INTERREG

RETEX

Results

Redaction: EuraMaterials / Fedustria / Centexbel / cd2e
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Circular economy and textile recycling

The **circular economy** aims to change the paradigm of the "linear" economy by limiting the waste of resources and the environmental impact.
With regard to the **3 areas of action of the circular economy** (ADEME definition, SUPPLY of economic stakeholders = production, DEMAND AND BEHAVIOUR of consumers = use, WASTE MANAGEMENT = end-of-life management), RETEX brings dynamism to the textile sector through the effective implementation of eco-design of products and through the sourcing of used textiles.

Challenges

RETEX is an ambitious textile circular economy partnership in the Euroregion.
It is financed in the framework of Interreg France-Wallonie-Vlaanderen
Its aim is simple: **Rethink, Reinvent, Reuse**, by reducing textile waste and stimulating innovation.

In the Euroregion, the **textile sector** represents more than 1,100 companies for 33,000 jobs; the **collection and sorting sector**, 75 companies for 1,800 jobs (2014 figures / beginning of the project); the collection capacity is 150,000 tons for consumer textiles alone.
While some of this is reintroduced into the second-hand market, **the volume to be recycled is constantly increasing**, potentially **reaching 75,000 tons, half of which is made up of cotton, polyester,** or a mixture of these two materials.
Despite this significant deposit, the textile sector is facing difficulties in developing eco-design using fibres from textile waste: **problem of regular access to deposits sorted by material and prepared for the recycling process, technological and economic locks, isolated and hardly profitable approaches, new markets to be identified, regulations.**
The structuring of a textile circular economy sector is becoming imperative, bringing new and non-displaceable activities, and generating jobs.
RETEX prioritizes the recovery of **end-of-life textiles or production waste in cotton/polyester, in 100% or in a mixture.**

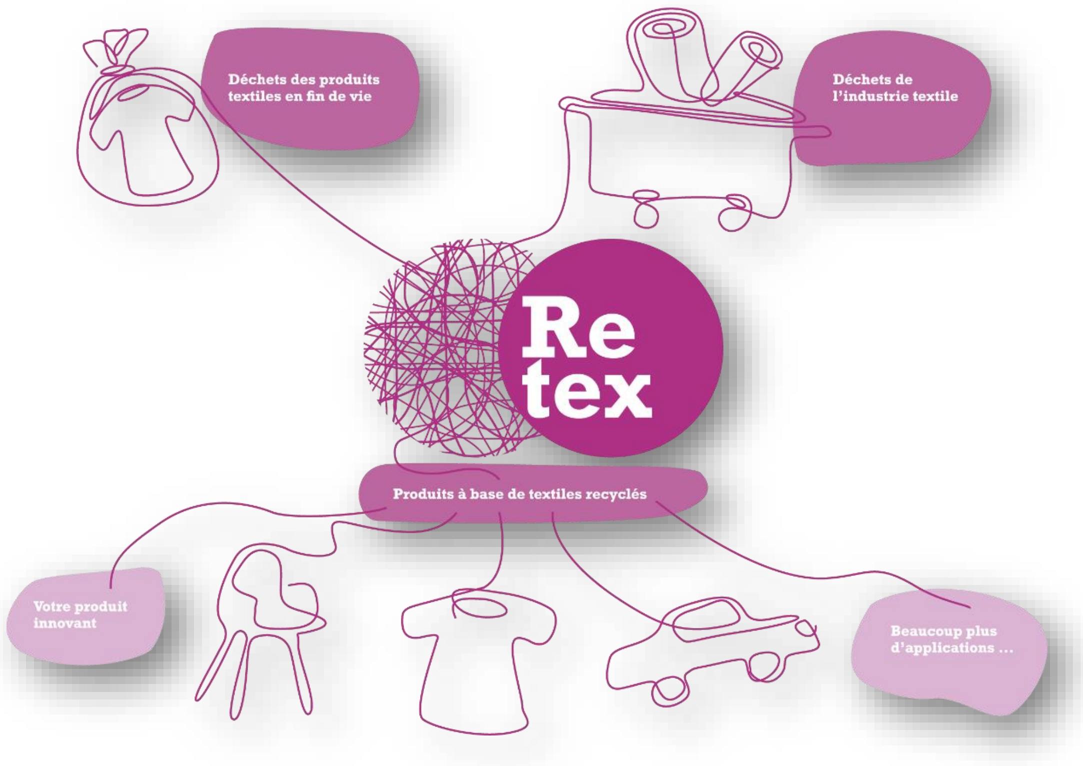
Project duration 54 months / OCT 2016 – MAR 2021
Budget: 1 610 780 € - FEDER : 885 929 €

Interreg France-Wallonie-Vlaanderen
UNION EUROPÉENNE EUROPESE UNIE
GoToS3
RETEX

Avec le soutien du Fonds Européen pour le Développement Régional

Mission

RETEX supports the development of **new raw "secondary" materials** from end-of-life textiles or production waste, for an innovative supply of eco designed products.
Indeed, since the start of the project, the partnership has set up a segmentation that considers the entire value chain.



The results of these studies and the presentations from the workshops are fed into the **DOTHERETEX website** (https://www.dotheretex.eu), a place for exchanges between players looking for resources and partnerships in the field of eco-design and recycling.

RETEX raises the awareness of the stakeholders of the textile sector to the benefits of the circular economy and proposes **several collective cross-border animation sessions for companies and laboratories** to develop the ecodesign and recycling topics. These workshops enable **working groups** to be set up to develop products resulting from **open or closed loop recycling.**

New value chains are set up throughout the product life cycle.

The project started on 1 October 2016 and ends on 31 March 2021.

Partnership

The project has a complementary operational partnership that allows for a very broad reach across the program area.

The consortium has associated partners to reach a maximum number of targets in all the value chains of the textile circular economy.

In Hauts de France

- **EuraMaterials,** the project coordinator, is the North European reference cluster for the textile, plastics, paper/cardboard, glass, ceramic and wood processing industries.
- **Cd2e** aims to facilitate the energy and ecological transitions of the regional economy.

Associated partners:

- **UITH,** textile and clothing trade union.
- **TEAM2,** collaborative innovation platform for the circular economy.
- **REFASHION,** the eco-organization that collects the contribution of textile, household linen, shoes distributors.

In Belgium

- **CENTEXBEL-VKC** is the reference technology centre for the textile and plastics industries, with an integrated offer of materials characterization, R&D and identification of new applications; it has textile and plastics research facilities.
- **FEDUSTRIA** is the professional organization that supports the textile, furniture, and wood industries in their economic, social and environmental development.

Associated partners:

- **RES-SOURCES**, a federation of social economy companies.
- **NEXT**, the BE.FIN program for the development of new activities in Wallonia

RETEX, a GoToS3 portfolio project

RETEX a GoToS3 portfolio project

The GoToS3 portfolio brings together 17 research, technology transfer and support projects for the development of innovation and the competitiveness of companies in the cross-border territory.

A hundred or so Flemish, French and Walloon actors combine their complementary skills within a very large network: competitiveness clusters, research actors, development agencies, companies and professional federations, cultural operators, etc.

These 17 projects are based on 6 key sectors of activity for the 3 regions, common to their "S3" strategies ("smart specialization strategy" - now you understand the name of the project! Go to S3... forward to smart specializations!).

- These 6 sectors are: Health and care; New materials and chemistry; Textiles; Agriculture and food; Cultural and creative industries; Mechatronics and mechanical engineering

The portfolio is coordinated by HDFID, POM West-Vlaanderen and Sowalfin.

The experience of the portfolio is very enriching - in addition to the support, tools and visibility that it has given us, as well as the regular exchanges with the other projects, which have enriched the network, opened up opportunities for cross-border cooperation and helped with project management, RETEX has participated in

- The experimentation of the Pitch - my project in 180 seconds, the video of which is available on the INTERREG program channel,
- Workshops for students to develop projects at the PROTOPITCH boostcamp, another project in the portfolio
- At the CROSS-INNOVATION event where we worked in groups of several portfolio projects to create design fiction projects

You can find all this information on the GOTOS3 website www.gotos3.eu.

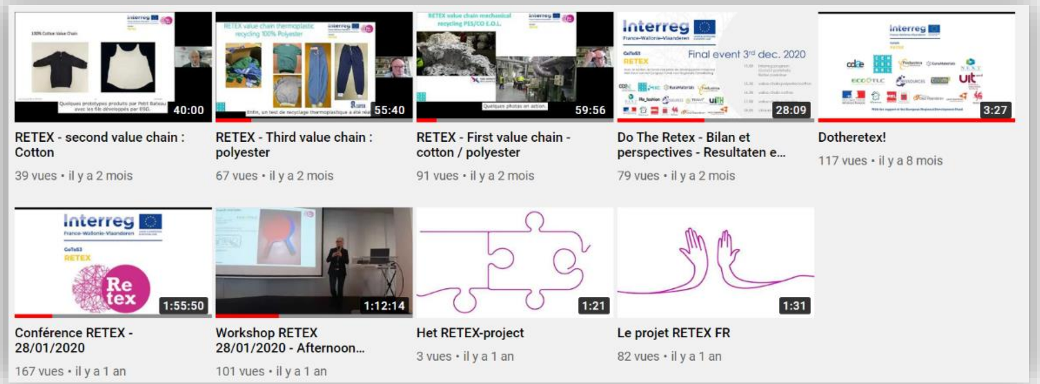
INTERREG RETEX Communication

Within the framework of the RETEX project, information and communication have also been the particular focus of all the partners

Tools:

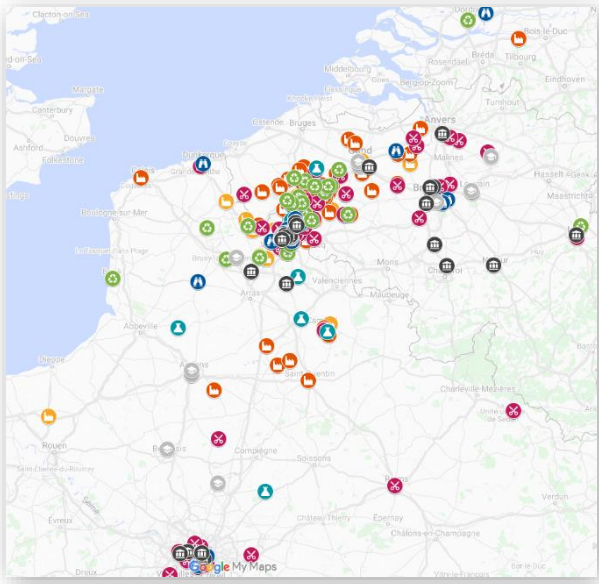
A website, Twitter and LinkedIn accounts, a YouTube channel

News briefs and articles and the sending of 8 newsletters throughout the project



Extranet:

RETEX aims to disseminate specialized information on the results through a knowledge base (workshop presentations, brochures, articles, etc.), a material library containing technical and environmental characteristics, such as life cycle inventories of the materials studied, and details of the companies involved in the project.



Working groups

As far as the working groups are concerned, the principle is that the companies active in the project offer human or machine time and material deposits to be processed along the chain. In exchange, they benefit from networking, the support of the RETEX project and the characterization of the tests at each stage.

Realizations

Awareness raising – workshops, visits, fairs

In a project of this magnitude, which is also long-term, communication is a key element. This is demonstrated by the numerous initiatives aimed at information on the one hand, and exchanges between companies, laboratories, universities, etc. on the other.

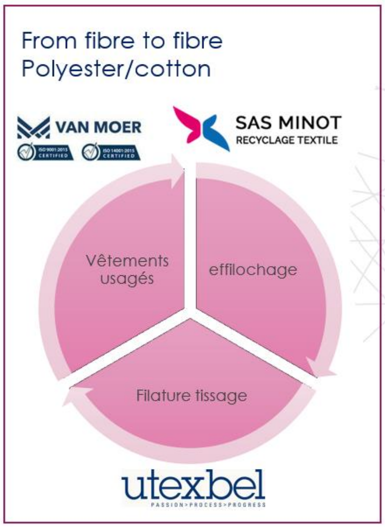
During the period, the consortium carried out

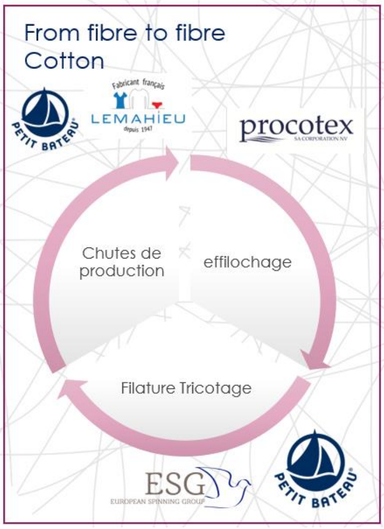
- **12 workshops/awareness-raising sessions** on the three sides of the territory with the participation of **more than 300 different entities**.
- no less than **150 interviews and individual meetings** were organized by the partners.
- Launch of a questionnaire to find out about the **flow of textile materials** in the RETEX territory; based on **40 replies, 60,000 tons of incoming flows and 6,700 tons of production waste were identified**
- Communication at trade fairs such as TECHTEXTIL and PREMIERE VISION, at AVNIR conferences, etc.
- Workshops :

- Presentation of the **state-of-the-art in textile recycling** with the testimony of TEXPERIUM, the Open Innovation Centre for textile recycling in the Netherlands
- **Visit of CETI and IFTH**, two technological platforms for the development of nonwovens, fibres and spinning
- Presentation of the **project's progress and the testimony of CODEM**, a technology transfer centre specializing in eco-materials
- **"Plastics processing" theme with a visit to the CENTEXBEL / VKC platform**. This platform is a centre of expertise dedicated to the plastics industry and has numerous tools and characterization equipment's for the production and recycling of synthetic materials.
- **"Ecodesign" theme at ENSAIT with the AVNIR platform** of the CD2E which offers, with the dedicated department of ENSAIT, a very advanced expertise on environmental analysis in the textile field.
- 3 workshops: **Preparation for the working groups on the different value chains**: cotton, polyester/cotton in a closed loop to make yarn and polyester in an open loop towards the plastics industry
- Market Place with the **results of the 100% polyester value chain** by thermo-mechanical recycling.
- Restitution of all the value chains and research into **alternative recycling solutions by compression for mixed deposits**
- Presentation of LACAMBRE's results in **3D printing** with recycled PET
- **Closing event** with the restitution of all the RETEX actions

Creation of value chains

The first objective of RETEX was the creation of value chains for industrial partners.
To achieve this, preliminary analyses to determine potential value chains and laboratory tests were required.





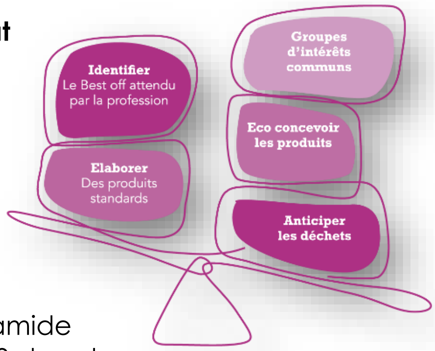
Data collection and analysis - questionnaire to businesses

To help build the recycling sector's offer, the consortium worked with the textile sector to identify the "best of" raw materials expected by the profession. This work has led to research and development of recycled products that meets the demand.

RETEX has organized the collection and analysis of numerous data to establish a list of opportunities.

