WP T2 – INNOVATION ON TEXTILE WASTE MANAGEMENT

ACTIVITY A.T2.3 PILOT CASES

D.T2.3.4

Pilot Cases Feasibility Study

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Partner:

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CONTENT

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ENTeR - Expert Network on Textile Recycling

ENTeR works in five central European countries that are involved in the textile business, to promote innovative solutions for waste management that will result in a circular economy approach to making textiles.

The project will help to accelerate collaboration among the involved textile territories, promoting a joint offer of innovative services by the main local research centres and business associations ("virtual centre"), involving also public stakeholders in defining a strategic agenda and related action plan, in order to link and drive the circular economy consideration and strategic actions.

The approach of the proposal and the cooperation between the partners is oriented to the management and optimization of waste, in a Life Cycle Design (or Ecodesign) perspective.

1. Pilot case - production of recycled aramid yarn from pre-consumer professional garments

1.1. Introduction

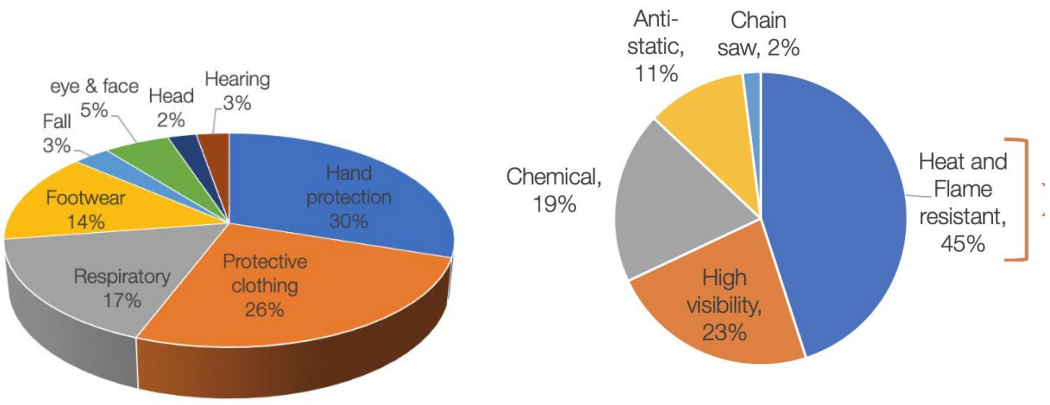
The aim of the present pilot case is to implement a practical excercise of recovery, recycle and reuse in the field of professional flame-retardant workwear, in order to analyse the technical and economical feasibility of the process.

This study covers only a part, though the most significant, of a whole circular supply chain in the specific industrial sector. In fact we have started from pre-consumer (or post-industrial) garments and the final output is the resulting recycled yarn. The upstream supply flow in case of post-consumer apparel (including sanitization) and the downstream flow from yarn to fabric and new garment have not been considered in this pilot case (see Annex 1).

Two different materials sources have been taken into account, with the objective of having different situations in relation with composition and structure of the garments. In particular the aim is to obtain a recycled yarn in original blue color for CASE A and a multicolor (millefiori) yarn for CASE B.

2. DEFINITION AND ANALYSIS OF A CIRCULAR SUPPLY CHAIN FOR FR PROTECTIVE GARMENTS

2.1. The European PPE market



Total PPE 10.8 billion $ in 2019

Europe is the second largest PPE (Personal Protective Equipment) market in the world after North America. The PPE market in Europe is about 10.8 billion $ in revenue. Protective clothing is the second largest PPE category representing a quarter of the PPE market.

FR protective clothing market represents about 45% of the total protective clothing market.

2.2. FR (fire-retardant and fire-resistant) Protective clothing: fibre in use

In thermal protective clothing, there is a need for high-performance fire-retardant/resistant textile fibers. There are two main categories of fire-retardant and fire-resistant fibers:

Fire-retardant fibers

Fire-retardant fibers are of chemically modified fibers. Flame retardant fibers are not flame-resistant or flame-proof but they are designed to slow down the spread of fire. They might also be self-extinguishing. When exposed to heat or flame, the chemical application will expel gases to help to suppress and slow the spread of the fire.

