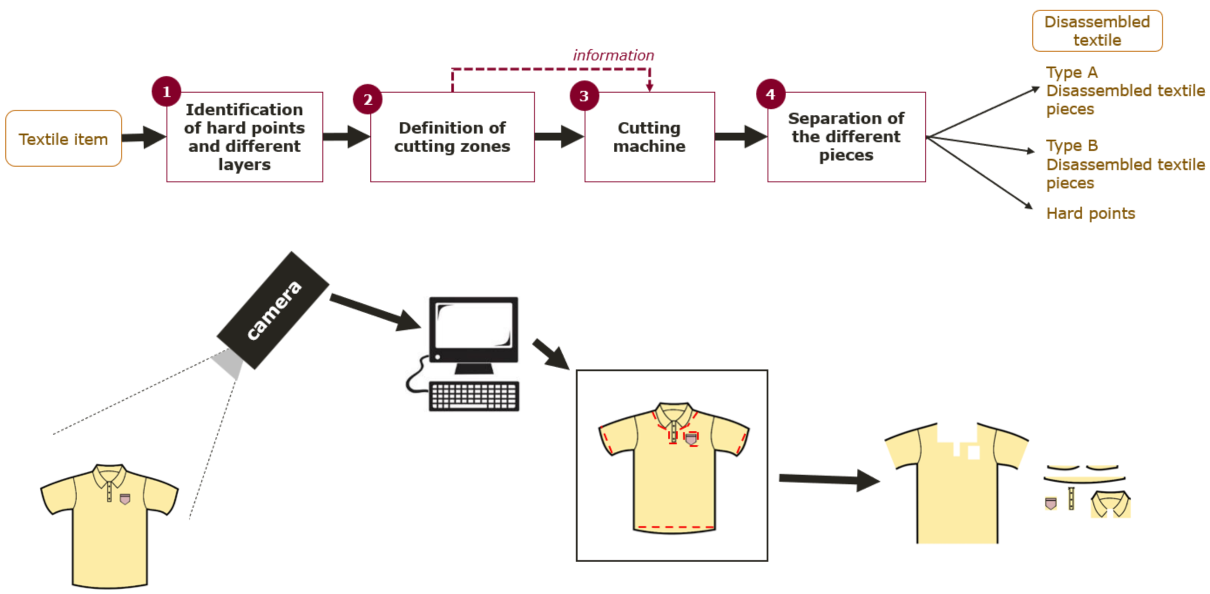
Automated customised cutting

Another automated disassembly concept consists in using innovative technologies (AI, robotic) to carry out customised **cutting of whole pieces** such as can be carried out during manual disassembly.

The principle

This concept is based on several steps that must automated:

- **identification** and localisation of hard points on a garment,
- the definition of **zones to be cut out** to remove them,
- the **cutting operation** itself,
- **separation** of materials once the item has been cut.



The definition of zones to be cut

Computer vision, using **cameras** and **algorithms**, can be used to recognise the type of item and identify the hard points on it.

An IT program then defines **how to cut out the item** to remove the hard points.

This step is very complex because defining the zones to be cut must be adjusted for each item. Properly laying out the item is also important here.

This is the type of research being headed by CETIA in its TRACE project.

Cutting

Following the computer-defined cutting zones, it is necessary to **physically cut the item.**

This could be carried out by a 2D automatic cutting machine or by a robot. A laser or a blade can be used for the cutting operation. It is crucial that the item is properly positioned.

CETIA is also working on this issue in the SCIRT project.

Separation

Once the item has been cut, it is necessary to **separate the pure textile clippings** from clippings containing hard points.

Automation of this step could be carried out with a **robot** or a **mechanical separation** system such as those previously described.

Operational feedback

This type of automated disassembly is **still in the R&D or proof of concept phase.** Feedback is therefore limited.

Such a disassembly technique would however have the advantage of **maximising the surface area** of disassembled textile clippings thus retaining a maximum of material and **fibre length.**

However, even if it is automated, this type of disassembly process is likely to be **more costly** than techniques with garnetting or clippings. It is thereby likely to be kept for **high added value** applications.