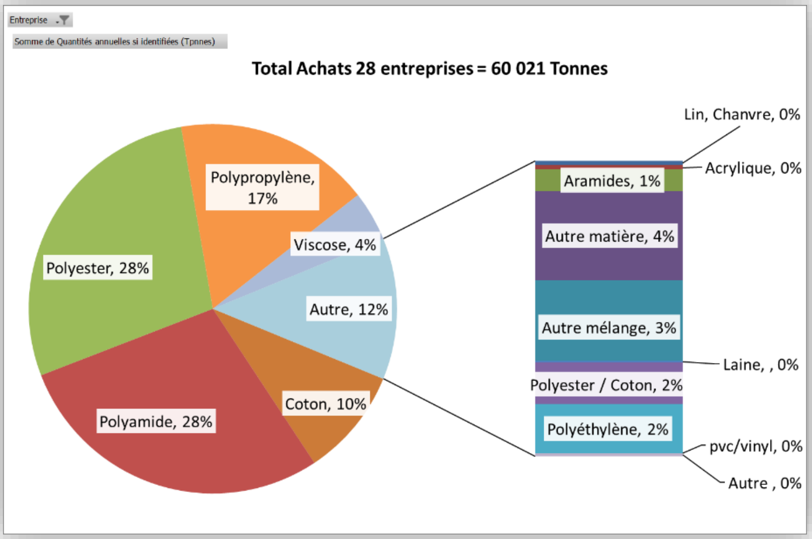
CD2E
ACCÉLÉRATEUR DE L'ÉCO-TRANSITION

The initial data collection was possible thanks to **28 companies that responded to a detailed confidential questionnaire**.
The analyses then allowed the precise quantification of relevant indicators such as the quantities of material purchased by companies in a sector, or the waste generated by these companies. And thus, to determine priorities.

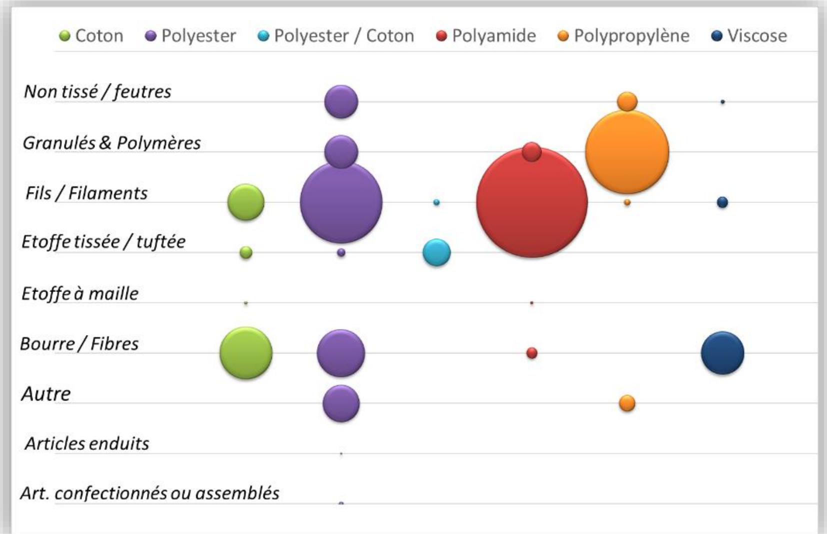


Purchases

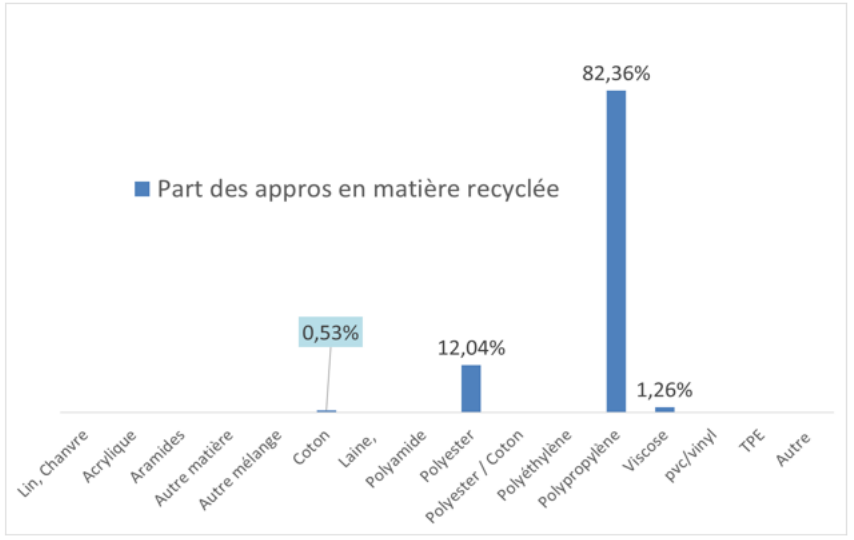
The top 3 places are occupied by polymers (73% of the total): polyamide and polyester are in the first rank, followed by polypropylene in 3rd rank. Cotton, with 10% of the total is in 4th place. Viscose, with 4%, is in 5th place. At this stage, there are very few purchases of blended raw materials (<5%)



Typologie des achats :

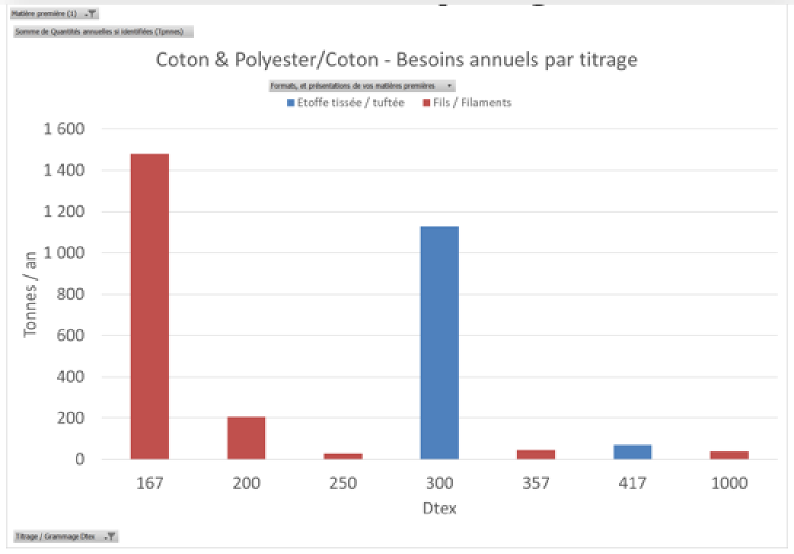


To go further in the analysis, another point of view on the composition of this purchases panel. In this graph, the 5 main components are displayed vertically, and the presentation formats of these purchases are grouped horizontally. When reading vertically, it is immediately apparent that polyamide is mainly purchased in the form of yarn or filaments, while propylene - on the right - is mainly purchased in granules.
On the contrary, polyester is purchased in 5 different forms: nonwovens, granules, yarns, fabrics, and flock.
Finally, a horizontal reading underlines a characteristic of our panel of companies that makes more than 50% of its purchases in the form of yarn or filament.

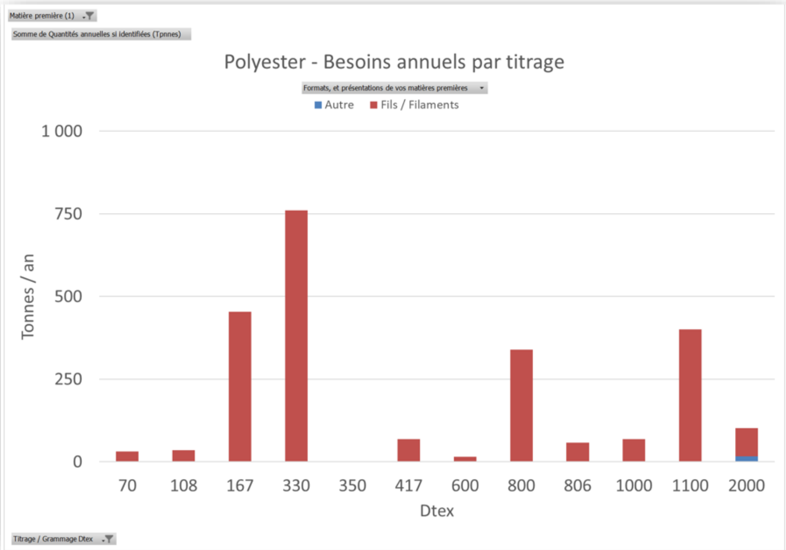


Does the textile sector buy materials from recycling?
The answer is certainly yes for polypropylene, with 82% of purchases coming from recycling... in the form of granules, we are in the field of plastics processing.
But also, partly for polyester with 12% of raw materials from recycling.
Beyond these two results, the areas of progress for the purchase of materials from recycling are real

The research areas
We looked to identify, by large masses, the future products resulting from recycling, which could find their markets among the needs listed.
We have thus crossed 2 dimensions
The first key is the materials, particularly those targeted by the RETEX project, in this case cotton and polyester. The second is the most popular presentation forms, with more than 50% of the panel being yarns and filaments.
The first analysis involves cotton yarns and filaments and highlights an annual demand of 1,500 tons in 167 Dtex and 200 tons in 200 Dtex.

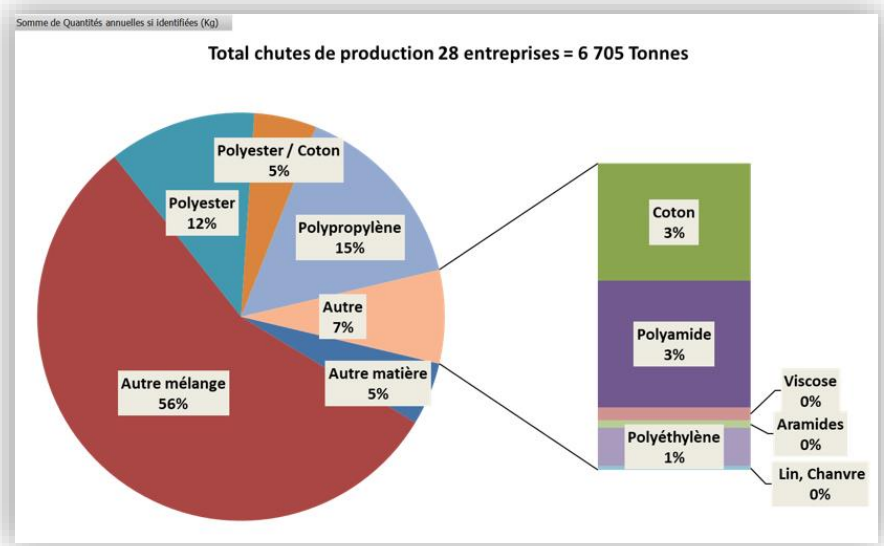


For polyester/cotton for fabrics, the expectations are 1,100 tons/year with 300 Dtex yarns.



We are now interested in polyester yarns, for which the annual demand is 450 tons in 167 Dtex and 750 tons in 330 Dtex for the finest grades.
But there is also an expectation for higher counts such as 800 and 1,100 Dtex, each at 400 tons/year.
The expression of these various needs - those of about thirty companies - underlines the interest of these areas of potential research
These research areas, together with a tangible "market" vision, will usefully feed into future calls for projects. And they confirm the relevance of current research programs.

Industrial offcuts



In this analysis by material, two things are immediately apparent: **the volume of these offcuts (6,700 t) and the preponderance of blends (56%).**
However, there is a deposit of unmixed materials with polypropylene (15%), polyester (12%) and polyester/cotton (5%)
Polyamide (3%) and cotton (3%) are found to a lesser extent.
The disparity of the trades, volumes worked, but also specificities of the products, does not allow to establish a realistic ratio between purchased quantities and volume of production waste, as this result would be enormous (>11%) and not representative. We have recalculated with a more representative panel of 25, which gives us a **waste rate of 7.4%.**
Considering the number of stages necessary to obtain a product, and the addition of unitary waste, this rate underlines the importance for companies to implement eco-design and thus be able to combat this major environmental impact

Within the framework of the project, 3 value chains were identified as the first to be developed:

- Cotton/polyester blends
- 100% cotton
- 100% polyester

This enabled recycling tests to be developed in these 3 chains, taking into account both end-of-life textiles and production off-cuts.

Companies have volunteered in the three fields envisaged, enabling three working groups to go into the heart of the matter and carry out a series of studies and tests.

Initial research

Textile waste streams in brief

Regarding textile waste streams, two main sources can be noted: end-of-life textile waste streams (consisting mainly, but not exclusively, of used and out-of-use clothing) and industrial textile waste streams

- At the end of life, a **significant proportion is made up of clothing collected** via voluntary drop-off points (consumer clothing); in **Belgium + Hauts de France, almost 130,000 tons** of clothing are collected in this way each year, 50% of which is sorted for reuse, but this means that around **65,000 tons per year are available for recycling**.
- Other textile waste streams of increasing volume are the industrial textile waste streams, consisting of **used professional and hospital clothing (from linen hire companies**).
- **Industrial textile waste streams** consist of production off-cuts from textile processing and manufacturing companies. These offcuts are **various material compositions and structures** (fibres, yarns, fabrics, knitted fabrics, cut selvedges, etc.)

The recycling routes in brief

Three textile recycling processes or technologies are available: chemical, thermoplastic and mechanical

- Chemical recycling of textiles is the **process of chemically breaking down** the material and reconstituting it into an identical (polyester) or different (cotton to viscose) raw material. This method is not included in the project, as it is **unavailable on an industrial scale in the region.**

- The recycling of thermoplastic textiles consists of the **transformation of textile waste flows by melting**. The resulting raw material is in the form of granules or pellets, destined for extrusion or injection. This route is chosen for the recycling of polyester production offcuts in the **VKC CENTEXBEL laboratory**

- Mechanical recycling consists of **transforming materials from textile waste into fibres by mechanical processes** (cutting, shredding, fraying): this is the route chosen for the polyester/cotton and cotton value chains.

First tests

Summary -----------

In 2018, laboratory-scale tests were carried out using garments of different materials from 5 collectors of used textiles or end-of-life hospital garments: RECUTEX, EUROFRIP, TERRE, EVADAM and TACOTEX.
These tests mainly involved LAROCHE (manufacturer of machines for fraying fabrics), UTEXBEL (spinning) and CENTEXBEL (analysis, tests) and led to the following conclusions:

- A mixture of heterogeneous garments generates, after fraying, very short fibres which will have to be mixed with virgin fibres, both in polyester/cotton and in cotton
- The deposit of hospital garments provided short fibres suitable for Open End spinning

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In 2018, laboratory scale tests were carried out by CENTEXBEL, LAROCHE and UTEXBEL.

The deposit:

CENTEXBEL asked 5 sorting collectors to take from their deposits clothes made of cotton, polyester or polyester/white cotton blends - these are materials that are usually destined for the industrial rag market.
CENTEXBEL also received end-of-life hospital garments from VAN MOER - a customer of the weaver-spinner UTEXBEL.

Preparation of the fibres:

The preparation of the fibres was carried out at LAROCHE, the machine manufacturer which has a test platform in Cours-La-Ville (France 69).
2 different machines were used to carry out the following steps:

- EXEL: a machine for removing hard points from garments ("dismantling"), eventually upstream of the fraying machine.
- CADETTE: a fraying machine consisting of several drums fitted with spikes to defibrate the textile materials

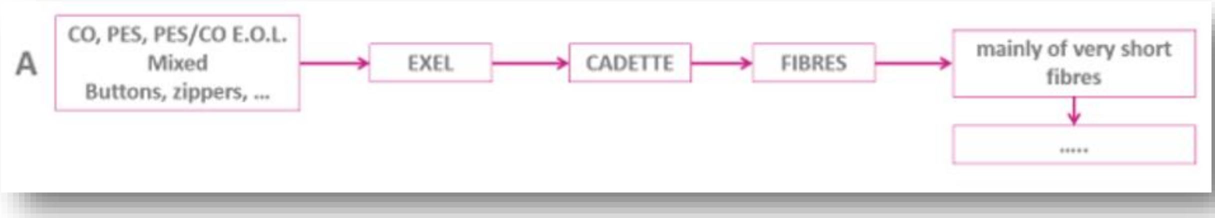
Tests

3 trials were carried out to test different possible routes, changing the origin of the clothes used and the process.
For each trial, the materials are shredded upstream, i.e. cut in both directions, both to ensure that hard points, if any, are easily removed, and also to ensure that the materials don't get blocked in the fraying drums.