Fire-retardant fibers are FR Polyester, FR Nylon, Modacrylic, Viscose FR.

Fire-resistant fibers

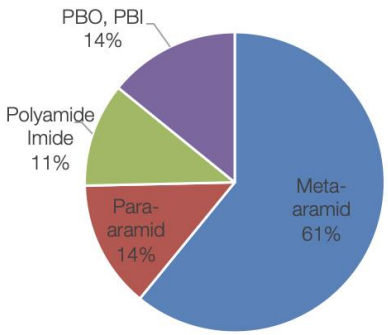
Fabrics made with fire-resistant fibers are inherently flame resistant. These fabrics will not melt, drip or support combustion in the air.

When exposed to extreme heat, flame resistant fibers changes its properties This reaction increases the protective barrier between the heat source and the skin when workers need it most.

Main flame resistant fibers are: Meta-Aramid (Nomex®, Teijinconex®, Heracron®), Para-Aramid (Kevlar®, Twaron®), Polyamide Imide (Kermel®), Polybenzimidazole (PBI), Polybenzobisoxazole (PBO).

The preference today is to use fibre blends that take advantage of the beneficial properties of several fibre types.

Meta and para-aramid are the main inherently fire-resistant fibres used in protective clothing.



Use of fire-resistant fibers in FR protective clothing

2.3. PPE and sustainability

Due to the pandemic, the use and disposal of single use Personal Protective Equipment (PPE) has reached unprecedented levels. All the debate about sustainable PPE is nowadays around the protective equipments related to healthcare, which is fully comprehensible and most probably beneficial for a more long-term sensitivity for the subject in other, broader areas of professional workwear.

This situation should have a positive impact on how Governments and Public Administrations will review their specs for PPE supplies, not only for medical and healthcare protection, but in all sectors. The New Green Deal Program in the EU will also be a strong driver for such a move.

Already in pre-COVID19 era, some encouraging signs of increased attention towards a sustainable supply chain in PPE have been introduced in the setup of calls for garments and uniforms, with a "bonus" for proposals that could guarantee a reliable and traceable use of recycled materials in the process.

For what concerns FR protective clothing, the technical performance and consequent compliance to severe standards and norms are apparently a constraint and risk to be an obstacle for the use of recycled textiles.

With the present study we focus the attention on how both technical performance and sustainability can match, if we look into garment construction with accuracy.

3. TEXTILE WASTES: LAWS AND NORMS

3.1. Currents norms in Italy and EU

Despite the textile and apparel business is global with involvement of many countries worldwide, the regulations around the management of textile wastes remain at local level. This situation does not help in having a global overview and a strategic vision for a harmonized approach to circular economy in this industry.

We will then focus our attention to the reference the legislation in Italy and at EU level.

Hereunder the milestones of the regulation system around waste and by-products, including textile and apparel.

1. DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 April 2006 on waste
2. Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste
3. COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT on the Interpretative Communication on waste and by-products, 21.02.2007
4. DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 on waste and repealing certain Directives

5. DECRETO LEGISLATIVO 3 aprile 2006, n. 152 Norme in materia ambientale.
6. MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE, DECRETO 13 ottobre 2016 , n. 264 . Regolamento recante criteri indicativi per agevolare la dimostrazione della sussistenza dei requisiti per la qualifica dei residui di produzione come sottoprodotti e non come rifiuti.
7. MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE, Circolare 30 maggio 2017, prot. n. 7619 - Circolare esplicativa per l'applicazione del decreto ministeriale 13 ottobre 2016, n. 264
8. Legge n. 128/2019, art. 14/bis (Cessazione della qualifica di rifiuto).
9. REGIONE TOSCANA - Delibera Giunta Regionale n.12 del 13-01-2020 - PRIME LINEE GUIDA PER L'APPLICAZIONE DEL REGIME DI SOTTOPRODOTTO NELL'INDUSTRIA TESSILE

3.2. Threats and opportunities vs. a circular economy approach

The big effort made since 2006 in regulation at European and national level was essentially driven by the increased attention to environment and the necessity to fight against illicit and criminal trade and treatment of wastes.

