Ecodesign in the Textile Sector

Unit 08: Recycling processes in the textile industry.

Paolo Ghezzo. paolo.ghezzo@centrocot.it
Roberto Vannucci. roberto.vannucci@centrocot.it

With this unit, the student will be able to:

- to learn about the different recycling processes applicable to the different stages of textile production;
- know the necessary information on the possible use of recycled materials in the design phase;
- Know the main "best practices" for environmental sustainability in the design phase.

Funded by the Erasmus+ Programme of the European Union

Ecoinnovation Skills for European Designers, Project number: 562573-EPP-1-2015-1-SI-EPPKA2-SSA. Disclaimer: The European Commission support for the production of this publication does not constitute endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsi-ble for any use which may be made of the information contained therein

8.1. Introduction

The textile industry as a whole generates a wide range of products of the world production system; this is one of the most articulated among the different industrial sectors. For this reason, the textile sector, made up of both large groups and numerous SMEs, presents itself as fragmented and heterogeneous, with one of the longest and most complex supply chains in the manufacturing industry.

The traditional model "take, produce, discard[1]", that does not pay attention to materials at the end of their life, must be modified in a model that can give new value to waste, including the replacement of the concept of "disposable" products with a view to enhancing the value of the waste or waste in the resource.

This perspective stimulates the use of specific techniques aimed at extending the life cycle of textile products and converting waste or end of life goods into new materials or products.

This type of approach is linked to the development of new production models[2], which provide for recycling and reuse of products, and the development of materials and technical solutions that ensure better performance.

This approach, which undermines the current production model of improving the quality of materials/increased production, requires a holistic vision of the available technology sector, a vision that, due to increasing awareness and continuous technological development, must be continuously updated.

The fundamental concepts for the creation of a sustainable system are the reduction of the consumption of primary resources (raw materials, energy, etc.) and the reuse and recycling of materials, products and by-products (including energy waste).

In other words, the objective is to adopt an economic system aimed at reducing the waste generated by a production system (design, production and distribution, use, maintenance and consumption, disposal) and, ideally, moves towards the complete elimination of waste and the full self-sustainability of the process.

Where applied, the closed-loop system has led to the optimisation of materials that can be reused again, such as raw materials or products or components, and has reduced the use of raw materials with significant energy savings.

The approach to sustainable management obviously also applies to the entire textile supply chain. More attention to processing processes, techniques and product design means focusing on improving materials in order to reduce waste (e.g. resistance to more wash cycles and/or less tendency to get dirty during use), transforming products or

[1] Defined as "linear economy", as opposed to the new "circular economy" approach.

[2] For example, also to cope with the economic crisis that has been developing for a decade through the Western world, systems of rental of textile materials - instead of sales - or even sales chains of used products.