CENTEXBEL analyzed the fibre length and composition at different stages of the process.

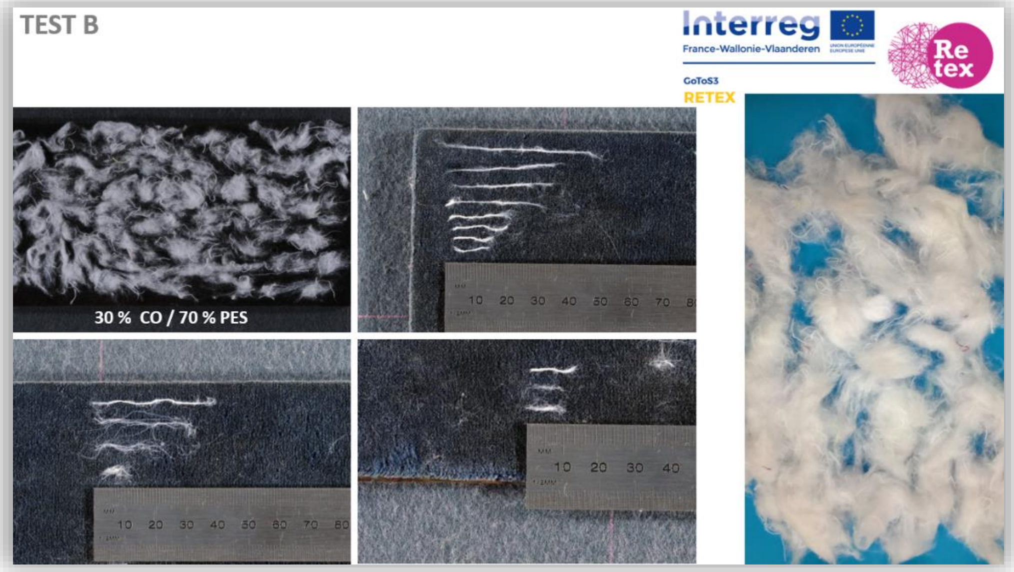
The results are as follows:

Test A
Various end-of-life cotton/polyester clothing, not unraveled, from the 5 collectors + EXEL process + CADETTE process
The diffuse deposit of the sorting collectors provides very short fibres at the output, which makes spinning tests problematic or even impossible.



Test B
Unraveled hospital garments supplied by VAN MOER + EXEL process + CADETTE
The deposit of hospital garments gives short fibres suitable for open-end spinning.
Successive washings of these garments during their use and defibration have reduced the proportion of cotton in the final composition.
The new article is composed of 35% cotton and 65% polyester. The composition of the article at the shredding stage is 31% cotton and 69% polyester

At the end of the process, there is 30% cotton and 70% polyester. The UTEXBEL spinner produced a fully industrially viable yarn (i.e., of sufficient quality); it was composed of 40% recycled fibres (half from end-of-life garments, the other half being production off-cuts from the spinning mill itself); in the yarn, almost all the cotton contained is from added virgin fibres. The yarn, 17 Nm (65% cotton and 35% polyester) was woven into a 300g/m2 gabardine and workwear, which finally contained 16% recycled fibres.



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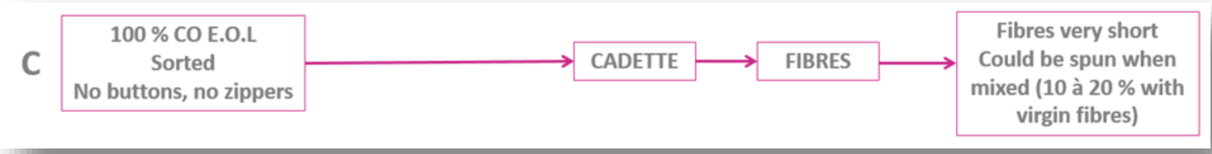


100% cotton garments manually unravelled upstream + CADETTE
Garments from diffuse deposits, previously unravelled by hand, give very short fibres, good enough for spinning, but imperatively needing to be mixed with virgin fibres.

Technical value chain

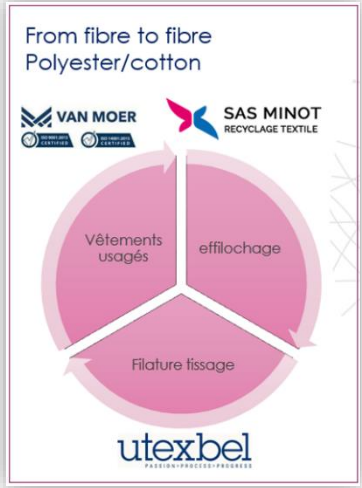
Summary -----------

Preliminary studies and trials have shown the potential to develop 3 value chains in polyester/cotton, 100% cotton and 100% polyester.
Industrial partners decided to join their experience and expertise to develop the polyester/cotton and 100% cotton value chains. Extensive testing was carried out in the 100% polyester value chain.
The transition from laboratory tests to large-scale industrial trials highlighted the difficulties inherent in each stage of the process, and thus also allowed solutions or alternatives to be developed

Discover these value chains in detail

- Polyester/cotton value chain - VAN MOER, MINOT, UTEXBEL
- 100% cotton value chain - LEMAHIEU, PROCOTEX, PETIT BATEAU
- 100% polyester value chain - CENTEXBEL,

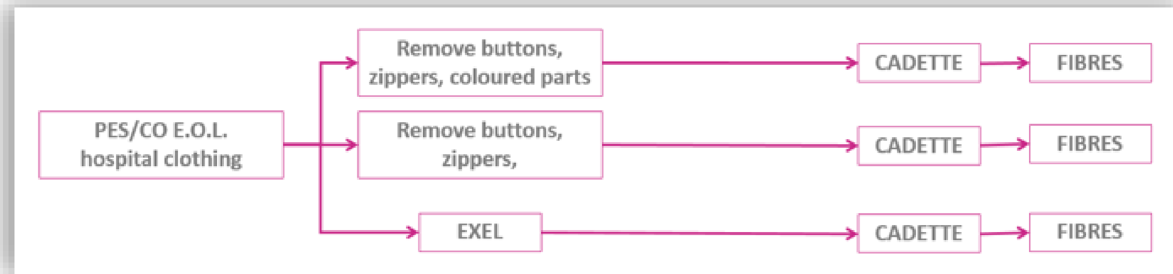
Polyester / Cotton technical value chain



Industrial partners: VAN MOER, MINOT, UTEXBEL

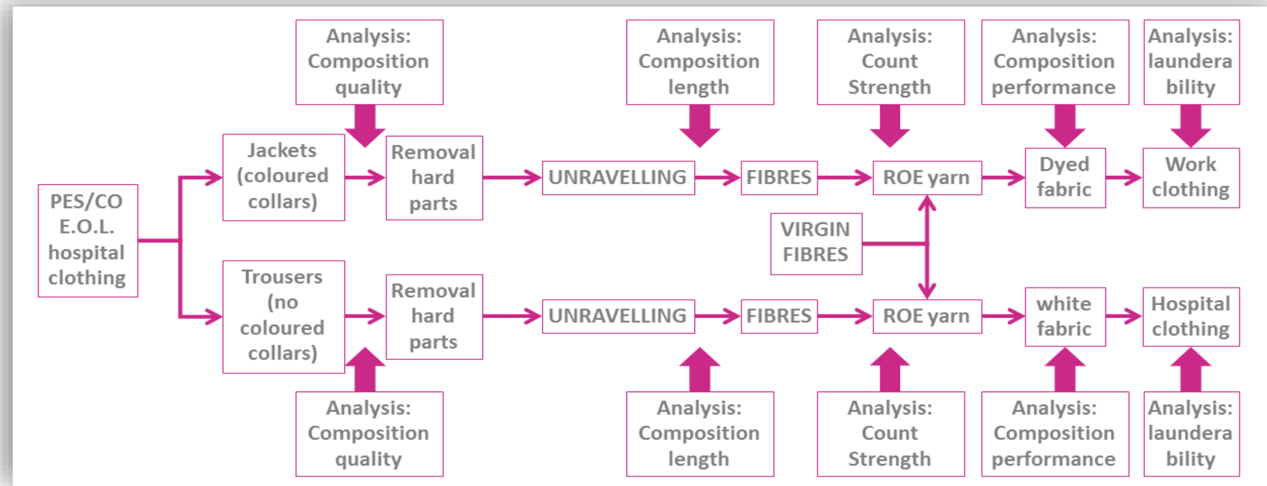
VAN MOER, a specialist in professional clothing, and UTEXBEL, a spinning and weaving mill, aimed to close the loop by re-making hospital clothing from other used hospital clothing.
To start the tests, VAN MOER provided **2 tons of end-of-life hospital clothes.**
For the preparation of the fibres, prior to fraying by MINOT RECYCLAGE TEXTILE (Hauts de France), the gowns and trousers were dismantled at ARCOR (Flanders) to remove the hard points (zips, buttons, tags)

For the organization of this value chain, 3 possible routes have been proposed.
2 routes in which the hard parts (zips, buttons, ...) and other "impurities" are removed before fraying (CADETTE), which allows for a softer fraying with a higher yield of long and therefore spinnable fibres, and 1 route in which the garment as a whole (with all hard parts and impurities still attached) is frayed by a harder process



After extensive discussions with all partners in the value chain, it was decided, especially at the request of the spinner, to remove all hard parts (buttons, zips, etc.) in advance in a separate process step
This additional step increases the cost of recycling, but has a positive influence on the properties of the fibres (length), which makes it possible to achieve a "higher standard": a yarn with a maximum proportion of recycled fibres and as fine as possible (yarn count) and with characteristics (strength, elongation, regularity, ...) that allow a normal and easy processing during weaving.

In addition, **jackets and trousers were treated separately.**
- jackets: contain snaps and coloured parts (collars, pockets)
- trousers: contain snaps, but no coloured components.

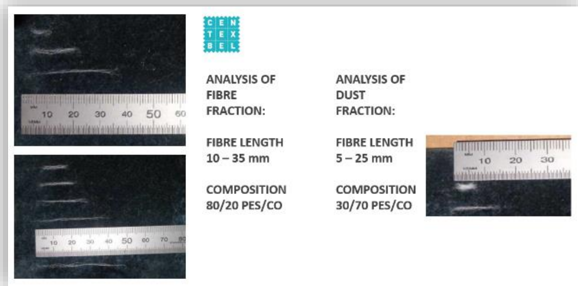


The chain finally implemented is as follows:
For spinning, it was necessary to work with a spinning mill able to spin short fibres, which is the case of UTEXBEL (Open End type spinning mill). The company actively participated in the fraying tests to validate them according to the fibre quality requirements for its spinning process.
In the end, the yarn with the recycled fibres from the trousers (uni-white) is used for the fabrics of new hospital garments while the yarn from the jackets is used for other workwear. In addition,

samples of eco-design compliant garments were made (using Wear2Go's degradable sewing threads).
Samples were taken and analyzed during the recycling process for standard setting.

Please note:
It is the deposit holder (VAN MOER), and also the garment maker, who proposes the specifications to UTEXBEL for the development of the products which are validated in the garment industry (washing tests, solidity, perceived quality, comfort, appearance, etc.)

At each stage, CENTEXBEL has analyzed the composition of the articles, the length of the fibres, the resistance, the objective being to propose a finished article containing a certain percentage of recycled fibres, which has the same properties, for the same use, as an article made with 100% virgin materials.



Throughout the process, the used garment, which originally contained 65% polyester and 35% cotton, lost 25% of the cotton fraction at the carding tape stage with a composition of 90% polyester and 10% cotton. The spinner therefore added virgin material for a viable recipe: a 1/30 Nm Open End yarn with 35% virgin cotton, 65% Polyester (25 frayed, 25 production off-cuts and 15 RPET bottles) and then a 210 g/m2 fabric.

Feedback:

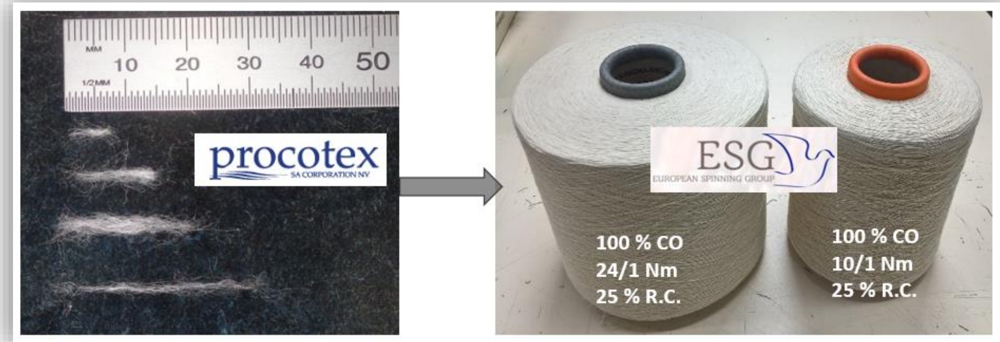
- Current fraying machines can generate fibres of sufficient length to be reusable.
- The waste streams must be sufficiently homogeneous (structure, weight, etc.)
- The elimination of hard points (snaps, tags etc.) is essential for 2 reasons: it avoids problems in fraying/carding/spinning and allows a softer fraying which damages the fibres less
- Worn clothing for the consumer market: this requires drastic sorting to make it usable in a closed loop
- For polyester/cotton used hospital garments, mechanical recycling mainly treats the polyester fraction because the cotton fraction is so degraded, due to frequent industrial washing, that the cotton fibres cannot resist the fraying/carding process.

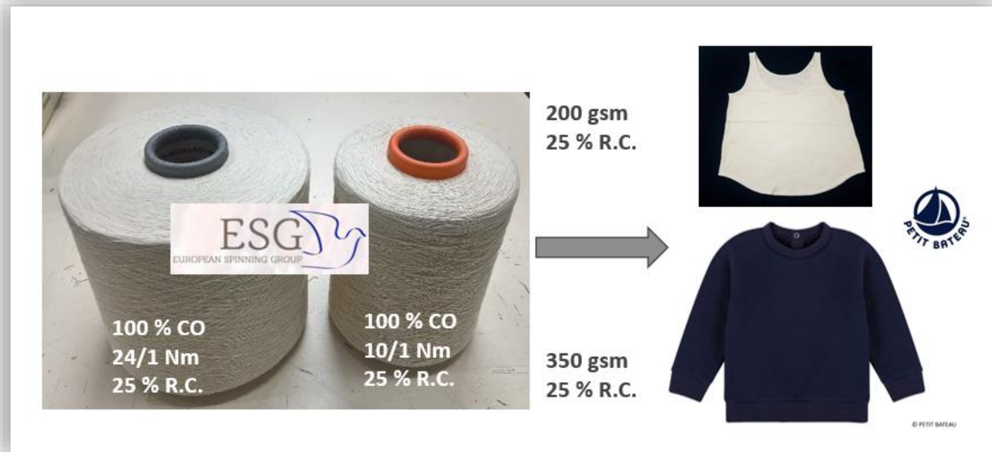
100% Cotton technical value chain

Industrial partners : PETIT BATEAU, PROCOTEX, ESG & LEMAHIEU

In this field, for LEMAHIEU (HDF) and PETIT BATEAU, the idea was (outside the area) to transform production offcuts into new knitwear for garments.
The preparation for spinning is carried out by PROCOTEX (W) and the ESG (European Spinning Group) spinning mill (VL) transforms the fibres from the fraying into yarns for knitting.
LEMAHIEU and PETIT BATEAU proposed their specifications based on their technology to ESG.