In the following 15 years the growing sensitivity to circular economy has led the legislators to integrate more and more rules and consequent procedures about the recover-recycle-reuse process.

The result is a quite complex and knotty bureaucratic system that can sometimes discourage the textile/apparel players to fully play the game and consider circular economy a priority in their business strategy.

Two main topics are still worth to be better analyzed with the aim of defining simpler and clearer rules, where both respect of legal principles and good business practice can match in a win-win perspective:

- Difference between waste and by-products in all the steps of the supply chain. This is particularly important for the recovery of pre-consumer (or post-industrial) materials.
- Harmonization of import/export procedures as far as textile wastes or by-products are concerned, since it is well know that most of the garment manufacturing (and sometimes the fabric manufacturing) is located outside Italy and the UE.

Branded certification systems for traceability and consequent reliability of a recycled material, such as GRS – Textile Exchange are for sure welcome in this scenario.

Its worldwide diffusion is undoubtedly a boost for the industry and a very interesting strategic marketing axe to be developed and continuously updated and improved.

In particular a more streamlined certification management system could be more effective where the supply chain is fragmented among many small-medium enterprises (SME) with involvement of different textile materials, such as the Prato district, where the circular economy in textile was probably born two centuries ago.

4. A CASE STUDY. SETUP OF A "CIRCULAR" SUPPLY CHAIN FOR FR GARMENTS BASED ON ARAMID FIBERS

4.1. Aramid fibers and their applications in flame resistant protective clothing

The characteristics of aramid fibers are particularly significant for all end uses where the protection from heat, flame and fire are concerned.

In particular:

- Military and Police
- Firefighters
- Industry
- Performance sportswear (eg. Motorsport racewear)

Aramid fibers are man-made high-performance fibers, with molecules that are characterized by relatively rigid polymer chains. The term "aramid" is short for "aromatic polyamide". Aromatic polyamides were first applied commercially as meta-aramid fibers in the early 1960s, with para-aramid fibers being developed in the 1960s and 1970s.

The main differences between meta- and para-aramid are linked to their production process (wet or dry spinning) and to the crystallinity level of their molecular structure.

As far as protective clothing against heat, flame and fire are concerned, meta-aramid fibre is the most suitable thanks to its high resistance to temperature (it does not burn or melt), chemical degradation and abrasion, as well as it is dyeable and has a relatively soft touch and feel.

The production of meta-aramid fiber is in the hand of a few man-made fibers producers in the world, such as DuPont (Nomex®), Teijin (Teijinconex®), Kolon (Heracron®),as well as some manufacturers in China. As a further step in the textile chain, the fibre is then transformed into yarn. In case of meta-aramid, staple yarn technology is dominant, while continuous filament production is negligible. Generally speaking the fibre producers are not vertically integrated with the spinning phase, so that they do not sell meta-aramid yarns on the marketplace.

The number of spinning companies who offer spun meta-aramid yarns is higher than the fibre producers, but it is still a limited group of specialized players.

In order to enhance its performance in protective clothing and the compliance to international standards of related fabrics and garments, the meta-aramid fibre is very often used in combination with other fibres that can also contribute for different end use requirements, such as comfort and look. Blends with para-aramid, viscose FR, nylon and antistatic fibres are the most common.

4.2. The current supply chain

There are two macro categories of products subject to end-of-life treatment. The first are the textile waste that comes from the production of yarns and fabrics, from the processes of clothing cut and sew and unsold stocks. In all these cases we can talk about post-industrial or “pre-consumer” waste.

The other category is that of textile waste after use, so called post-consumer waste. The life average of a piece of protective clothing can vary a lot from case to case. Unlike fashion clothing, which is often placed in charity circuits (organized sales, collections, donations) , protective clothing end on their life cycle in landfills or burnt in thermal incineration plants.

A typical supply chain for protective clothing, with aramid fibres ingredients is described in Annex 1.