Manufacturing with special threads

The last disassembly technique identified is based on a different principle because it requires **working** on a garment's **eco-design.**

It is about **using special threads** that will ease garment **disassembly** at the end of its service life.

The principle

These methods are based on **stitching threads** that have specific physical properties allowing them to be **broken down** at the end of their service life without damaging the rest of the garment.

1. During **manufacturing**, a **special stitching thread** is used.
2. At the **end** of its **service life**:
   - the garment passes into a machine that will **only break down the stitching thread**,
   - the different parts of the disassembled garment can be separated.

Today two types of threads have been developed.

Thermal disassembly

A first technique is based on **thread** made from a **polymer** which **melting point** is **lower** than that of other fibres present in clothing.

Passing the textile item through an oven at a temperature just above that of the melting point will melt the thread without melting the remaining textile.

This is the technology developed by Resortecs.

Disassembly using microwaves

Another technique uses the principle of **microwaves**.

The thread is made from a **polymer** incorporating metallic **particles.**

When a garment made with this thread is put into a **microwave oven**, the particles will react with the microwaves, resulting in the breakdown of the sewing thread without damaging the rest of the textile.

This is the Wear2 technology.

Operational feedback

While the development of this type of threads seems to be **advanced** and the associated disassembly technique to be **working**, the entire disassembly process at products' end-of-service life does not yet seem to be entirely automated.

Indeed, it is also necessary to feed the machine ("oven") with textile items then separate the materials from the disassembled items.

The advantage of this technique is that it can **maximise the size of textile pieces** recovered because no cutting takes place. Separation is performed at the stitch level.

However, this disassembly system remains limited to stitches.

The main limitation resides in the fact that disassembly is **only possible for garments that are already conceived** with such thread. Limitations are therefore similar to those of RFID for material sorting.

It is also necessary to be able to identify at the **end-of-service life which type of sewing thread** has been used in order to apply the correct disassembly technique.

Target applications concern in the first instance textiles that remain in short loops: customer returns, unsold items, items with defects, professional clothing, etc.

Lastly, the potential recycling disrupting nature of this type of thread will need to be checked in case it has not been removed.

Conclusions about disassembly

Disassembly is a more confidential subject than material sorting, but just as **crucial in the recycling value chain.**

It is also a **more technical** and intrinsically **linked to recycling processes** that it feeds downstream. To date, little information is publicly available and the number of stakeholders is smaller.

There is **less feedback** on automated disassembly from **other sectors**, such as optical sorting used in packaging for example.

However, there are some interesting developments to be noted. **Garnetting/tearing lines** have seen their **performance** in hard point **removal rates** improve. Even if these do not claim meeting the needs of all recycling routes, this is the **most mature** and the mostly used automated disassembly method.

Purpose-designed automated textiles disassembly equipment is starting to appear using the **clippings separation** principle. This resembles the beginning of a garnetting process. The **detection** of trims by **cameras** seems a **promising breakthrough.**

In order to achieve more accurate disassembly and maximise fibre length, some **alternatives** are being studied. Image recognition and robotics for **customised disassembly** is an interesting concept but still in **R&D stage**.

The use of **special sewing threads** to ease disassembly is more advanced but requires to review textiles' design. This technique is therefore **not suited** for the majority of the textile feedstock to recycle **in the short to medium term.**

Disassembly / trim removal technology suppliers

ANDRITZ Laroche

Country	France
Type of disassembly	Garnetting with integrated and automated trim removal
Equipment type	Complete tearing lines integrating several hard points and textile fibres separation modules
Link with textiles	Machines are already used by several garnetting operators such as Renaissance Textile.
Contact	Site: https://www.andritz.com/products-en/nonwoven-textile/recycling/textile-recycling Contact: laroche@andritz.com
Illustration	 *Double cutting machine STARCUT*  *Picker/opener*

ANDRITZ Laroche, a French machinery designer and manufacturer for over 100 years, offers industrial equipment for textile recycling, the nonwoven industry and for the bast fibres industry.

In 2021, the company joined the nonwoven division of **ANDRITZ**, an Austrian industrial solutions group.