The European Spinning Group made two Open End yarn counts with 25% recycled material; according to the spinner, he could have put much more recycled content in the composition but due to lack of material and time, this was not done during the project. **PETIT BATEAU made a fleece with the 1/10 Nm and a jersey with the 1/24 Nm**



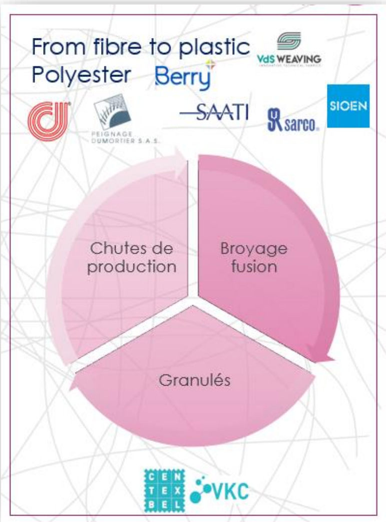


Some conclusions on the technical feasibility of mechanical recycling of cotton waste streams:

- Here too, industrially available fraying machines can be used
- And the length of the fibres, the homogeneity of the waste deposit and the absence of hard points are very important factors.
- 100% cotton production off-cuts are perfectly recyclable mechanically into fibres.

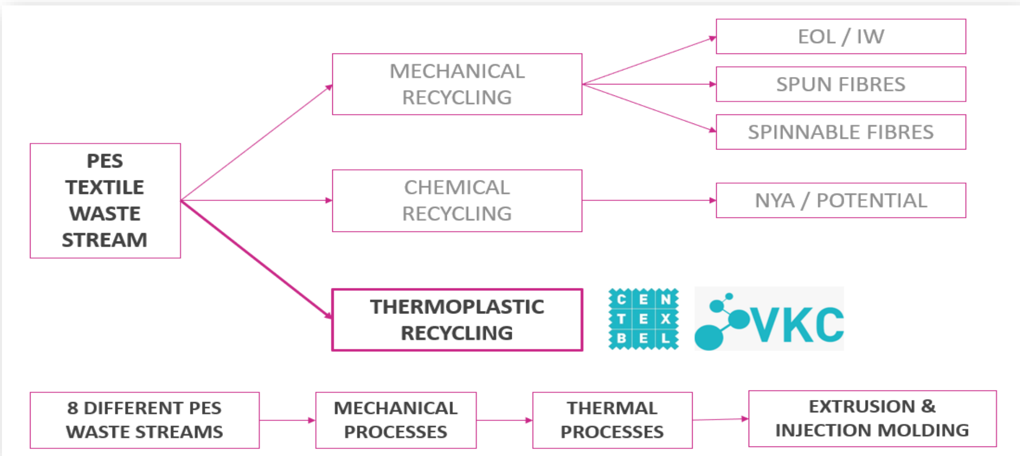
- In the case of end-of-life cotton, a distinction must be made between textile fabrics washed by domestic users and those washed industrially: industrial washing causes such a degradation of the cotton raw material that mechanical recycling is useless / unrealistic.
- This cotton seems better suited for processes where this high degradation may, in fact, be a requirement.
- It should be kept in mind that mechanical recycling remains the way for the future. There is a way to adapt used household cotton garments to mechanical recycling.
- For this, selection and sorting is the major challenge (technically and economically), as the DP or degradation state is not a simple and quickly measurable parameter.

100% Polyester technical value chain



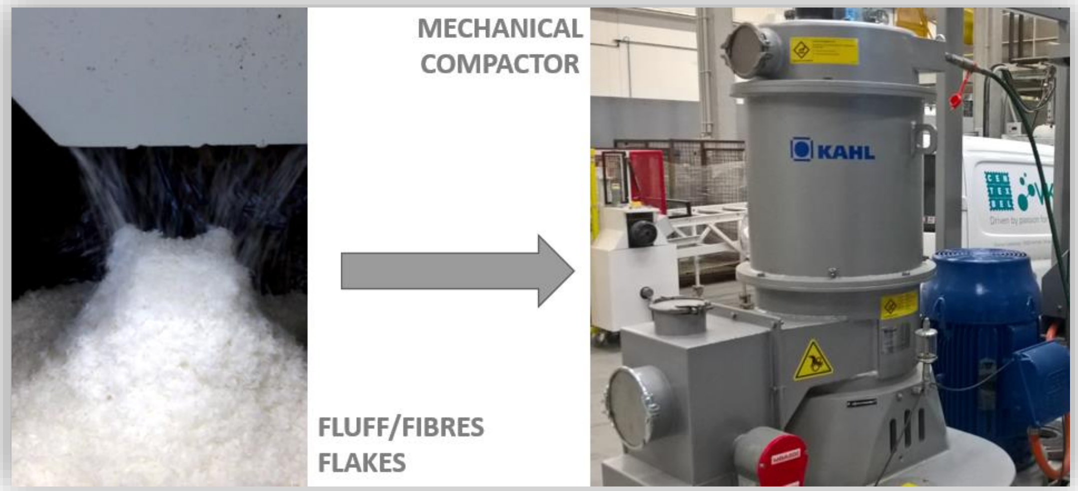
The last value chain treated in the RETEX project is the thermoplastic recycling of polyester textile waste streams, either from production or end-of-life.
Of course, polyester waste streams can also be recycled mechanically into spinnable polyester fibres, but this is only if the deposit consists of fibres that can be frayed into spinnable fibres.
The chemical route is also an option that has great potential, but is not yet available on an industrial scale

In a first set of tests, we processed 8 different polyester textile waste streams and studied their thermoplastic recycling possibilities.
The sources involved are 7 industrial waste streams and 1 end-of-life clothing stream.
The condition, of course, is that the composition is 100% polyester

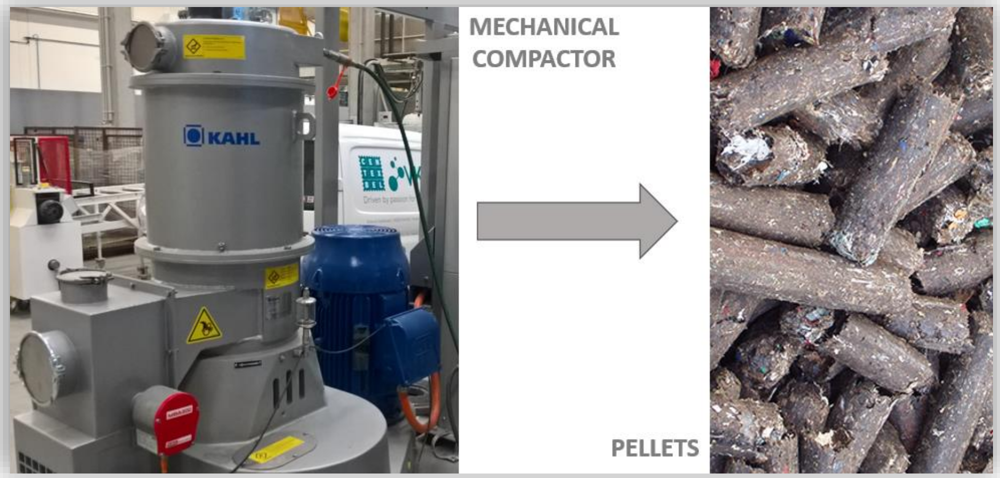


The 8 waste streams were treated separately, so the materials were not mixed:
Where necessary, cleaning was undertaken: i.e. the removal of hard or non-polyester parts (buttons and labels from end-of-life garments, cutting paper residues from garment off-cuts, etc....)

- The materials were then shredded; depending on the structure of the material, this generates a mass of fluffy or very plushy fibres.
- This mass of fibres was then compacted into pellets (compaction is a mechanical action, but it also generates heat through the friction that the mass of fibres undergoes when it is pressed through the holes).
- These pellets are then thermo-granulated in a compounding machine.



As polyester is involved, the pellets must be crystallized before thermo-granulation, and they must be dried.
The resulting granules are the raw material for the extrusion or injection moulding process.



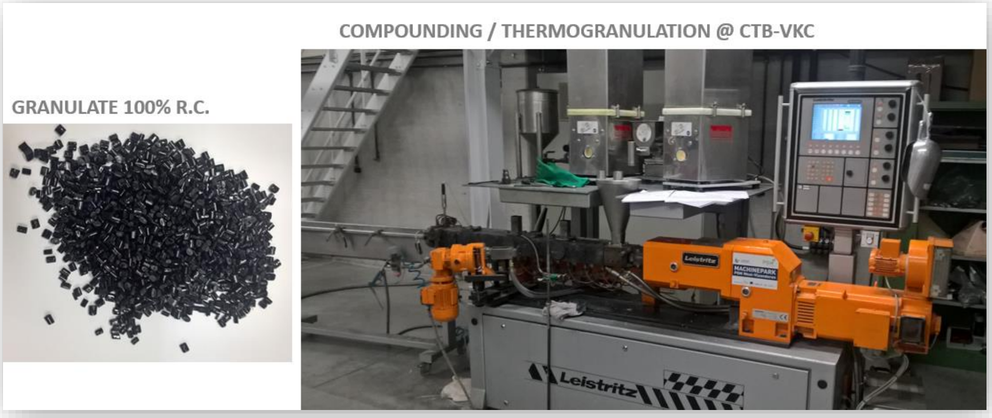
The main parameter to be considered, both in terms of processability (extrusion) and the quality of the final product, is the intrinsic viscosity of the granules. This value has been determined for the 8 different streams and shows obvious differences.

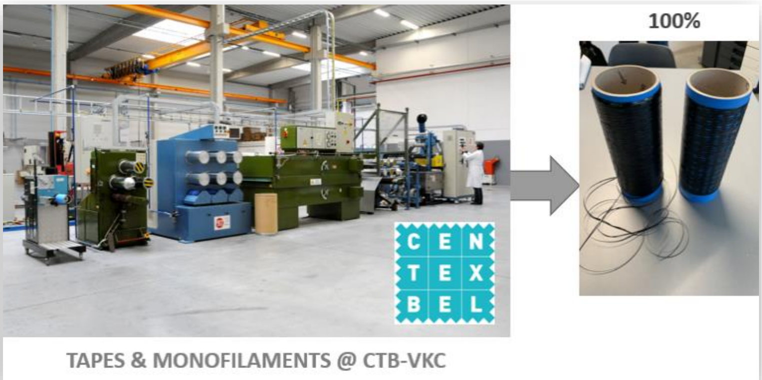
These differences are caused not only by differences in the quality of the polyester streams, but also by the difficult drying conditions of the pellets
With these granulates, extrusion and injection tests were carried out: multifilaments (with up to 75% recycled content), tapes and monofilaments (100% recycled content) and injection moulded parts (also 100% recycled content)

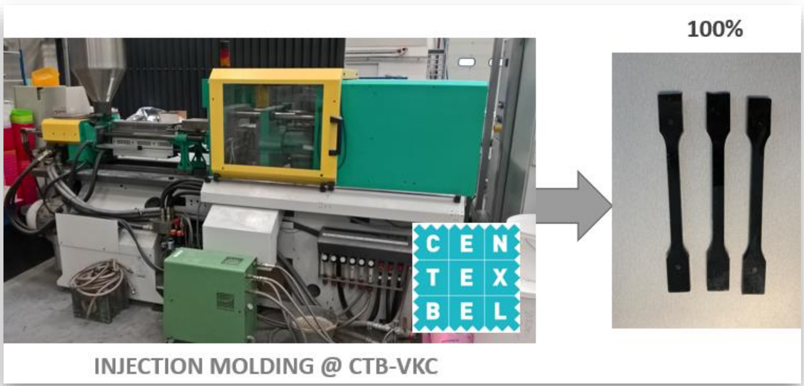
RESULTS DETERMINATION INTRINSIC VISCOSITY

VDS => 0,63 dl/g
Sarco => 0,52 dl/g
Depoortere => 0,49 dl/g
Dumortier => 0,49 dl/g
Berry Global => 0,57 dl/g
Ieperband => 0,65 dl/g
Saati => 0,53 dl/g
Sioen => 0,61 dl/g

The tests were carried out at CENTEXBEL-VKC.







We checked the properties that were relevant for these tests.
Here are some conclusions:

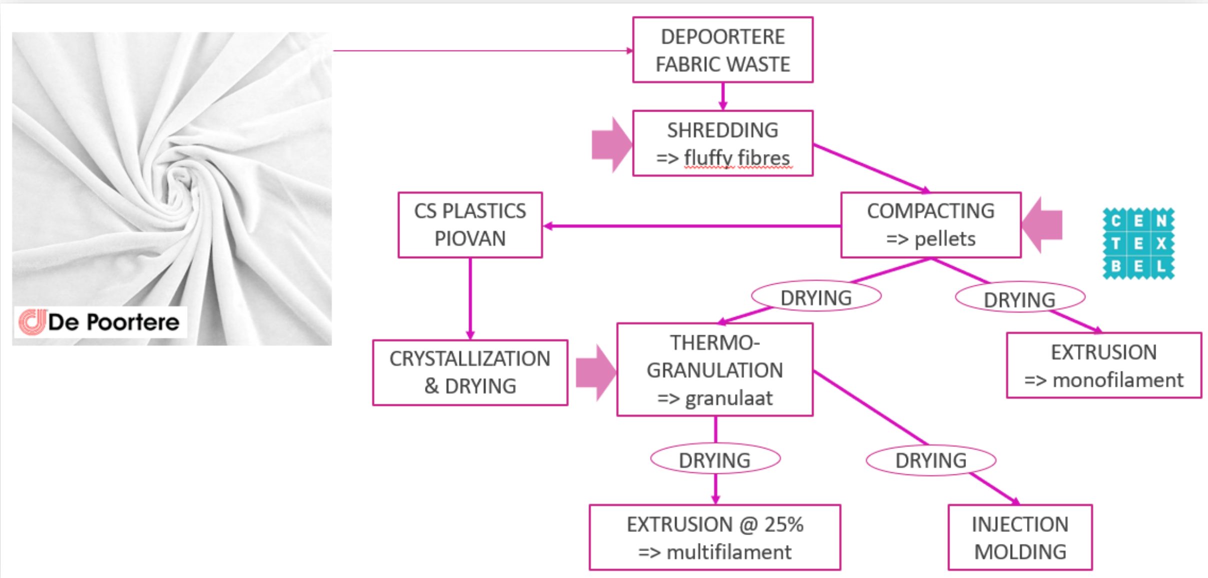
- In most cases, the aggregate has a **low intrinsic viscosity**, which limits its processability (the melt is very liquid).
- This causes a **high friability** of the products
- The modulus of elasticity is high, and the **elongation of the threads is limited**; there is also a lower impact resistance in injection moulding
- The **presence of additives and contaminants** also complicates processing.
- And, of course, the dye in the polyester can cause **surprising colour changes** (due to sublimation)

Adjustments/improvements were therefore necessary for the subsequent experiments:

- Better drying of the material before melting and possibly crystallizing it, thus increasing the intrinsic viscosity.
- Improved grinding and compacting.
- Possibly work on the percentage of recycled material (do not be too ambitious).