In Annex 2 the process flow of recover, recycle, reuse is shown in synthesis.

5. A PILOT CASE: PRODUCTION OF RECYCLED ARAMID YARN FROM PRE-CONSUMER PROTECTIVE GARMENTS

We have considered that the best way to challenge the "core" of the process flow described in Annex 1 and 2 was to set up a pilot case.

The aim of the pilot case is to implement a practical exercise of recovery, recycle and reuse in the field of professional flame-retardant workwear, in order to check the technical and economic feasibility of the process.

Two different materials sources have been considered, with the objective of having different situations in relation with composition and structure of the garments.

The two suppliers are major Italian brands, specialized in professional workwear, particularly focussed on heat and fire protective-wear. Both have been briefed about the target of the project and have been very keen to make their materials available for the pilot case implementation.

5.1. The size of the pilot case

The pilot case has been run with a total of 56 pieces of clothing, coming from two different sources, in particular from the warehouses of the two suppliers, before being sold to customers and therefore in a pre-consumer status.

The following garments have been utilized for the pilot case:

1. CASE A: N. 15 complete "non operational" uniforms (15 jackets+ 15 trousers) of firefighters with the following characteristics:
   - Composition: 70% meta-aramid – 28 % viscose FR – 2% antistatic
   - Total weight: 16,7 Kg
   - Colour: navy blue
   - Simple structure, no linings, limited number of accessories (reflective tapes, zips, buttons, hook and loops, embroideries and labels)

2. CASE B: N. 26 trousers and "salopettes" of forest fireguards with the following characteristics:
   - Composition:
     - outer layer: 93% meta-aramid – 5% para-aramid – 2% antistatic
     - inner layer: 50% preox – 25% meta-aramid – 25% viscose FR + PU membrane
   - Total weight: 34,8 Kg
   - Colour: Outer layer orange and blue, inner layers black
   - Complex structure, with two main layers, waterproof breathable membrane, large number of accessories (elastic tapes, reflective tapes, zips, buttons, hook and loops and labels)

The objective has been to test different situations in relation with composition and structure of the garments. In particular the aim has been to obtain a recycled yarn in original blue colour for CASE A and a multicolour (millefiori) yarn for CASE B.

5.2. Description of the production and logistics process flow

The garments have been shipped by courier – no particular precaution needed for pre-consumer apparel – to the selected dismantling platform, a "cooperativa sociale" in Biella area.

Before proceeding to the dismantling operation, the selection criteria have been agreed, which means which parts of the garments had to be kept for the recovery and which parts had to be put apart, because not relevant for the purpose of the project. In particular:

CASE A (qty per uniform):

- 5 reflective tapes
- 3 buttons
- 8 zips
- 2 woven labels
- 2 embroideries
- 36 hook and loops
- 4 plastic hook

CASE B (qty per trouser/salopette):

- 2/6 reflective tapes
- 4/26 buttons
- 1/1 woven labels
- 14/14 hook and loops
- 1/1 elastic tapes
- PU membrane

After a preliminary qualitative check with Filatura di Soprana, the materials for recover have been eventually separated, prepared and shipped to the fraying unit for the second step of the pilot case - fraying and garnetting.

The fraying and garneting operations have been set up in third part companies under the technical control of Filatura di Soprana.

As expected, both fraying and garnetting phases have suffered low yield due to the reduced amount of treated material (waste is respectively 80% in fraying and 32% to 37% for garnetting), but, according to the material quality and the industrial experience, a standard yield of respectively 94% and 88% could be easily reached in case of standard volumes (> 500 Kg per batch).

The materials issued from these preliminary operations have been consequently prepared and shipped to the spinning unit in Filatura di Soprana for carding and spinning, the core process for the production of a recycled yarn.

A preparation phase is needed, where the raw material coming from the garnetting is blended and homogenized with a targeted quantity of original staple and/or recovered laps in order to assure a regular quality and reliable textile characteristics of the resulting spun yarn.