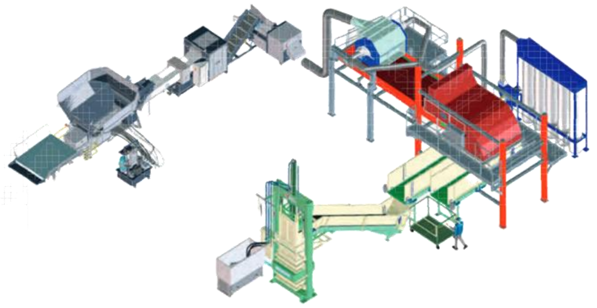
ANDRITZ Laroche's tearing lines can integrate different separation methods during the garnetting process to separate hard points from textile fibres.

Dell'Orco & Villani

Country	Italy
Technology	Garnetting with integrated and automated trim removal
Equipment type	Complete tearing lines integrating several hard points and textile fibres separation modules
Link with textiles	Machines installed in France at CETIA or Ouatéco (garnetting operator) for example.
Contact	Site: https://www.dellorco-villani.it/en/ Contact: info@dellorco-villani.it
Illustration	 *Cutting machine, picker-opener and garnetting module*

Dell'Orco & Villani (D&V) is an Italian company specialised in textile recycling lines (garnetting). The type of equipment and trim removal operations are similar to that offered by ANDRITZ Laroche.

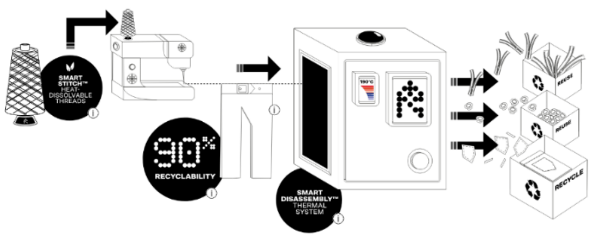
Valvan (TRIMCLEAN)

Country	Belgium
Technology	Separation of textile clippings with and without trims
Equipment type	Line carrying out cutting operations, trims detection and separation of textile clippings in two streams
Link with textiles	Winning project of the 2019 Refashion Innovation Challenge (description, result)
Contact	Site: https://www.valvan.com/ Contact: Jean-François Gryspeert jfg@valvan.com
Illustration	 *3D drawing of the TRIMCLEAN facility*

In the TRIMCLEAN project (financed by Refashion), Valvan has designed a textile clippings trim removal machine that will soon be marketed.

It is based on a textile clipping (with or without any trims) identification system using cameras and an image recognition IT programme. A metal detector completes the line.

Resortecs

Country	Belgium
Technology	Degradable sewing threads
Equipment type	**Smart Stitch**™: Thermally degradable sewing thread for textile products eco-designed for recycling **Smart Disassembly**™: Oven enabling the threads degradation and fabric pieces to be sorted before recycling
Link with textiles	Involved in several European projects and collaboration with several brands.
Contact	Site: https://resortecs.com/ Contact: annamc@resortecs.com
Illustration	 *Schematic diagram of disassembly through Resortecs sewing thread*

Resortecs (REcycling, SORting, TEChnologieS) is a Belgian company that has been developing since 2017 a range of **sewing threads** that can be **thermally broken down,** plus the associated oven.

Wear2Go

Country	The Netherlands
Technology	Degradable sewing threads
Equipment type	**Wear2 ® thread**: sewing thread that can be broken down by microwaves. The microwave oven that breaks down the threads is under development.
Link with textiles	CircTex project (Interreg NWE) on the recycling of professional PET clothing
Contact	Site: https://wear2.com/en/ Contact: info@wear2.com
Illustration	 *Microwave tunnel project*

WEAR2GO is a Dutch company created in 2018 which recovered the Wear2® technology that had been developed in the United Kingdom. WEAR2GO offers **threads** and **microwave** equipment for **disassembling items** made from these threads.