To improve and optimize the process parameters, tests were carried out with a larger industrial waste stream from the DE POORTERE FRERES company; these were offcuts from the production of unbleached, 100% polyester furnishing velvet.

This deposit was treated as shown in this diagram: the fabrics were shredded, giving a fluffy material that had to be compacted. The pellets were granulated and then extruded into multifilaments with 25% recycled polyester. For drying and crystallization we called on external expertise (CS Plastics)



Monitoring of the intrinsic viscosity value throughout the process shows that there is a significant decrease in intrinsic viscosity during compaction and thermogranulation, which, without intervention on the material, will cause a significant embrittlement of the material once extruded and a poorer processing during extrusion.
The cause of this degradation is the insufficient drying of the compacted fibre mass (due to the fact that these pellets have not been able to be thoroughly dried)

RESULTS OF ANALYSES:	INTRINSIC VISCOSITY	
SHREDDED FIBRES	→ 0,734 dl/g	
COMPACTED FIBRES (=> PELLETS)	→ 0,688 dl/g	→ DEGRADATION DUE TO HEATING WHEN COMPACTING
COMPOUNDED PELLETS (=> GRANULATE)	→ 0,588 dl/g	→ DEGRADATION DUE TO MELTING WHEN THERMOGRANULATING

Lastly, a thermoplastic recycling test was carried out with another source of end-of-life polyester clothing from the SARCO company.
The test scheme was kept as simple as possible, trying **to thermogranulate directly from the fibres (i.e. skipping compacting) and indirectly via compacting (pellet -> granulate).**
The objective was to improve the rheological (I.V.) properties of the aggregate as much as possible.
For this purpose, we used a "viscosity booster" (added for melting in a ratio of 2.5 and 5%).
The influence of the booster on the V.I. of the grains is clearly visible and this allows the extrusion of multifilament yarns with a recycled content of 40%.

RESULTS OF TESTS:	INTRINSIC VISCOSITY	/ PROCESSIBILITY MULTIFILAMENT EXTRUSION
SHREDDED FIBRES	→ 0,673 dl/g	
GRANULATE FROM FIBRES	→ 0,519 dl/g	→ MAX. 20% R.C.
GRANULATE FROM FIBRES + 2,5% BOOSTER	→ 0,584 dl/g	→ UP TO 40% R.C.
GRANULATE FROM FIBRES + 5% BOOSTER	→ 0,650 dl/g	→ UP TO 40% R.C.

The same raw material, not in the form of granulates but in the form of pellets, was also used to extrude a thick rod (diameter 1.75 mm) as raw material for 3D printing. The results of the evaluations are already known and are very positive: the rod runs without any problems in a 3D printer.

RESULTS OF TESTS:	INTRINSIC VISCOSITY	/ PROCESSIBILITY MONOFILAMENT EXTRUSION
SHREDDED FIBRES	→ 0,673 dl/g	
COMPACTED FIBRES (PELLETS)	→ 0,666 dl/g	→ 95 % + 5 % BOOSTER → 47,5 % + 47,5 % VIRGIN + 5 % BOOSTER

Some conclusions on the recycling of thermoplastics:

- **Thermoplastic recycling of textile waste streams** to make new textile raw materials is **technically possible in principle if rheological degradation can be avoided or compensated.**
- Most of the machines currently used in the recycling process are clearly designed for the recycling of plastics, which can lead to practical problems in the recycling of textile materials, especially in the mechanical preparation phase.
- The **drying of textile fibres** (shredded and/or compacted) also needs to be improved.
- A very interesting field of application is the **recycling into filament for 3D printing**, as the rheological, physical and mechanical value for such a product is significantly lower than that of yarns made of multifilaments.
- Special attention must be paid to the **filtration of impurities**.

Economic analysis of the value chains

Economical Evaluation of the Value Chains : introduction

RETEX identified 20 value chains (hereinafter“CV”): CV1 till CV20

- 18 of the 20 value chains were selected for further economical analysis (CV1 till CV18); evaluation based the principle “ **recycled material should be cheaper than virgin material** “
- CV19 or “**Ecocreativity**” : out of the box concepts created by ENSAV students using 3D printing of filaments of 100% polyester waste made by RETEX ; those concepts are not marketable
- CV20 or “**Ecodesign**”: workwear stitched with Wear2Go yarn did not yield better dismantling times compared to classically stitched equivalents

In total, **20 value chains were identified**, of which 18 were selected for further research into economic viability. The most important criterion for assessing economic feasibility is that the recycled product should be cheaper than the product made from virgin materials. In our opinion, this is the only realistic way to perpetuate textile waste recycling in the long term.

The 19th value chain, indicated as CV19 in the table, illustrates an Eco creativity approach in partnership with students from ENSAV (Ecole LACAMBRE), Brussels. The students made 3D printed products with a 1.75 mm diameter rush made at VKC from 100% polyester production waste. The concepts were very creative but far from market expectations, which is why we do not continue our research in this direction.
The same goes for the 20th value chain, CV20: 25 hospital gowns were assembled with conventional sewing thread and 25 with Wear2Go's microwaveable thread. Disassembly time was measured for both cases, and it was found that the Wear2Go thread did not provide much improvement in disassembly time.

Value Chains of RETEX: three main groups

- **Mechanical recycling of polyester-cotton**
  3 value chains: based on industrial waste and end of life clothes
- **Mechanical recycling of 100% cotton**
  3 value chains: based on industrial waste, end of life and unsold clothes
- **Thermoplastic recycling of 100% polyester**
  12 value chains: based on industrial waste, end of life and unsold clothes

The 18 value chains were divided into three groups:

- Mechanical recycling of cotton/polyester with 3 value chains from textile production waste and end-of-life garments.
- Mechanical recycling of 100% cotton, with 3 value chains, from knitting and garment production waste, end-of-life garments and unsold goods.
- Thermoplastic recycling of 100% polyester, from production waste, end-of-life textiles and unsold goods

Polyester/cotton economic value chain

Mechanical Recycling of Polyester Cotton

- CV1 : industrial waste
- CV2 : end of life workwear from industrial laundries
- CV3 : end of life clothing from sorting centers

REMARK: waste flows are homogeneous in composition and colour
PARTNERS: Van Moer, Minot, Utexbel, Centexbel

The value chains for mechanical recycling are numbered CV1 to CV3 and deal respectively with industrial waste, end-of-life hospital garments from industrial laundries and end-of-life garments from sorting centers. The partners in the CV2 value chain are listed at the bottom of the slide. The waste streams are homogeneous in composition and colour

Mechanical Recycling of Polyester Cotton

Value Chain CV2 - Sliver cost price

END OF LIFE ("EOL") HOSPITAL CLOTHING ORIGIN: INDUSTRIAL LAUNDRIES	cost/kg	Virgin material euro/kg	in kg	out kg	Material loss	Total cost
virgin fibers 100% polyester		1,05 €				
virgin fibers 100% cotton		1,50 €				
material cost EOL	**0,00 €**					
manipulation	0,10 €					
sorting	0,00 €					
transport > remove hard parts	0,05 €		100,00	100,00		15,00 €
remove hard parts	0,32 €		100,00	87,00	-13,00%	32,00 €
transport > unravelling	0,05 €		87,00	87,00		4,35 €
unravelling	0,25 €		87,00	73,95	-15,00%	21,75 €
transport > spinning mill	0,05 €		73,95	73,95		3,70 €
carding/cleaning	0,15 €	0,15 €	73,95	53,98	-27,00%	11,09 €
						87,89 €
	100% PES carded	1,20 €		Cost recycl.fibers	euro/kg	1,63 €
	100% cotton carded	1,65 €				

The table shows a spreadsheet for estimating the **cost price of a carded sliver in the spinning mill, made from recycled polyester-cotton fibres, based on RETEX measurements**.
The left-hand column contains the **different steps in the process** that mechanical recycling has to follow collection in the laundry, transport to the workshop where the hard points will be removed, then transport to the shredder, and finally transport to the spinning mill where the fibres will be processed into sliver. We stop our calculations at this point.

The next column shows **the unit cost prices, then the incoming and outgoing flows per process step with a shrinkage rate at each process**. The total cost per process step is calculated by multiplying the input stream by the unit cost price.
All steps are then added together to give the total cost of the value chain. This cost is then divided by the mass flow out at the end of the value chain.
In our example, the total cost is €87.89. 87.89 divided by 53.98 kilograms gives a cost of 1.63 euros per kilogram, which is the cost price of the wick containing recycled fibre.
Note also that **100 kg of waste results in 53.98 kg of usable fibre, a loss of 46% in mass.**

Mechanical Recycling of Polyester Cotton

Cost price of sliver combination

Yarn number	composition	material	CV1	CV2	CV3
Nm 30/1	25,00%	effiloché/unraveled	0,92 €	1,63 €	2,09 €
	25,00%	industrial waste PES	€ 0,30	€ 0,30	€ 0,30
	17,00%	R-PET (**)	€ 1,30	€ 1,30	€ 1,30
	33,00%	virgin cotton	1,65 €	1,65 €	1,65 €
recycled fiber cost price (A)		euro/kg	**1,07 €**	**1,25 €**	**1,36 €**
virgin cost price (B)		euro/kg	**1,35 €**	**1,35 €**	**1,35 €**
DELTA (*) gross margin		%	**20,64%**	**7,49%**	**-1,10%**
INFLUENCE LOGISTICS		%	**23,40%**	**11,97%**	**3,38%**

(*) DELTA = (B - A) / B in %
(**) RPET price 1,15 EUR/kg+0,15 card.

We calculate the cost of a spinning recipe by combining several blended slivers to produce **a final commercial yarn of Nm 30/1. This yarn contains 33% virgin cotton, 17% RPET, 25% RETEX and 25% spinning waste.** Taking this composition into account, the cost price of this blend of ribbons at the spinning mill entrance is calculated and compared to the cost price of its equivalent made up exclusively of virgin material, which in our case is 1.35 euro/kg.
Then, the parameter "DELTA" defined as a measure of the percentage difference in gross margin between the recycled ribbon "A" and the virgin ribbon "B". It can be deduced from the formula that DELTA becomes positive for a smaller "A" than "B". A positive delta is the sign of a profitable value chain. In our case, CV1 and CV2 are economically viable channels with margins of 20.64% and 7.49%. CV1 and CV2 include the recycling of industrial polyester/cotton waste and end-of-life hospital garments respectively.
Even though CV1 generates higher margins than CV2, **we continue to work with CV2 here because RETEX has finally gained real experience. It is a guarantee of success, because RETEX aims at the industrial transfer of this value chain.** The CV3 value chain is based on consumer end-of-life clothing from sorting centres and is not profitable. We draw your attention to the line "influencing logistics" where all logistics costs have been set to zero, as a theoretical exercise. We find that logistics improves the margin by 3 to 5 points

Mechanical Recycling of Polyester Cotton

Value chain : CV2

Influence of waste removal price and RPET market price

Waste removal price euro/ton	DELTA / gross margin RPET sliver 1,30 euro/kg	Fiber price RPET euro/ton	DELTA / gross margin Waste at 0,00 euro/kg
-300,00 €	17,79%	800,00 €	13,79%
-100,00 €	10,92%	1.000,00 €	11,27%
0,00 €	7,49%	1.300,00 €	7,49%
100,00 €	4,05%	1.500,00 €	4,97%
300,00 €	-2,81%	1.900,00 €	-0,08%

In this table, we calculate the impact of the collection price on the gross margin of the recycling process for CV2. The previous tables assumed that end-of-life hospital garments were collected free of charge from the industrial laundry.

Now we assume that the deposit holder pays 100 or 300 euros per ton for the collection of these clothes.
This is indicated by "-100" and "-300" on the table. The profitability of recycling logically increases as the collector receives an additional revenue stream. If, on the other hand, the collector buys 100 or 300 euros per ton from the deposit holder, recycling becomes unprofitable above 100 euros per ton.
We also see the influence of the price of bottled RPET fibre. The lower price of RPET slightly improves the profitability of the CV2 value chain.

Mechanical Recycling of Polyester Cotton
Value Chain CV2
Do I recycle or do I incinerate ?

REGION	INCINERATION COST euro/ton	GROSS MARGIN (%)
VLAANDEREN	170,00 €	13,33%
WALLONIE	165,00 €	13,15%
HAUTS DE FRANCE	115,00 €	11,44%

We ask ourselves why we should pay to incinerate our waste, if we could spend the same amount on mechanical recycling? Here you can see the price of incineration in the Euro Region, where not only incineration was charged, but also transport and the rental of the waste container. And what do we see? That recycling could clearly be an alternative to incineration. The gross margin is positive and varies between 11 and 13%.

Mechanical Recycling of Polyester Cotton
Conclusions Economic Analysis

- Recycling of homogeneous streams of industrial waste or EOL workwear from industrial laundries yields positive gross margins
- Recycling of EOL of sorting centers is not profitable
- Low RPET prices slightly improve the profitability of the value chains
- Increase incineration taxes may deviate waste flows towards recycling
- Import taxes at the EU borders and waste removal taxes within the EU can finance the creation of an EU recycling industry

For the mechanical recycling of polyester-cotton, we conclude that :

- **Industrial waste and end-of-life garments from laundries generate positive margins.**
- The same cannot be said for consumer end-of-life clothing from sorting centres.
- The low prices of RPET slightly improve the profitability of the recycling process. The price of waste incineration is no longer as far away from the cost of recycling. This may lead to the relocation of some textile waste streams.
- At the EU's borders, import duties should be applied to textile waste streams to pay for the cost of recycling. This would allow the EU to create a new recycling industry. This would create jobs.

What are the next challenges?

- Machine manufacturers must rethink their machines to **ensure maximum fibre length**. Especially at the fraying stage.
- **The automation of colour and raw material sorting in sorting centres is a necessity** if a paradigm change is to be achieved. The same applies to the removal of hard parts. **Ecodesign is becoming essential** and will require an adaptation of existing norms.
- **Industrial laundries must make their washing processes less aggressive.** Today, there is too much "cotton waste" in the defibration and carding processes.

100% cotton economic value chain

Mechanical Recycling of 100% Cotton

- CV4 : industrial waste from cutting operations
- CV5 : unsold clothes from distributors
- CV6 : end of life clothes from sorting centers

REMARK: waste flows are homogeneous in composition and colour
PARTNERS: Petit Bateau, Lemahieu, Procotex, ESG, Centexbel

The value chains for mechanical recycling of 100% cotton are based on the following waste streams: production off-cuts from cutting plants, collection of unsold garments and end-of-life garments from sorting centres. The waste streams are homogeneous in composition and colour. Centexbel coordinated the CV4 value chain with Petit Bateau, Lemahieu, Procotex and ESG.