For both cases of the pilot project a final count of Nm 14/1 has been targeted for the resulting spun yarns. As a consequence, the following blends have been prepared:

CASE A: 50% material from garnetting – 50 % recovered laps, navy blue dyed 100% meta-aramide

CASE B: 70% material from garnetting – 30% original staple fiber 100% meta-aramide greige

In both cases the carding and spinning process has run smoothly, with no significant issues in the machines.

The only remark is once more linked to the small quantities that have led to poor yields. This situation was however totally expected, and not particularly worrying if we consider an upscale to industrial trial size.

The output from the spinning line has been the final product of the pilot case.

5.3. Mass balance and technical-economic data

For the Pilot Case, two types of yarn were obtained (CASE A and CASE B), whose technical characteristics are tested in the CENTROCOT laboratories.

In Annex 3, the final mass balance for both cases are reported, as well as the cost structure by phase and as a whole process. As far as costs are concerned, the reported value refer to a projection of semi-industrial volumes (1000 Kg of initial material) and not strictly to the size of the pilot case, where the small treated quantities have affected the yield in processing.

6. CONCLUSIONS AND RECOMMENDATIONS

The main outcome of the present analysis is that it has been proven – even if on a small pilot scale – that technically reliable recycled yarns, based on aramid fibers, can be industrially produced from recovery of dismissed protective garments.

The most important deliverable is that the key players in the “core” process, the dismantling and selection platform, the preparation steps for re-spinning and the carding/spinning itself have delivered a yarn with reasonable textile characteristics and comparable costs vs. an “original” aramid based yarn.

A more conservative approach in recycled material re-use is also possible, with no major technical issues. After the garnetting phase the resulting secondary raw material can effectively used for nonwoven production, wherever FR characteristics are required.

In case of post-consumer material, two main topics have to be thoroughly considered:

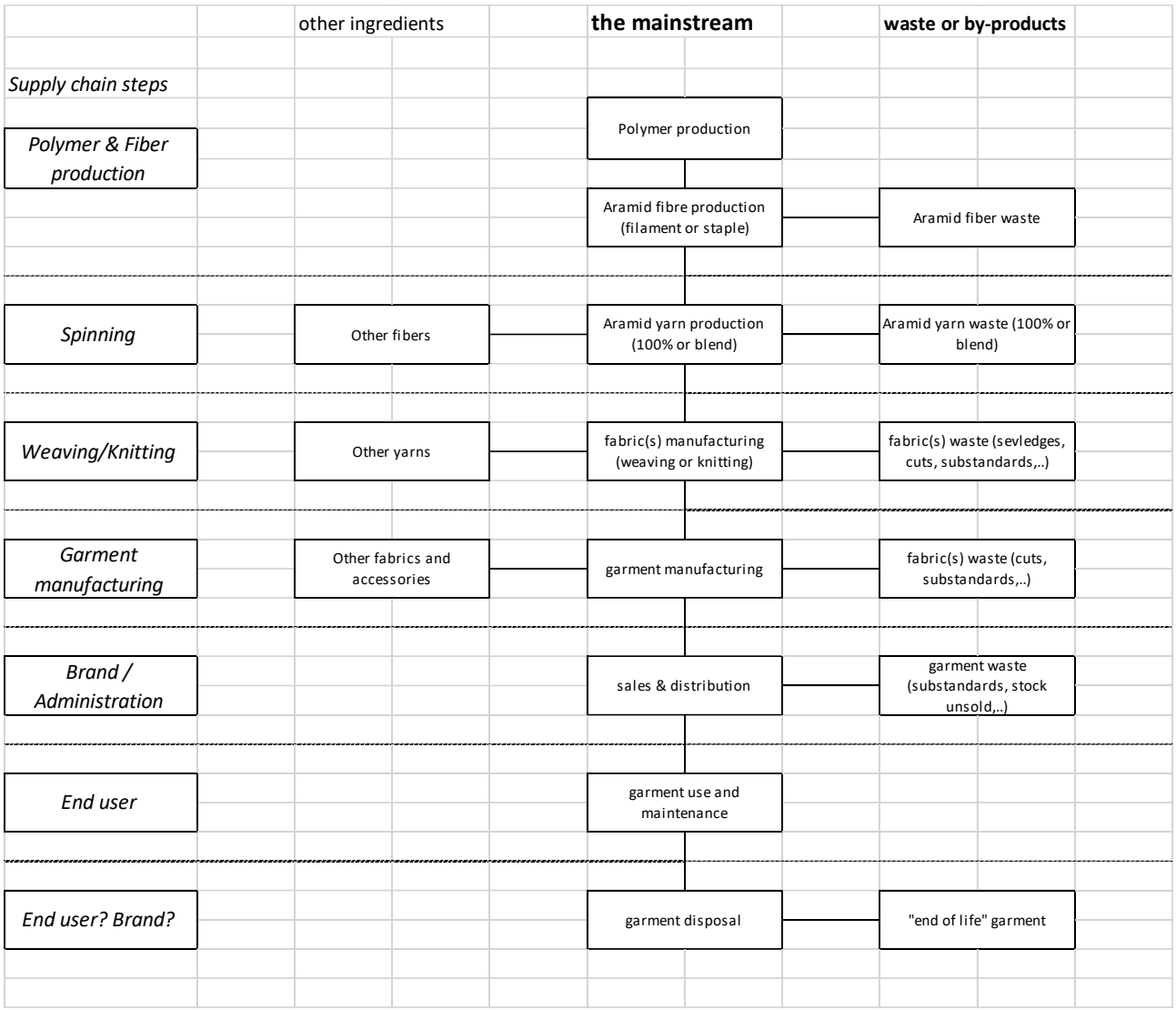
- Logistics, or how to move the “end of life” garments from the final user back to the sanitizing/dismantling platform
- Regulation, or how to handle each single step of storage and transport, being aware that the material will remain a non-dangerous special waste till when it will be transformed into secondary raw material in the dismantling platform.