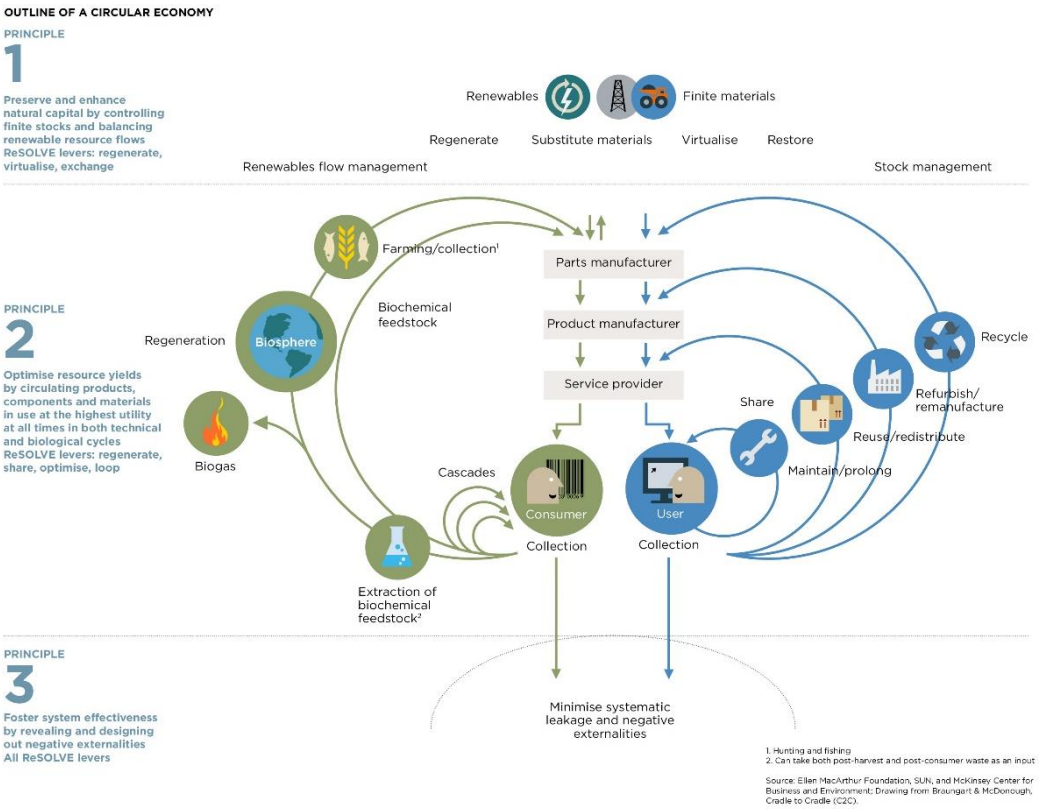
giving them a new life through refurbishment or a new destination and, finally, recycling and using closed-loops system for production/consume/reuse: all these approaches can be adopted in a sustainable strategy.

8.2 Circular Economy

In contrast to the traditional linear model ("take, produce, discard") a sustainable approach has been defined over the years, ideally tending towards the zero impact generated by human activity, defined as "circular economy".

The model, proposed by the NGO (non-governmental organisation) Ellen MacArthur Foundation [3], analyses them and outlines the different ways of moving towards sustainable management[4].

A circular economy aims to rebuild the capital employed, whether it is financial, productive, human, social or natural



[3] www.ellenmacarthurfoundation.org

[4] The circular economy model synthesizes many major schools of thought. It includes Walter Stahel's "performance Economy"; William McDonough and Michael Braungart's "Cradle to Cradle" design philosophy; "biomimicry" as defined by Janine Benyus; Reid Lifset and Thomas Graedel's industrial ecology; Amory and Hunter Lovins and Paul Hawken's natural capitalism; and Gunter Pauli's approach to blue economy systems.

The strategy adopted is based on the following concepts:

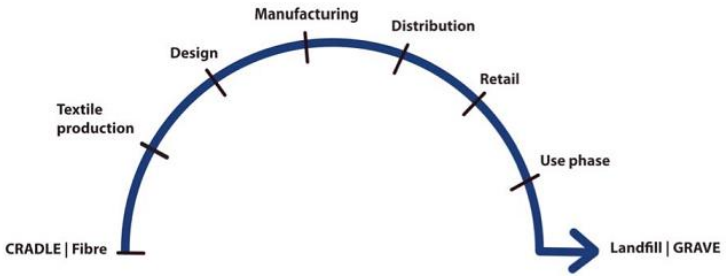
- design in order to avoid waste and pollution (e.g. optimised product and component design);
- maintaining products and materials in use (e.g. materials designed to support multiple disassembly cycles, re-use of materials and component parts);
- regenerating natural systems (e.g. restoration instead of disposal).

For the textile and clothing sector, the Ellen MacArthur Foundation has prepared the report "A new textiles economy: Redesigning fashion's future"[5], which describes a new vision based on the principles of the circular economy is elaborated.

[5] Ellen MacArthur Foundation, A new textiles economy: Redesigning fashion's future, (2017, http://www.ellenmacarthurfoundation.org/publications).