Mechanical Recycling of 100% Cotton
Cost price of sliver combination for use in Nm 28/1 yarn
Waste removal cost : 100 euro/ton paid to waste producer

	composition	material	CV4	CV5	CV6
	25,00%	effiloché/unraveled	1,31 €	1,98 €	2,64 €
	0,00%	IW PES	€ 0,00	€ 0,00	€ 0,00
	0,00%	R-Pet	€ 0,00	€ 0,00	€ 0,00
	75,00%	virgin coton	1,65 €	1,65 €	1,65 €
recycled fiber cost price (A)		euro/kg	1,57 €	1,73 €	1,87 €
virgin cost price (B)		euro/kg	1,65 €	1,65 €	1,65 €
DELTA		%	5,10%	-5,01%	-13,55%

DELTA = (B - A) / B in %

As explained in the polyester-cotton value chain, for the mechanical recycling of cotton waste, the cost has also been calculated to produce a sliver from 100% recycled cotton fibres.
In this table, for CV4, it comes to 1.31 euro per kg. Then, in the same table, the cost price is calculated for a combination of ribbons to produce a 100% cotton yarn with metric number 28/1 and containing 25% recycled cotton and 75% new organic cotton. The cost price of this combination - called "recycled fibre cost A" in the table - is compared to its virgin equivalent called "virgin cost B". This is done for all three value chains. The difference between the two cost prices, called the delta, must be positive to obtain a recycled yarn that is cheaper than its virgin equivalent.
Only the CV4 value chain working with recycled industrial waste was profitable with 1.57 euro/kg for the recycled version against 1.65 euro/kg for the virgin equivalent. The DELTA margin is 5.10%.
The other two value chains CV5 and CV6 are not considered further as they generate negative margins. Important: In the CV4 value chain, 100 euros per ton is paid by the collector to the waste producer. This is not a free collection as in the case of mechanical recycling of polyester/cotton.

Mechanical Recycling of 100% Cotton
Value Chain CV4
Influence of waste removal cost and virgin cotton price

Waste removal price	DELTA / gross margin	Price virgin cotton	DELTA / gross margin
euro/ton	%	euro/kg	%
-300,00 €	16,98%	0,80 €	-9,57%
-100,00 €	11,04%	1,00 €	-3,56%
0,00 €	8,70%	1,20 €	0,67%
100,00 €	5,10%	1,50 €	5,10%
-	-	-	-

The following table therefore calculates the impact of the cotton waste collection price - referred to in the table - on the gross margin, previously referred to as delta, for the same CV4 value chain.
With free collection at 0.00 euro per ton, the gross margin improves to 8.70%.
When the deposit holder starts paying for the collection of his waste, see the "-100 or -300 euros per ton" in the table, recycling becomes even more profitable. Up to 16.98% for 300 euros per ton.
Cotton price variations cancel out the economic model of mechanical recycling for cotton prices of 1 euro per kg or less.

Mechanical Recycling of 100% Cotton
Value Chain CV5
What about unsold garments ? Options ?

Waste removal cost	DELTA
euro/ton	%
-300,00 €	5,23%
-100,00 €	-1,60%
0,00 €	-5,01%
100,00 €	-8,43%
-	-

We move to another value chain, i.e., CV5 being the mechanical recycling of unsold clothes still in 100% cotton.
Let's say I'm a retailer with large quantities of unsold clothes and I don't want to destroy them. I am looking for a circular solution.
Then, the calculation presented in this table, shows that from a collection price of 300 euros per ton, indicated as "-300 euros" in the table, to be paid by the retailer, a recycling operation becomes possible.
Once again, it seems that the choice of a circular solution is increasingly possible. Again, we remind you of the cost of incineration, which varies between about 100 and 200 euros per ton.

The conclusions of the economic study are as follows:

- Only the **recycling of unwashed industrial cotton off-cuts from the cutting plants generates positive margins**. The other value chains are not profitable. Often, in the case of end-of-life garments, the cotton fibre is damaged by the washing process.
- Unsold clothes can be transformed into other textile products through mechanical recycling at a cost of 300 euros per ton.

- The difference between incineration (at €100-200 per ton) and a circular solution via the CV4 value chain at an additional €300 per ton is shrinking and clothing retailers are beginning to have other options. Recycling is preferable to incineration. Building a better image can justify spending this extra cost.
- 300 per ton can also be levied on imports into the EU - the borders allowing the EU to fund a whole new recycling industry. Creating jobs.

What are the next challenges?

- Machine manufacturers need to rethink their machines to ensure maximum fibre length. Specifically, we are thinking about reducing the damage to the fibres in the fraying process.
- The automation of colour and raw material sorting in sorting centres is a necessity if a paradigm change is to be achieved. The same applies to the reprocessing of hard points. Ecodesign must be generalized, if necessary, with additional training for designers.
- Industrial laundries must make their washing processes less aggressive. Today, there is too much "cotton waste" during defibration and carding.

100% Polyester economic value chain

Thermoplastic recycling of
100% polyester industrial waste

- CV7 : shred > compact > granulation
- CV8 : fray/unravel>compact>granulation
- CV9 : shred > compact
- CV10 : fray/unravel > compact

REMARK: waste flows are homogeneous in composition NOT in colour

PARTNERS: VDS Weaving, Ieperband, Depoortere Frères, Dumortier, SAATI, Berry Global, Sioen

The thermoplastic recycling of industrial textile waste composed of 100% polyester involves four routes:
First, shredding, compacting and then granulating the industrial waste
Secondly
First fray/unravelling, then compacting and granulating again
The technical feasibility study shows that if compaction produces abrasion resistant granules, the expensive granulation becomes unnecessary. This simplified route is included in the economic calculations because, if feasible, it represents a financial breakthrough in the recycling of thermoplastics from 100% polyester waste.
So CV9 with only crushing and compacting. And CV10 with fray/unravelling and then compacting.

Thermoplastic recycling of
100% polyester end of life clothes

- CV11 : shred > compact > granulation
- CV12 : fray/unravel>compact>granulation
- CV13 : shred > compact
- CV14 : fray/unravel > compact

REMARK: waste flows are homogeneous in composition NOT in colour
PARTNERS: Sarco

The same thing happens with end-of-life clothing.

Thermoplastic recycling of
100% polyester of unsold clothes

- CV15 : shred > compact > granulation
- CV16 : fray/unravel>compact>granulation
- CV17 : shred > compact
- CV18 : fray/unravel > compact

REMARK: waste flows are homogeneous in composition and colour

And for unsold garments too.

Thermoplastic recycling of 100% polyester
Price comparison of recycled and virgin chips

Value Chain : CV7		RPET	PET virgin		
chips in 100% polyester (euro/ton)		€ 1.150	€ 1.390		
	EUR/ton	kg in	kg out	Material Loss (%)	Total cost (*)
Industrial waste (rolls, selfedges)	0,00 €	1000	1000	0,00%	0,00 €
transport (+ container rental) to recycling center	70,00 €	1000	1000	0,00%	70,00 €
Incineration (no relevance in CV7)	0,00 €	1000	1000	0,00%	0,00 €
shredding	200,00 €	1000	975	2,50%	200,00 €
compacting	75,00 €	975	951	2,50%	73,13 €
transport recycling center to thermoplastic plant	30,00 €	951	951	0,00%	28,52 €
drying/recrystallisation	100,00 €	951	922	3,00%	95,10 €
compounding (no booster)	280,00 €	922	899	2,50%	258,16 €
total cost of all operations				**For 899 kg**	**724,90 €**
total cost resp. gross margin in euro per ton	**EUR/ton** 806,39 €	**Margin /ton RPET** 343,61 €	**Margin/ton virgin PET** 583,61 €	**Per ton**	**806,39 €**

(*) in euro per ton

In this table, for the CV7 value chain - i.e. shredding, compacting and pelletising - the cost price of a 100% recycled polyester off-cuts pellet is calculated and compared to the market price of RPET and virgin polyester chips, shown in red at the top of the table.

- The left-hand column shows the different stages of the process: collection and transport of the waste by container to the recycler where it is shredded and compacted, then transport to the compactor for recrystallisation, drying and granulation into a recycled granulate.

- The next three columns show the unit costs and mass balance of the inputs and outputs of the waste stream, with the corresponding figures per line in the next column.
- The total cost per process step is calculated in the last column as the input stream in tons multiplied by the corresponding unit cost.

The cost of all steps is added together and divided by the weight of the outgoing stream at the end of the recycling process.
In our example, the total cost is 724.90 euros for a final output of 899 kg or converted to 806.39 euros per ton. The last figure is included in this box at the bottom of the table. In this same cell, the market price of RPET and virgin polyester - shown in red at the top of the slide - is subtracted from the EUR 806.39 per ton. This difference is shown in the square at the bottom of the table.

Recycling according to the CV7 value chain gives a positive margin of 343.61 euros per ton compared to the market price of RPET, which in our example was 1150 euros per ton.

Thermoplastic recycling of 100% polyester

Comparison of the margins of all value chains

Value chain	margin/ton (*)	Processing routes
CV7	343,61 €	Industrial waste : shred > compact > granulation
CV8	238,97 €	Industrial waste : fray/unravel > compact > granulation
CV9	759,05 €	Industrial waste : shred > compact >> pellets not abrasion resistant
CV10	656,95 €	Industrial waste : fray/unravel > compact >> pellets not abrasion resistant
CV11	-462,36 €	End of Life Clothes : shred > compact > granulation
CV12	-688,58 €	End of Life Clothes : fray/unravel > compact > granulation
CV13	-9,75 €	End of Life Clothes : shred > compact
CV14	-224,80 €	End of Life Clothes : fray/unravel > compact
CV15	-29,91 €	Unsold Clothes : shred > compact > granulation
CV16	-192,53 €	Unsold Clothes : fray/unravel > compact > granulation
CV17	401,35 €	Unsold Clothes : shred > compact >> pellets not abrasion resistant
CV18	-403,24 €	Unsold Clothes : fray/unravel > compact

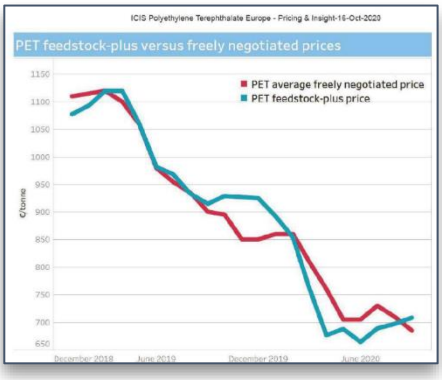
(*) versus RPET market price

In the following table, the margin is calculated for all value chains.
This shows that only the processing of homogeneous industrial waste generates positive margins.
CV9 and CV10 are the most profitable - which is to be expected - but as it has not yet been possible to produce sufficiently abrasion-resistant granules, this value chain will be neglected in this study in benefit of CV7 and CV8.
End-of-life garments from sorting centres cannot be processed economically. See CV11 to CV14.
The same applies to unsold clothes with the value chains CV15 to CV18. 200 per ton, a distributor of unsold clothing can opt for a circular solution.

Thermoplastic recycling of 100% polyester
Value Chain CV7

Model sensitivity versus waste removal price		Model sensitivity RPET market price	
euro/ton	Margin RPET	euro/ton	Margin RPET
100,00 €	232,37 €	1.150,00 €	343,61 €
0,00 €	343,61 €	900,00 €	93,61 €
-100,00 €	454,85 €	700,00 €	-106,39 €
-300,00 €	677,33 €	500,00 €	-306,39 €

Back to CV7: in this table, the influence of the price of waste collection on CV7's margin is again examined.
The economic situation looks good. This is also the reason why many companies process their own industrial waste internally. It is even possible to give the waste holder EUR 100 per ton, so the margin is EUR 232.37 per ton. If we pay the waste holder 300 euros per ton - indicated by "-300" in the left-hand column of the slide - the margin increases to 677.33 euros per tonne. The influence of the RPET price on the margin is shown on the right-hand side of the same table.
900 per ton for RPET, recycling becomes unprofitable.



The harsh reality of the market is that prices are low for both RPET and virgin PET, as shown in the graph: at the end of 2018, the price of polyester was between €1100 and €1200 per ton and is now down to around €650 to €700 per ton.

Thermoplastic recycling of 100% polyester
Value Chain CV7

Booster price : 12,25 euro/kg and waste removal price 0,00 euro/ton

RPET price sensitivity versus % booster on margin in euro/tonne			
% booster	RPET price : 1.150,00 €	% booster	RPET price : 700,00 €
0,00%	343,61	0,00%	-106,39
2,50%	64,50 €	2,50%	-385,50 €
5,00%	-201,32 €	5,00%	-651,32 €
10,00%	-696,72 €	10,00%	-1.146,72 €
20,00%	-1.563,66 €	20,00%	-2.013,66 €

To strengthen the physical-chemical properties of the polyester waste, an activator is added. On the left side of the slide, you can see a simulation of the high RPET prices, i.e. 1150 euros per tonne. This shows that only 2.5% booster can be added if we want to operate profitably.

At lower RPET prices of 700 euros per ton - as today, on the right-hand side of the slide - the addition of the booster can be completely forgotten, at least from an economic point of view. The booster is very expensive. We paid 12.25 euros per kg.

Conclusion: **Homogeneous industrial waste consisting of 100% polyester can be economically processed into pellets by shredding or fray/unraveling**. This conclusion does not apply to end-of-life clothing from sorting centres or unsold clothing.
However, unsold garments can be processed in a circular way if an additional charge of 200 euros per ton is paid.
A real technological and economic breakthrough will come when it will be possible to compact enough abrasion-resistant granules, making granulation unnecessary. Unsold garments can then also be processed profitably WITHOUT being taxed. This will be a new route for RPET production.
Low oil prices - and therefore low RPET prices - negate efforts to recycle textile waste from an economic point of view.

What are the next challenges?

- **Compacting machine builders need to include a cooling system in the process to maintain maximum intrinsic viscosity**.
- Automation of colour and raw material sorting is needed. The same applies to the removal of hard parts from garments. Ecodesign should be able to help in this respect.
- The removal of pigments and additives is essential.
- **Additives disturb the intrinsic viscosity in thermoplastic processes**.
- There are new processes on the market that can achieve this. These are outside the scope of RETEX.
- If the addition of boosters becomes unavoidable, the chemical industry must invest in additional capacity in order to achieve lower market prices.

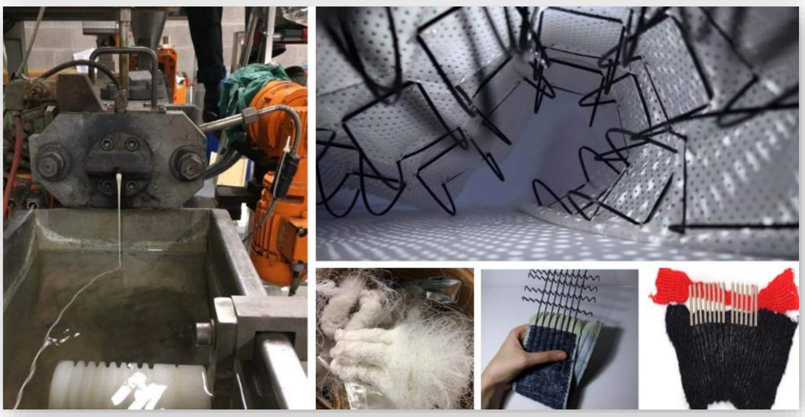
Complementary research

LaCambre Workshop in Brussel

The students created different concepts by 3D printing with a 1.75 mm diameter filament produced at VKC from industrial waste composed of 100% polyester.

La Cambre

Flux de matières et fibres recyclées – « Atelier plastique »



3D printing with NEFILATEK startup in Haut-de-France Region

The creation of a 100% polyester filament with a diameter of 1.75 mm for 3D printing, which was tested at Nefilatek.
The technical results are encouraging. The filament contains 47.5% recycled polyester from Sarco clothing, 47.5% virgin polyester and 5% booster.

Making with the WEAR2 thread

The aim of the tests was to compare the time taken to unravel a classic hospital garment with the same garment sewn with WEAR2 thread, the aim being to improve the time and therefore the cost price of unravelling.
This first test allows to gain in material (85% against 58% in hand cutting) however it does not allow to save time; invoked causes, the high rate of humidity in the garments to be untied, very resistant seams linked to the expected specifications of professional garments
It will be necessary to aim at improving the microwave process with a new oven planned in the CIRCTEX project (CENTEXBEL and EuraMaterials are part of the consortium).