Automated disassembly / trim removal projects

Revive/Recycle (Recuprendra)

Country	France/Spain
Techno	Separation of textile clippings with and without any hard points
Supplier	In-house development
Project leader	AIR coop
Other partners	Recuprenda (Spanish sorting centre) In-Cycle (British technical consulting firm)

The **Revive/Recycle** project ended in May 2022 and had two parts: one on clothing repair and the other on disassembly for recycling. The second part was financed by Refashion as part of its 2019 Innovation Challenge (description, result).

This project's concept is separation based on **textile clippings** with **mechanical separation** systems (air separation).

CETIA

Country	France
Techno	Garnetting with integrated + automated disassembly Automated cutting.
Supplier	Dell'Orco & Villani
Project leader	CETIA
Lien	https://cetia.tech/home-en/

CETIA is working in several areas for textile disassembly:

- **disassembly** with equipment used in **garnetting lines** (the CETIA has Dell'Orco & Villani machines),
- **disassembly** by **cutting** with the definition of a cutting trajectory with AI (private TRACE project) and the automation of the cutting operation within the European SCIRT project.

SCIRT

Country	Belgium / France / Austria / Germany / Netherlands	SCIRT.
Techno	Smart cutting	
Supplier	-	
Project leader	VITO	
Other partners	18 partners including CETIA and Valvan	
Lien	https://scirt.eu/	

The SCIRT project (System Circularity & Innovative Recycling of Textiles) is a 3-year European project financed by the EU (Horizon 2020).

The project includes a sorting part described above but also a disassembly part via an **automated laser cutting** system.

Synergies TLC

Country	France	SYNERGIESTLC
Techno	Clippings / garnetting	
Supplier	Andritz Laroche	
Project leader	Synergies TLC	
Other partners	Les Tissages de Charlieu	
Lien	https://synergies-tlc.com/	

In addition to material sorting, **Synergies TLC** is integrating disassembly/trim removal stages in its material preparation factory project.

Synergies TLC is working with Andritz Laroche on the disassembly part of this project.

Conclusion

Material sorting

Textile material sorting for recycling implies having technologies able to recognise these materials.

Near-infrared spectroscopy is currently the **most mature technology in this area.** Several automated sorting lines using this recognition technology have been identified in Europe and other large-scale capacity projects have been announced.

The number of suppliers offering sorting equipment or spectrometers suitable for textile materials has significantly grown over the past three years.

The detection of textile materials using near-infrared however presents **some limitations**:

- surface analysis of material (problems with multi-layers, coatings, non-uniform structures, etc.),
- detection is more difficult when materials are in very small proportions (e.g. elastane) or in blends with more than two materials,
- some pigments or primers may disrupt the correct detection of materials.

R&D is continuing, and equipment is gradually improving with joint work amongst manufacturers, sorting operators and recyclers.
The level of performance achieved could however already meet the needs of some recyclers.

In the longer term, methods based on **digital product passports** such as **RFID**, could facilitate sorting of post-consumer textiles. This would however demand a certain level of standardisation and a generalised use by marketers.

Disassembly

Textiles **disassembly** is the **key stage in preparing materials** for recycling.

This stage consists in **removing all hard points** or any elements that could disrupt recycling processes. Even if manual disassembly has been practised for a long time, its automation is essential to reduce costs and develop textile recycling in Europe.

The type and level of disassembly greatly **depends** on the **targeted recycling process**. This is an issue **specific to textiles**, that is technical and therefore more confidential than material sorting. This is reflected by less information publicly available and a smaller number of stakeholders.

Certain forms of disassembly/trim removal are **already mature and industrialised**. Today garnetting operators use **tearing lines** that include hard points separation and removal systems. Performance of these lines in trim removal has improved over the last few years.

Purpose-built equipment is also starting to be developed based on the principle of **cutting textiles into clippings**, followed by their separation according to whether or not they contain any hard points. Separation can be mechanical or via image recognition.

More innovative concepts, still in R&D, aim at reproducing **customised cutting on full garments**, similarly to manual operations, but based on robotics and artificial intelligence.

Lastly, there are disassembly techniques based on the use of **special sewing threads** during textile products manufacturing. These threads allow for an easy disassembly at the end of a product's service life, being degraded by specialised equipment (e.g.: ovens). It will not be possible to use this technique on textiles made with standard threads.