8.3 Approaches to the sustainability of textile products and materials

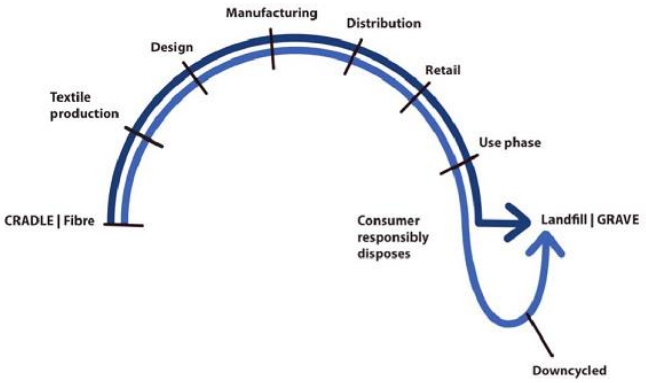
8.3.1 Downcycling



Alice Payne, 2011

A traditional production life cycle involves the production of fibres[6] to create fabrics and final goods (clothes and curtains, for example), through the phases of design and production, followed by distribution and sales, use by consumers and disposal in landfills.

Through downcycling, textile disposal in landfills is postponed as shown in the following figure:

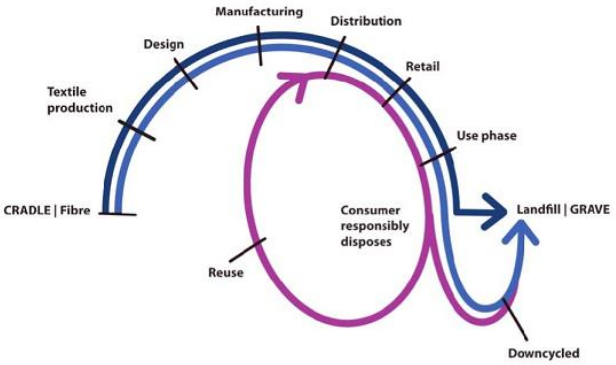


The term downcycling is used when products are recycled and transformed into other materials and/or products of lower value and quality. The transformation processes shorten each time the product is recycled because of the continuous reduction in quality and its value until it is no longer possible to recycle, at which point the product will destined to landfill.

[6] In the case of natural fibers (vegetable or animal), compared to man-made fibers (artificial and synthetic), we speak more properly of growth and collection.

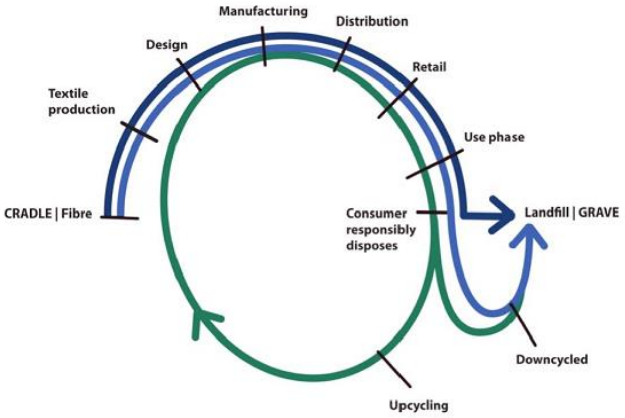
An example in the textile sector is the use of fibres from the process of unravelling rags to make building components (e.g. panels). The fibrous material in this case is used to give the new product characteristics of lightness or thermal insulation or soundproofing depending on the intended use.

8.3.2 Reuse



On the other hand, when consumers decide to give second-hand goods to other people (family members, acquaintances, organisations, etc.), or to sell them at second-hand markets, they are entering a new life cycle. Thus begins a "second life", which resumes the cycle from the distribution phase to move along another phase of use and, potentially, will return to live in other subsequent life cycles, if preserved and repaired with the right attention.