Conducting life cycle inventories of recycling processes

The objective is to validate the environmental relevance of the recycling chain implemented in the framework of the project.
All the LCIs were carried out by the AVNIR platform of the CD2E

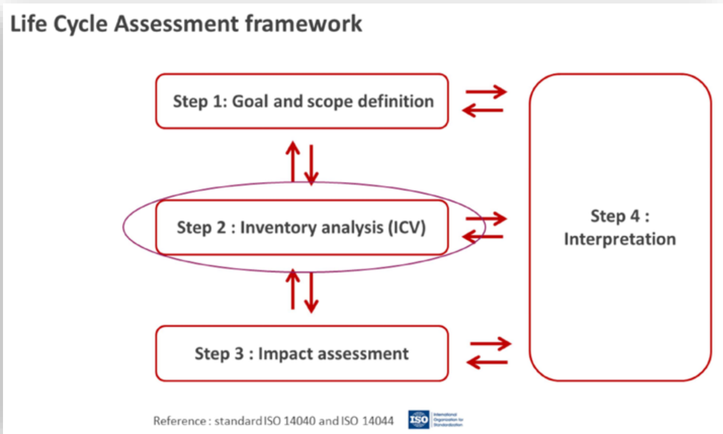
For the 3 recycling lines:
- Mechanical recycling of cotton-polyester textile waste
- Mechanical recycling of 100% cotton textile waste,
- Plastic recycling of 100% polyester textile waste

As a preliminary, what is LCA / Life Cycle Assessment?

It is a method for calculating the environmental impacts of a product or service. It is a multi-stage method because it takes into account all the stages of the product's life cycle (from the extraction of raw materials to the end of life) and multi-criteria because a whole series of indicators are studied, not just CO2

This method has the advantage of avoiding transfers of pollution from one stage of the life cycle to another or from one impact indicator to another.

It is a method that is standardized and framed by the iso 14040-44 standards



The standard describes 4 steps in conducting an LCA:

- Definition of the objectives and scope of the study, where you define the perimeter of the study (everything that you will or will not consider in your assessment)
- On the basis of this perimeter, you will carry out the life cycle inventory, i.e., collect all the data that will enable you to model the life cycle of your product.
- Then in step 3 you model your life cycle in software and calculate the impacts
- And in conclusion you interpret the calculated results (to identify sources of impact, etc.)

So, in the framework of the project, what we were mainly interested in was stage two, the life cycle inventory - inventory data are essential in LCA to carry out the studies

A life cycle inventory is therefore the set of incoming (material consumption, energy consumption, etc.) and outgoing (final products, waste, emissions) flows, which will enter or leave the life cycle perimeter of your system.

LCI - polyester/coton value chain

Here you have the scope of the value chain set up within the framework of the project for this waste stream. This is post-consumer hospital clothing provided by VAN MOER, which is unraveled in an integration workshop at ARCOR, frayed at MINOT RECYCLAGE TEXTILE and finally spun at UTEXBEL

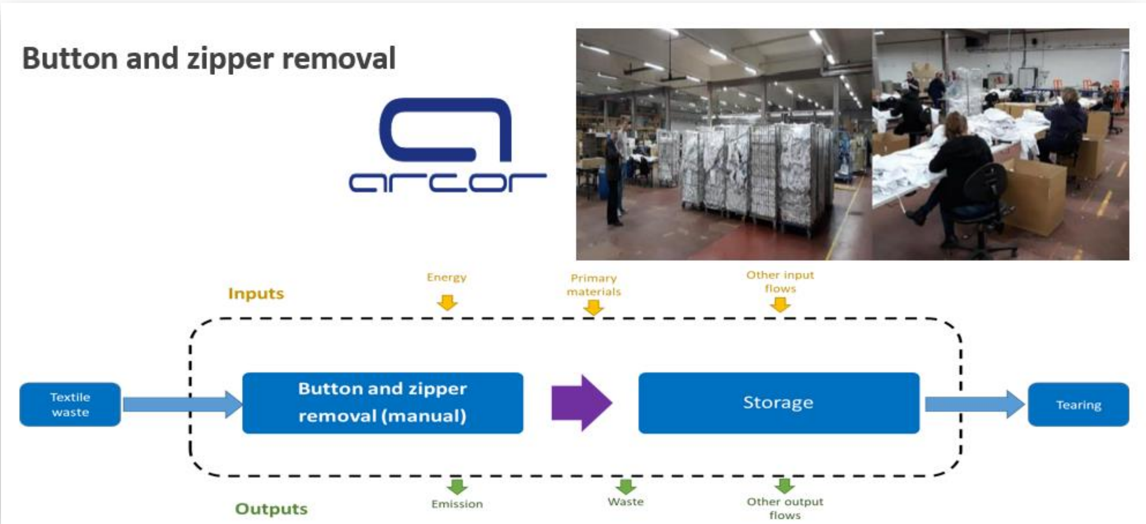
In this case study, we will study the **production of 1kg of 30/1 metric yarn, composed of 25% fibre from fraying, 25% polyester fibre from industrial waste, 15% recycled PET from bottles and 35% virgin cotton.**

Functional unit : *« Produce 1kg of yarn, 30/1Nm »*

Yarn characteristics :

Metric number	30/1
Composition	- 25% polyester/cotton fibres from the fraying of post-consumer waste; - 25% polyester fibres from industrial scraps; - 15% recycled PET fibre (bottles); - 35% virgin cotton fibre.

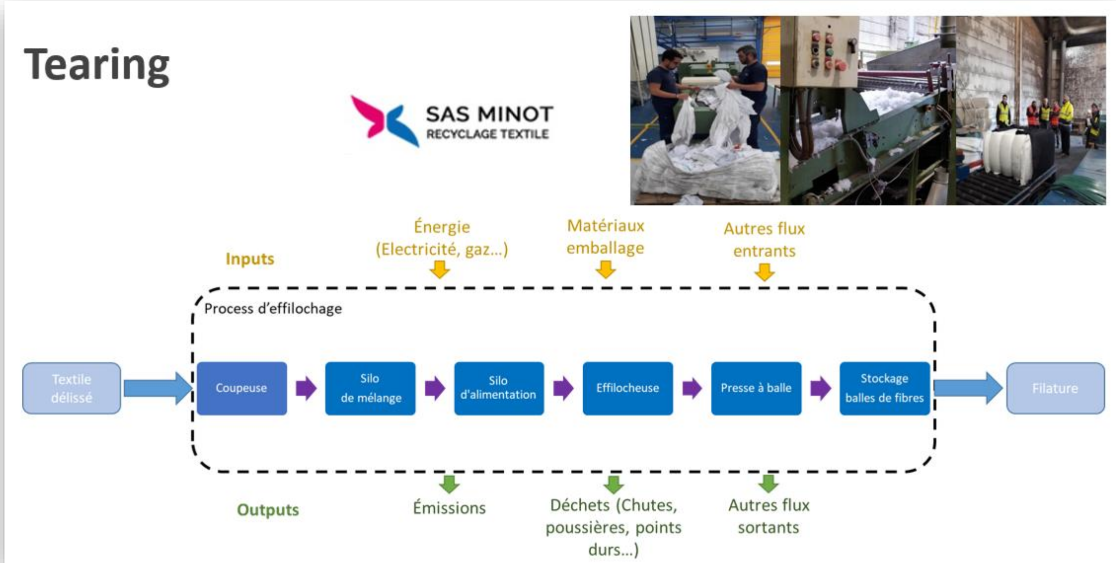
In the case of cotton-polyester waste from post-consumer hospital garments exposed to industrial washing, the cotton fibres are too damaged and shortened to be used after shredding.



To carry out the inventories, we have broken down each step into sub-processes and collected the related inputs and outputs. In the framework of the agreement, this is done by manual unravelling

It is a fairly simple process; the inputs are mainly textile waste, and the outputs are unraveled textile and waste for treatment.

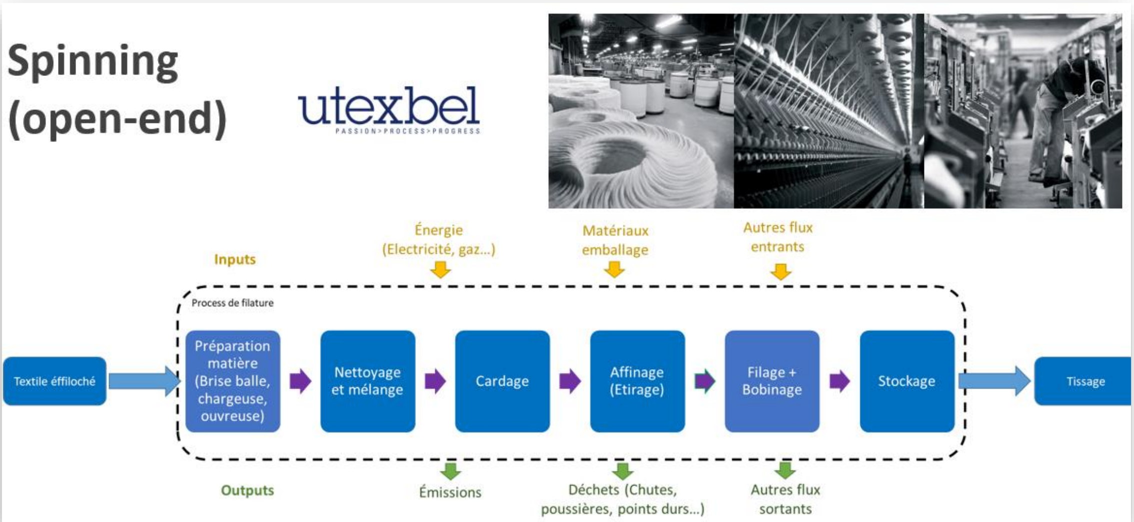
Inputs	Input material flow (textile waste)
	Energy consumption of the site
Outputs	Outgoing material flow
	Waste products and treatments



The fraying process is then broken down mainly into a cutting stage of the unraveled textiles, a mixture, the actual fraying (i.e., to return to the fibre) and the press to create bales of fibre. The data collected are those related to material consumption (the unraveled textile), the energy consumed during the process (cutting, fraying, pressing), the packaging.

In the case of output flows, we have mainly defined the quantity of fibre obtained and the waste generated (remains of hard points, dust, etc.) as well as their treatment process

Inputs	Input material flow
	Process energy consumption (fraying, press)
	Other site energy consumption
	Packaging
	Machinery
Outputs	Outgoing material flow (cotton/polyester fibre)
	Wastes produced (textile waste, remnants of button and zipper, dust) and treatments
	Direct emissions from the site



s

Finally, the open-end spinning at Utexbel, with mainly material preparation, carding and spinning + winding to obtain the 30/1 yarn.

In terms of the data collected, we considered:

- Material input streams (frayed fibres, recycled polyester fibres, R-PET fibres and virgin cotton fibres).
- Energy consumption for each sub-process (carding, spinning, etc.)
- Packaging etc.

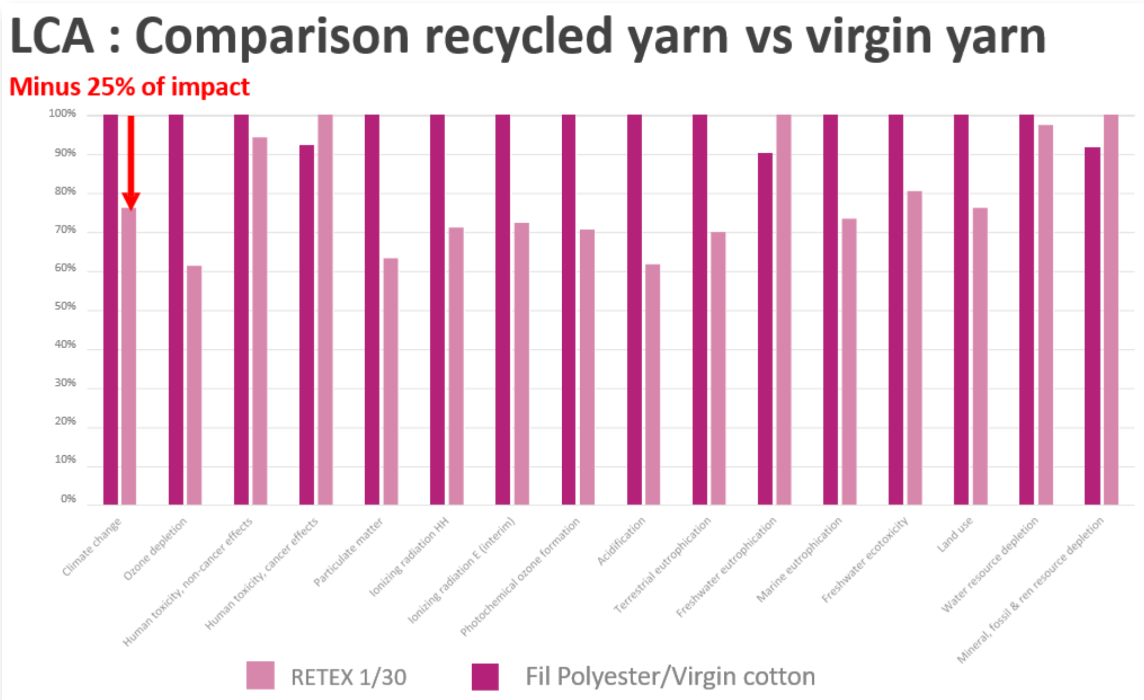
Inputs	Input material flow (Polyester/cotton fibres, polyester fibres, R-PET fibres, virgin cotton fibres)
	Process energy consumption (carding, spinning)
	Other site energy consumption
	Packaging
	Machinery
Outputs	Outgoing material flow (Yarn)
	Wastes produced (textile losses, dust) and treatments
	Direct emissions from the site

And for the outflows, mainly the product flow (cotton-polyester yarn) as well as the production waste and its treatment.

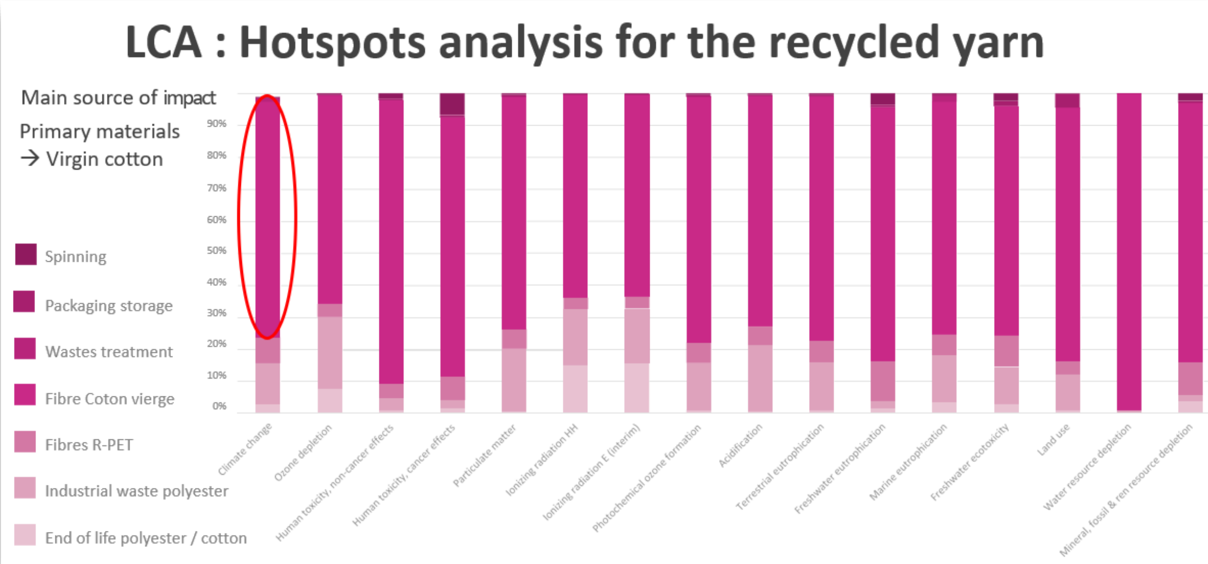
This will allow us to collect all the inventory data for our product.