The Pilot Case has been a very interesting excercise that encourages a further step in the direction of a “circular” supply chain for PPE (Personal Protective Equipment).

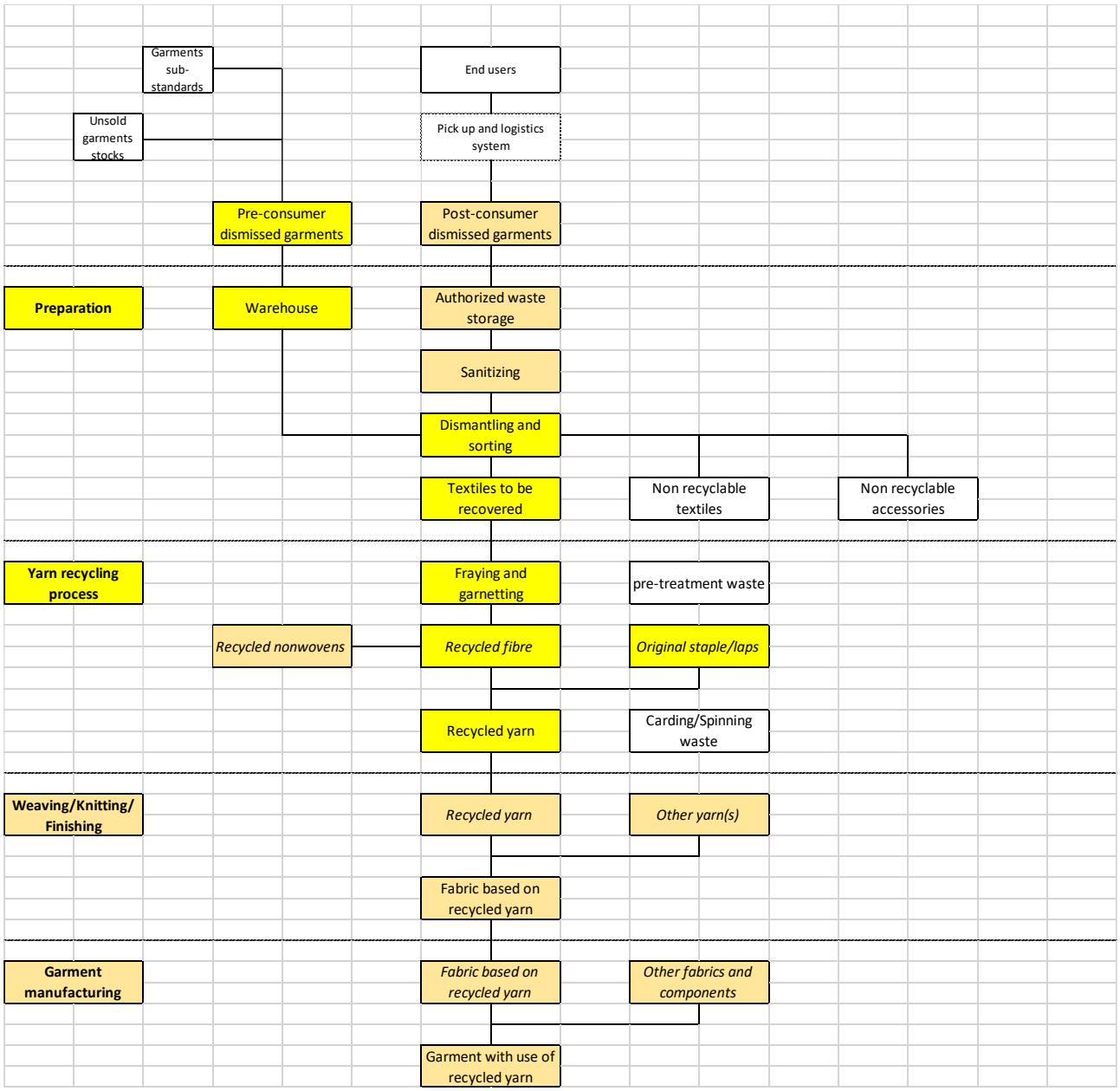
There are concrete opportunities to consider the dismissed fire-retardant uniforms as a valuable source for recycling high added value fibres, such as aramids.

The design of the garments plays a relevant role in terms of economical impact on the recycling process. The higher the number of different components, ingredient materials and garment complexity, the lower is the process yield. It is clear that in this field the technical and protection performance is THE priority, but there should be room for improvement at design stage in order to get more benefits in recovering-recycling-reusing.

7. Annex 1 - The current supply chain for FR (aramid based) protective clothing



8. Annex 2 - The process flow for a circular supply chain in protective garments.



9. Annex 3 – Pilot case: Mass balance and cost structure

Annex 4 - Mass balance and cost structure CASE A