8.3.3 Upcycling

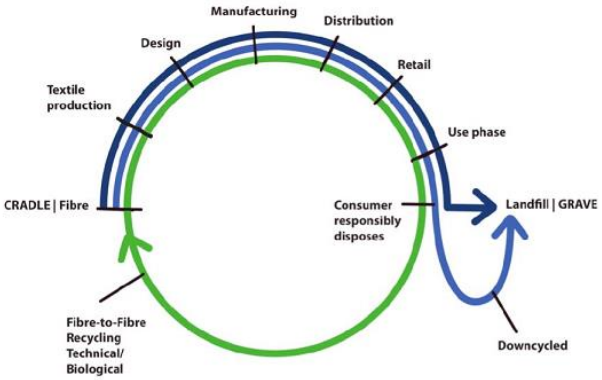


As the term suggests, "upcycling" is a practice that transforms a product at the end of its life into another. The main feature of upcycling is that new products will have the same or better quality or value than the original ones.

Existing clothing or textile products can be transformed into new products, resulting in a new life cycle of the product. This process starts at the design stage, has a positive effect on the entire life cycle and allows more actors to interact.

For example, it indicates the transformation of a waste material into a new fashion element through a creative process. The concept of upcycling is well defined and, above all, very different from the more known term "recycling", which instead describes an industrial process of transformation of waste.

8.3.4 Cradle-to-Cradle



The last example of recycling a product at the end of its life is the "closed loop", which indicates a circular process that starts and ends with the fibre.

This model comes directly from the "Cradle to Cradle" philosophy, in which all types of waste can become a "resource" for new life cycles, as happens in nature.

An example of industrial excellence in circularity is the production of nylon 6 Econyl®, designed and manufactured by the Acquafil [7] group, from 100% regenerated raw materials, from post-consumer waste (finished products composed in whole or in part of polyamide 6 and end-of-life joints) and pre-consumer waste (generated by the production cycle of nylon 6).

The approach to circularity is not only aimed at production efficiency (less use of raw materials, for example) and economic efficiency, but also social and ethical.

The objective is for industry to preserve and enhance nature's ecosystems and biological cycles, while maintaining production cycles, in a kind of "technological metabolism", according to which all materials after use must return to industry to be reused.

To make this possible, a new design approach to products and processes is needed, which consists of assimilating industrial processes to nature in order to use materials that can be regenerated.

[7] www.aquafil.com

8.4 Classification of textile waste

Textile waste can be divided into three main categories:

- pre-consumer textile waste
- post-industrial textile waste
- post-consumer textile waste

Pre-consumption textile waste are waste generated during production processes, such as spinning waste, knitting waste, weaving waste, packaging waste, waste from wet processing of fabrics.

Post-industrial textile waste is generated between the production and the consumption phase. Generally, this is waste generated within the distribution system or for commercial reasons (for example: unsold and stock products).

– Post-consumer textile waste is end-of-life products destined for disposal or landfill: for domestic use, e.g. used clothes. These types of waste can be recovered from the consumer chain through separate urban collection or specific collection actions, for example by charities or by producers themselves;
– for industrial use, e.g. agricultural nets. In this case, as the volumes involved are generally high, the recovery must be specially designed.

8.5 Waste Management Strategies: the "3R" approach

The common approach to disposing of textile waste is to implement waste management strategies, also known as "3Rs": reduction, reuse and recycling. These strategies aim to obtain the greatest potential benefits from products in order to extend their life cycle, first of all by avoiding landfilling. The two macro-areas are divided by type of product treatment: products that do not undergo changes at the end of their life, or products that are brought back to the state of fabric or fibre.

Waste management strategies take place at the end of the industrial process and shall contribute to offsetting the negative environmental impacts of the generation of waste[8].

[8] It is useful to note that, although these strategies intervene in the final stages of the production

They are used to interrupt the linear flow of linear material through the industrial system, i.e. a flow in which raw materials are taken from the environment, processed, used and then released from the system into the environment in the form of emissions and waste.