To give you an example of what we can do with this data, the objective is to model it for an LCA

Here the inventory of Retex yarn compared with a 100% virgin yarn



In dark purple you have the 100% virgin PE-CO yarn and in lighter purple the recycled yarn. **If we look at the CO2 indicator,** which is the one that speaks to most people, **we see a 25% reduction in impact by using recycled material.**



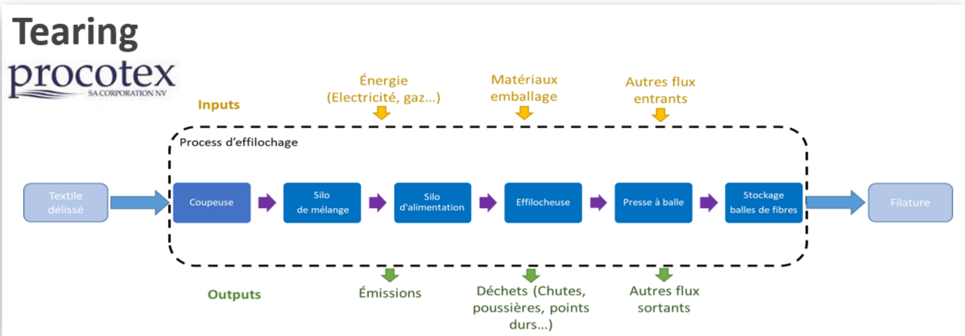
If we look at the details of the recycled yarn, we can see that **70% of the impact comes from the added virgin cotton (which is a known polluting material).** One possibility to improve the environmental balance of the product would be to integrate recycled cotton fibre.

LCI - 100% coton value chain

We are based on a recycling of 100% cotton waste from production off-cuts. The waste was supplied by the clothing manufacturers Petit bateau and Lemahieu and is considered to have no hard point as it comes from offcuts. The fraying was done by Procotex and the spinning by ESG.

We studied the production of **one kg of 100% cotton yarn of metric number 25/1 Nm**.

The yarn is made of a mixture of recycled and virgin fibres.



The fraying phase is essentially identical to the one carried out for the cotton-polyester waste value chain, except that here it is carried out by Procotex with different machinery and settings

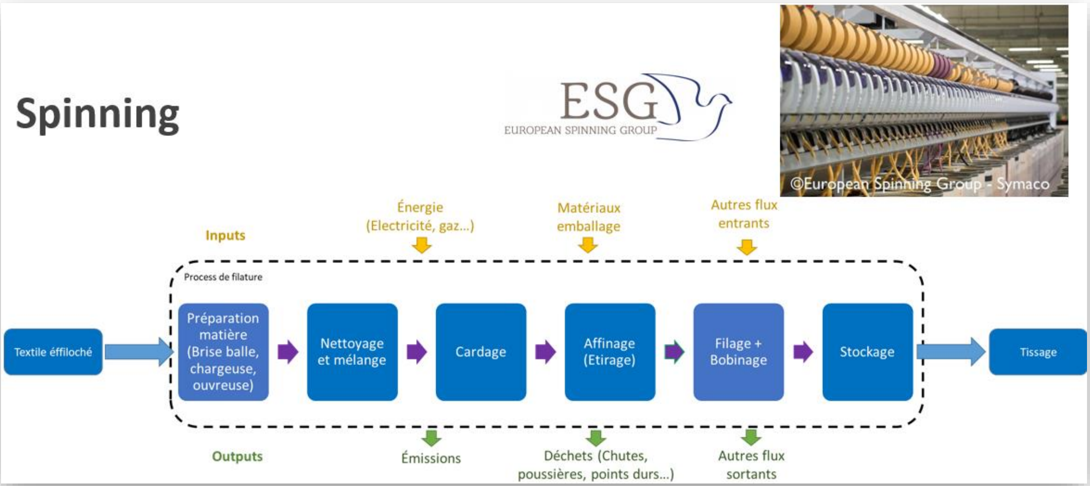
But there are also the stages of cutting the waste, fraying and baling the fibres.
The data collected is also incoming:

- Quantities of cotton production waste,
- The energy consumption of the process
- Packaging, ...

Output:

- The quantity of cotton fibre produced
- Waste and its associated treatments.

Inputs	Input material flow
	Process energy consumption (fraying, press)
	Other site energy consumption
	Packaging
	Machinery
Outputs	Outgoing material flow (cotton/polyester fibre)
	Wastes produced (textile waste, dust) and treatments
	Direct emissions from the site



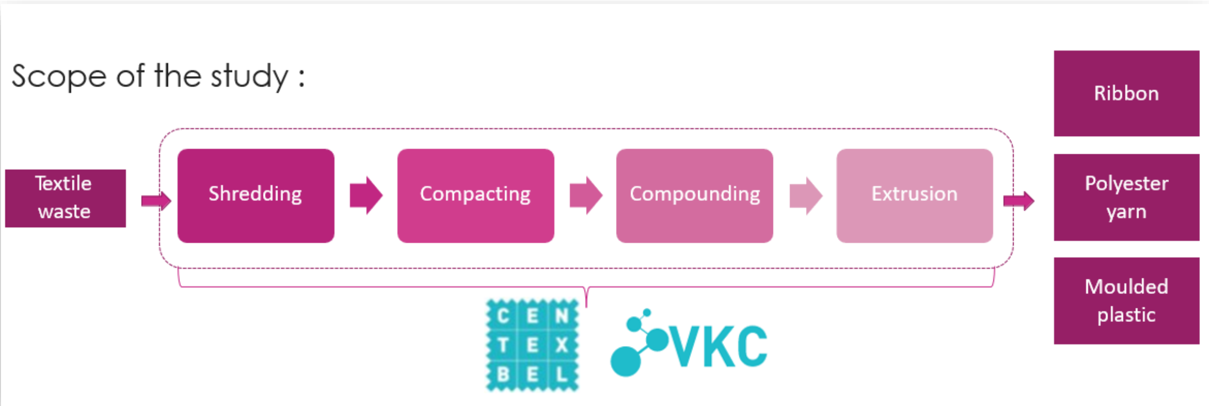
For the spinning phase, ESG has carried out this stage for this value chain. The spinning process is classical, with a preparation of the material, a carding stage before spinning the yarn.

For this stage, the inventory data for the production of the yarn includes

- The consumption of cotton fibres from the fraying process and of virgin cotton fibres,
- Energy consumption for the different stages of spinning,
- Production waste and offcuts as well as associated treatments.

Inputs	Input material flow (recycled cotton fibres, virgin cotton fibres)
	Process energy consumption (carding, spinning)
	Other site energy consumption
	Packaging
	Machinery
Outputs	Outgoing material flow (Yarn)
	Wastes produced (textile losses, dust) and treatments
	Direct emissions from the site

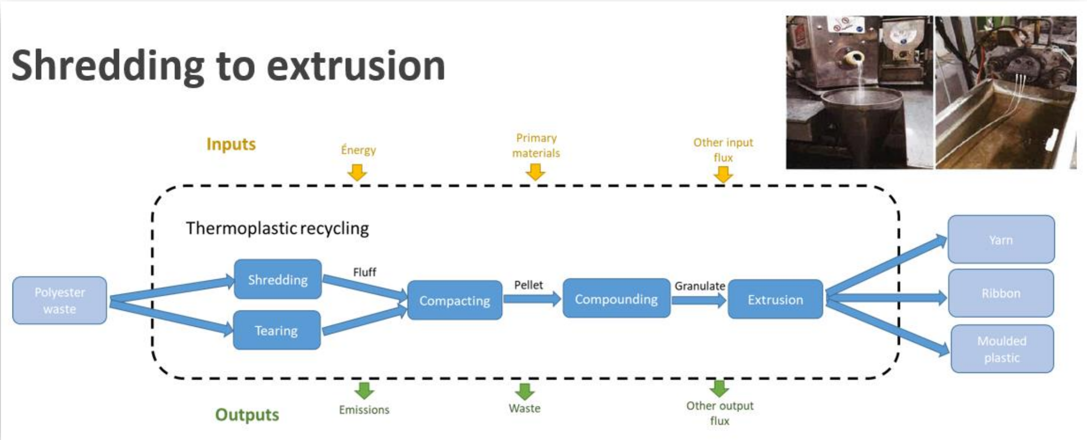
LCI - 100% polyester value chain



The entire recycling process has been implemented at Centexbel - VKC.
At the input, we take into account production offcuts. The waste therefore does not require a splitting stage.
The splitting process consists of 4 steps:

- Shredding of the waste,
- Compacting the resulting fibres,
- A Compounding stage,
- Extrusion of the finished products.

To illustrate, we consider the **production of a multifilament yarn (24 filaments) of 200 Dtex. The yarn will be composed of 50% polyester from recycled polyester waste and 50% virgin polyester**.

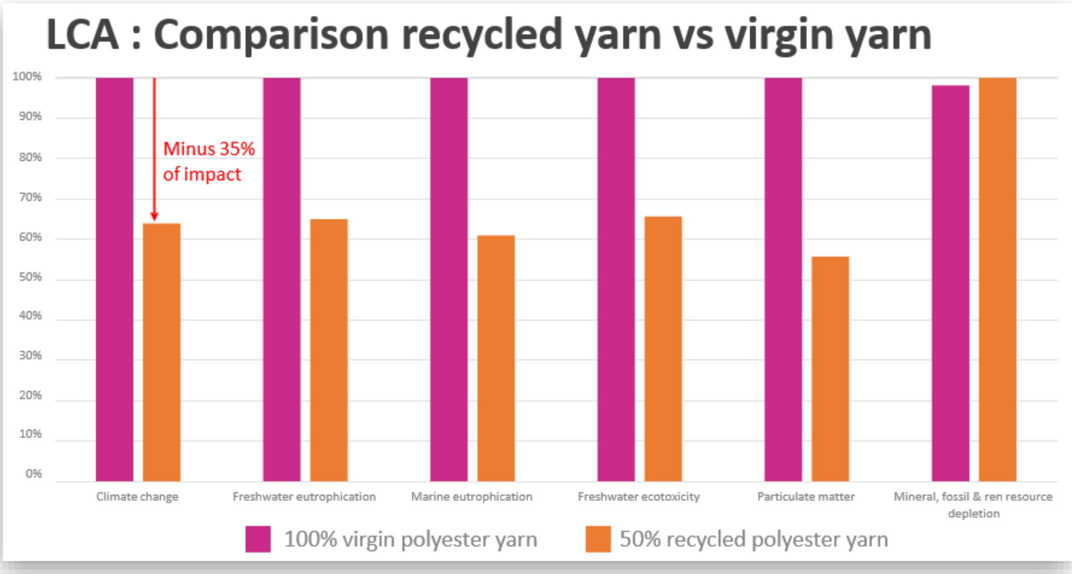


The boundaries of the system studied are as follows:

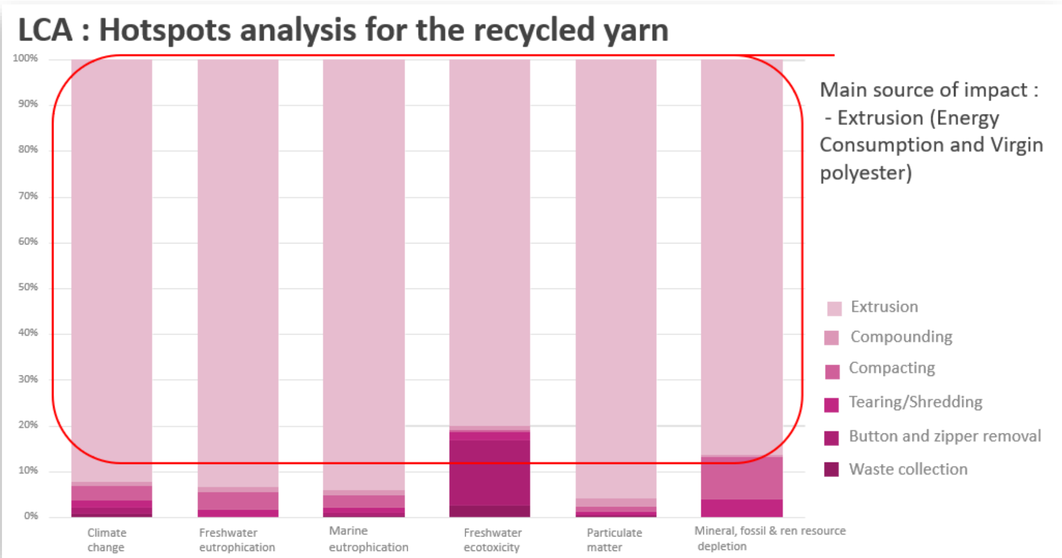
- The polyester waste is shredded to obtain the fibre,
- The fibre itself is then compacted to produce pellets,
- These pellets are compounded by adding a chemical additive, the "booster", which fluidises the polyester and forms granules.
- These granules are then dried and mixed with virgin polyester granules to extrude the final products from the perimeter.

In terms of data collection, we considered material consumption (waste polyester, booster, polyester, virgin, etc.). All energy consumption for each sub-process (shredding, compacting, etc.).
In outflows, we consider the flows produced, the waste and its treatment as well as all other direct emissions

Inputs	Input material flow (polyester waste, booster, etc.)
	Process energy consumption (shreddind, compacting, etc.)
	Packaging
	Machinery
Outputs	Outgoing material flow (yarn)
	Wastes produced and treatments
	Direct emissions from the site



Here is a case of comparison in life cycle assessment (LCA), using the inventory of the yarn from the recycling process implemented in this value chain, with an equivalent yarn but produced from 100% virgin cotton fibre.
The comparison is based on the production of 1kg of 200 Dtex yarn, produced in the context of a Belgian spinning mill, thus with the Belgian energy mix.
Illustration of 6 indicators: on the left the indicator on climate change, then a series of indicators on water pollution and on the right the depletion of resources.
Purple is the yarn produced from 100% virgin material and orange is the yarn produced in the Retex value chain.
Looking at the climate change indicator, there is a 35% reduction in impact when recycled material is incorporated.



If we look at the detail of the impacts per stage of this value chain, we can see that on all the indicators, it is the extrusion phase that represents 80 to more than 90% of the impact. This is mainly due to the energy consumed in extrusion and the addition of 50% virgin polyester.

All the information is on the website www.dotheretex.eu
Technical data sheets, economic evaluation, LCI.

Perspectives

Under construction

Thanks

To the organization's that responded to the flow questionnaire / participated in the working groups

AUNDE BELGIUM
BERRY GLOBAL (BERRY PLASTICS)
BEXCO NV
CELESTA NV
CENTRE TERRE & PIERRE
CHARGEURS ENTOILAGE
COPACO SCREENWEAVERS N.V.
CROIX ROUGE
CS PLASTIC
DE POORTERE FRERES
DELORGE
DELTRACON
DEPOORTERE FRERES
EMPIRE CARPETS INTERNATIONAL NV
ESG EUROPEAN SPINNING GROUP
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PROCOTEX CORPORATION SA
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