					Reference initial weight (Kg)	Unit cost of phase (Euro/Kg)	Total cost of phase (Euro)	Cumulated process cost (Euro)	Cumulated process cost per Kg (Euro/Kg)
	Post-consumer garments logistics								
	100				1000	*0,05*	*50*	*50*	
	Authorized waste transport								
	100				1000	*0,10*	*100*	*150*	
Preparation	Warehouse								
	100				1000	*0,05*	*50*	*200*	
	Sanitizing								
	100				1000	*0,00*	*0*	*200*	
	Dismantling and sorting								
	100				1000	*1,50*	*1500*	*1700*	
	Textiles to be recovered								
	91				910				
		Non recyclable textiles		Non recyclable accessories					
		0		9	90	*0,18*	*16*	*1716*	
Spinning process	Fraying	Fraying waste							
	94	6			855	*0,30*	*273*	*1989*	
	Garnetting	Garnetting waste							
	88	12			753	*1,20*	*1026*	*3016*	4,00620656
	Recycled fibre	*Original staple/laps*							
	70	*30*			323	*20,00*	*6452*	*9468*	9,7826051
	Recycled yarn	Carding/Spinning waste							
	90	10			968	*7,00*	*7528*	*16995*	17,5603829

RELEVANT STEPS IN THE PRESENT PILOT CASE

NOT APPLIED PROCESS STEPS IN THE PRESENT IN THE PILOT CASE