There are different types of waste management strategies. This chapter analyses three of them, based on the consumption of energy and materials, from the most efficient to the least efficient use of resources:

1. reduction and saving of raw materials and energy consumption
2. product re-use, repair and refurbishment
3. recycling

All of the three strategies described above can be applied to the textile sector and are described in detail below. Every strategy has its strengths and weaknesses, conditioned by a greater or lesser tendency to downcycling the material used.

The recovery of materials used for low cost applications leads to a general reduction in their general characteristics, unlike when they are used for products with a high added value. For example, when different fibres are mixed together to produce a lower quality mix, for example when used as insulating panels or mattress padding, instead of being reused as high value components, such as clothes.

The possibility of improving the characteristics is represented by the upcycling activity in which the recovery and use processes and practices increase the perceived value of a product and the economic returns deriving from the qualitative aspects of the project, based on a mix of factors such as customized production, the use of expensive and scarce materials, and the emotional aspects linked to experience and craftsmanship.

8.5.1 Reduction of raw material and energy consumption

The reduction in the consumption of raw materials, energy and chemicals used in the textile industry is mainly linked to the optimisation of production processes, as well as the development of new technologies[9].

The concepts of "saving" and "reducing" applied to production processes focus on the objective of energy efficiency, in line with strategies to reduce energy costs and water consumption.

These topics are covered in the units:

processes, they must be conceived and developed during the initial design phase of the product and the process for its realisation.

[9] For example: sol-gel processes to give tissues functional characteristics (e.g. hydro- and oleo-repellence) based on treatment cycles at lower temperatures.

- 02 as regards production processes;
- 09 as regards Design and Eco-Design.

8.5.2 Reuse, Repair and Renew products

Re-use is the simplest strategy available: it consists of re-using products as such and allows their life cycle to be extended, targeting new uses, consumers and markets.

This approach requires limited energy consumption as it does not require any particular resources, which are generally limited to collection and resale. In the case of clothing, the energy used to collect, order and resell used clothing can be 10-20 times less than the energy needed for recycling.

For example, the practice of reuse has been adopted in fashion thanks to the "vintage" style, which has become established thanks to specific channels such as auction houses, local markets or online shops, and also by the return of barter and second-hand practice for fashion and accessories.

With reuse, there is great potential for development given the amount of objects discarded by consumers every day. It may be useful to subdivide the consumer's behaviour into categories: a pyramid system in which one can distinguish cutting-edge consumers, opinion leaders, fashion obsessions, followers, etc...

Another important aspect is that reuse can be convenient for both the seller and the buyer as it reduces the use of raw materials and the production of waste, promotes sharing and the mixture of styles and ways of being.

Repairing and refurbishing products is more beneficial than producing new ones, although savings are less than re-use. This is due to the work required to repair the product or give it a new appearance.

Repairing and rearranging textile articles is an old practice, mainly influenced by economic needs (the relationship between labour costs and materials) and the availability of goods.

Typical examples related to family life are the replacement of the collar or cuffs of the shirt, the patches on the elbows of jackets, the parading of knitted garments to obtain the thread and the reuse of old sheets in every possible way.

Excluding the domestic field, repairing and re-setting products requires more resources, usually artisan experience able to work with different types of products. In recent decades, repair, both domestic and artisan has been negatively affected by factors such as:

- reducing the cost of products, especially in the context of fast fashion, which makes it more convenient to buy back rather than repair;
- an increase in labour costs, which leads to a large imbalance in costs when compared with the 'new' product (as indicated above);
- rapid obsolescence of fashion, which immediately makes a product out of date due to frequent style changes;
- consumer behaviours, the common attitude towards the use of repaired products are seen as an indicator of economic restraint.

However, in recent years, thanks to an increased awareness of environmental issues, there has been a growing interest in product repair and maintenance practices.

There are several organisations that promote the culture focused on material efficiency, such as "Occhio del riciclone"[10] (Eye of recycling-man) which explore the potential offered by reuse as a practice to be re-evaluated, as well as being a criticism of consumerism.

In addition, these practices have become significant tools for a niche of designers and manufacturers[11], who have adopted techniques such as restyling, clothing redesign, additive decorations and overprints, in order to give new life to the fabrics used, increasing their value and delaying (or avoiding) the disposal in landfill.

In addition, the use of vintage fabrics and clothes, the creation of patchwork, and other old things that have maintained their style over time, have managed to strengthen the image of an ancient era compatible with the values of sustainability (vintage effect).

8.5.3 Recycling of textiles

"Recycling" is the process of converting end-of-life materials into a new production process and thus into a new life cycle.

During the recycling process, fabrics have to be converted into fibres or even polymers for reuse. In the mechanical processes, which allow the fabrics to be cut, crushed and carded without any distinction by type of fibre, the fibres are unravelled. Chemical recycling processes, on the other hand, focus on chemical properties and are therefore directly related to the type of fibre or, in some cases, to the type of blend.

The first step in the recycling process is the sorting of the waste collected. Currently there isn't the perfect sorting technology for textile waste: each technology has its own strengths and weaknesses, and may be addressed to a related type or origin of waste.

The 4 main technologies currently available are:

[10] www.occhiodelriciclone.com
[11] Such as: Pentatonic (www.pentatonic.com)

- manual sorting: This is the traditional method, carried out by workers who select fabrics by hand. It offers small margins and the selection is made on parameters easily determinable by humans.
- Fourier Transform Infrared Spectroscopy (FTIR): FTIR has the potential to determine the colour and fibre composition of textiles and, as a consequence, the selected recycled product would have to achieve slightly higher prices due to the higher homogeneity achievable. The method needs further development so that it can also be applied in industrial areas.
- Radio Frequency Identification (RFID) label: An RFID label could be attached to each textile item. In theory, this could lead to lower costs and a dynamic classification based on a wide range of criteria, in response to market demand, and thus to recycled products with high added value. However, RFID tags have to go beyond the product use phase (mainly maintenance, e.g. washing and ironing) and therefore resistance to washing cycles is the challenge currently under way[12].
- 2D Barcode: A 2D barcode could be used to give the reader the information needed to select items, and achieve the same benefits as RFID tags. The 2D bar label must be presented manually to a reader, which means that the condition and quality of the textile can be verified simultaneously.

The recycling process requires more resources in terms of energy and technology than previous sorting methods, but still requires less resource use compared to virgin materials.

Recycling technologies are based on the raw materials used and the kind of final goods produced at the end of the process:

- primary recycling is the recycling of a product in its original form (generally used for industrial waste that is reused in the same form);
- secondary recycling, involves mechanical treatment of the waste and generally a decrease in the physical-mechanical and/or chemical properties of the product compared to the original;
- tertiary recycling, is carried out chemically (hydrolysis, pyrolysis) and converts the waste material into monomer or chemical substance;
- Quaternary recycling consists in the process of combustion of a solid waste in order to generate heat.

➢ Mechanical recycling

In mechanical recycling processes, textile waste is torn up, clothing is dismantled and fabrics are cut into small pieces. Subsequently, the materials are passed into a special carding machine that breaks down the fabrics into shorter fibres than the original lengths, giving rise to the production of yarns of inferior quality[13]. One way to improve

[12] Furthermore, label readers are not yet able to determine the physical position of an individual label in a stock, which is a prerequisite for the development of automatic sorting machines.
[13] The quality of new yarns depends on the length, fineness and strength of the fibres obtained

the quality of this type of yarn is to use waste from pre-consumer sources, the quality of which can be controlled or mixed with longer virgin fibres.

Pre-consumption and post-industrial waste usually ensure higher quality through homogeneous fibre blends (especially when carefully collected and sorted according to colour, type, mix...); however, post-consumer waste is extremely heterogeneous and of poor quality due to the very different origins of the waste and to the fact that clothes, which have been worn, have been subject to many stresses throughout their life cycle.

Depending on the quality of the fibre:

- higher quality fibres can be reintroduced into the production chain in the form of knitting and weaving yarns for clothing, lining and upholstery;
- Mid-level fibres can be used to produce fabrics;
- lower quality fibres will be used as reinforcement, nonwovens, carpets, footwear interiors, thermal and acoustic insulation, padding for toys and other finished products.

Wool fibres are usually recycled and blended with virgin wool to produce new textile products: the final product will be less soft, but certainly more durable.

Pure white cotton fibres can be converted by chemical transformation into superabsorbent polymers for the production of medical textiles.

Coloured cotton waste, as well as white cotton, can be converted into drawing paper by a suitable process of dissolving and depositing the pulp. Cotton can also be used as a raw material for the development of new cellulosic and regenerated fibres.

In addition, appropriately treated textile waste can be brought back to life by using it in new applications, for example, as acoustic absorbers, mats, padding felts, sofa and mattress padding.

Blends of fibres, especially cotton and polyester, are macerated because of their lack of homogeneity and used for the production of non-woven fabrics and felts for thermal and acoustic insulation.

A mechanical process is also widely used to recycle thermoplastics, including plastic bottles and some polyester fibres. Plastic waste is cut into small flakes which are melted and then extruded into filaments to produce yarns. Although recycled polyester is not very different from virgin fibres, not all recycled thermoplastic fibres have similar properties to virgin fibres, so this process cannot be used for all fibres.

➢ Chemical recycling

Chemical recycling is the main method used to process synthetic fibres collected in the textile sector. As regards natural fibres, only cotton and other cellulosic fibres which are

from the "waste material" and on their colour.

processed by a chemical process can be mentioned, as shown below. This process is part of the tertiary recycling class that requires the depolymerisation of synthetic fibres into molecules to be re-cured.

For waste made up of 100% a single fibre, it is better to use mechanical recycling because it has less impact than chemical recycling: chemical recycling requires more energy and a specific production plant and therefore requires investments for large-scale production. Market developments and interest in the recycling process are expected to lead to a wider uptake of available production facilities.

- The polyester recycling process: this process can be used to recycle PET bottles (as a substitute for the mechanical process) and also to recycle the collected end-of-life clothing, pre-consumers fabric waste, waste yarn or other plastic materials. The waste are reduced into small pieces to form a chip. The chips are depolymerised to form dimethyl terephthalate, then polymerised again and extruded into new polyester fibres and yarns.
- Nylon and spandex are another very common blend, especially in high-performance sportswear and active wear. In this case, the spandex is in a small percentage so it is dissolved to recycle the nylon. The process involves a heat treatment to degrade the spandex and then subject the tissue to a washing process using ethanol to remove any residue.
- The recycling of blends of fibres is more complicated than pure fibres due to the different physical and chemical properties of the fibres present in the waste. For example, the most common blends of cotton and polyester are transformed with a selective degradation method: the fibres are chemically separated using an agent that dissolves the cellulose; the pulp is filtered and then the polyester is reformed into new fibres, while the dissolved cellulose is used in the common processes of spinning cellulose (viscose and derivatives).

8.6 Final comments

The circular economy is a developing global trend, with a growing awareness that available resources will be increasingly scarce.

In all fields and sectors of industry, creative and technological solutions are waiting to be identified and explored.

If you want to deepen the topics of this unit:

For further information on the topics covered in this unit, please refer to the following references:

- http://www.ellenmacarthurfoundation.org/
- http://ec.europa.eu/environment/circular-economy/index_en.htm

To deepen the circular economy in the textile industry:

- Ellen MacArthur Foundation, A new textiles economy: Redesigning fashion's future, (2017, http://www.ellenmacarthurfoundation.org/publications)
- Euratex, Prospering in the circular economy (2017, http://euratex.eu/press/position-papers/).