ECOTEX

Learning materials

Circular Economy Innovative Skills in the Textile Sector

Intellectual Output 4

Module 4

Circular Economy

Module 4: Circular Economy

Index

Introduction to the module

In order to reduce the inefficiencies in production including waste generation coming from the textile and fashion industry, the companies/producers are encouraged to be part of the transition from a linear economy to a circular economy (closed loop). The circular economy principles include energy, water, raw materials and all the inputs necessary to make a product.

Unit 4.1 Circular economy definition and principles

4.1.1 Introduction

A circular economy encourages sustainability and competitiveness in the long term.

The circular economy is a relatively new system of operation, which aims to 'close the loop' and design waste out of the system. This means a transition from the outdated 'take, make, dispose' linear operating model, which is highly wasteful and detrimental to the environment, to a more responsible all-encompassing and abundant resource management system. This current system mines resources, uses them in the manufacturing of a product and then disposes of these valuable materials at the end of use; usually to landfill or incineration, meaning a large amount of resource value is lost. On the other hand, the circular economy closes this resource loop by providing a system of operation that designs wastage out of the system, avoiding landfills and incineration altogether and keeping resources in use for as long as possible through reuse and regeneration of new products.

4.1.2 Short description

Knowledge	**Skills**	**Competencies**
At the end of this unit the learner will:	*At the end of this unit the learner will be able to:*	*At the end of this unit, learner will have acquired the responsibility and autonomy to:*
• Define the methods for implementing the Circular Economy principles.	• Select the most suitable methods to prepare and implement the strategies in the company.	• Implement the selected strategies and principles in the textile sector • Use Decision-making capacity

4.1.3 Content unit

Topic 4.1.3.1 What is Circular Economy?

According to the European Commission, in a Circular Economy, the value of products and materials is maintained for as long as possible. Waste and resource use is minimised, and when a product reaches the end of its life, it is used again to create further value.

The Ellen MacArthur Foundation presents the most common definition of Circular Economy (CE) as "an industrial economy that is regenerative or restorative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models"[1].

According to Kirchherr, Reike & Hekkert[2] circular economy refers to the 3Rs: Reducing materials need and waste, Reusing products and product parts and Recycling materials.

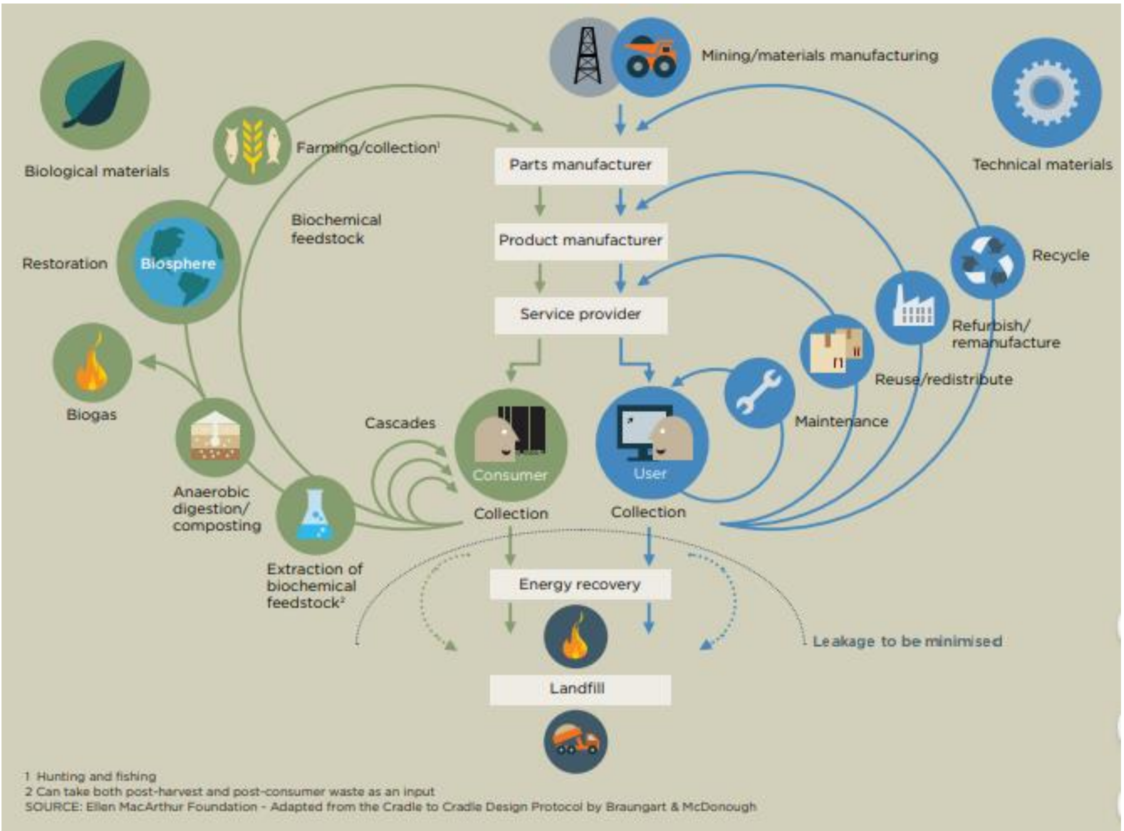

Figure 1. Outline of a circular economy [3]

[1] The Ellen MacArthur Foundation, *Towards the circular economy*, Volume 3, 2013

[2] https://www.sciencedirect.com/science/article/pii/S0921344917302835

[3] https://www.ellenmacarthurfoundation.org/circular-economy/what-is-the-circular-economy

Figure 1 presents the outline of a circular economy as an economic system capable of regeneration. This is possible through ecodesign and recycling. The circular economy is an economic system where products/services are treated in closed loops. In a circular economy material cycles are closed by following the example of natural ecosystems, therefore toxic substances are eliminated and there is no waste, because all residual streams are valuable as resource. Moreover, products are taken back after use for repair and remanufacturing in order to reuse the products a second time, and residual streams are separated in a biological and technical cycle[4].

Topic 4.1.3.2 The importance of circular economy

Circular Economy aims to reduce the waste to a minimum and to extend the life cycle of a product. In order to achieve this, the products are designed to last and optimized for a cycle of disassembly and reuse.

When a product reaches the end of its life the goal is to keep the materials in the economy as long as possible. This refers to the transition from the traditional, linear economic model which is based on manufacture-consume-throw away to a circular model (figure 2), creating further value. In this case the production and consumption model is based on two complementary loops drawing inspiration from biological cycles: one for 'biological' materials (which can be decomposed by living organisms) and one for 'technical' materials (which cannot be decomposed by living organisms).

Figure 2 Circular economy[5]

[4] https://www.ellenmacarthurfoundation.org/circular-economy/concept
[5] http://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits

The extraction of raw materials has a huge impact on the environment, that's why it is important to keep the materials in circulation longer. An example for textiles is offered by Ellen Macarthur foundation presented in figure 3.

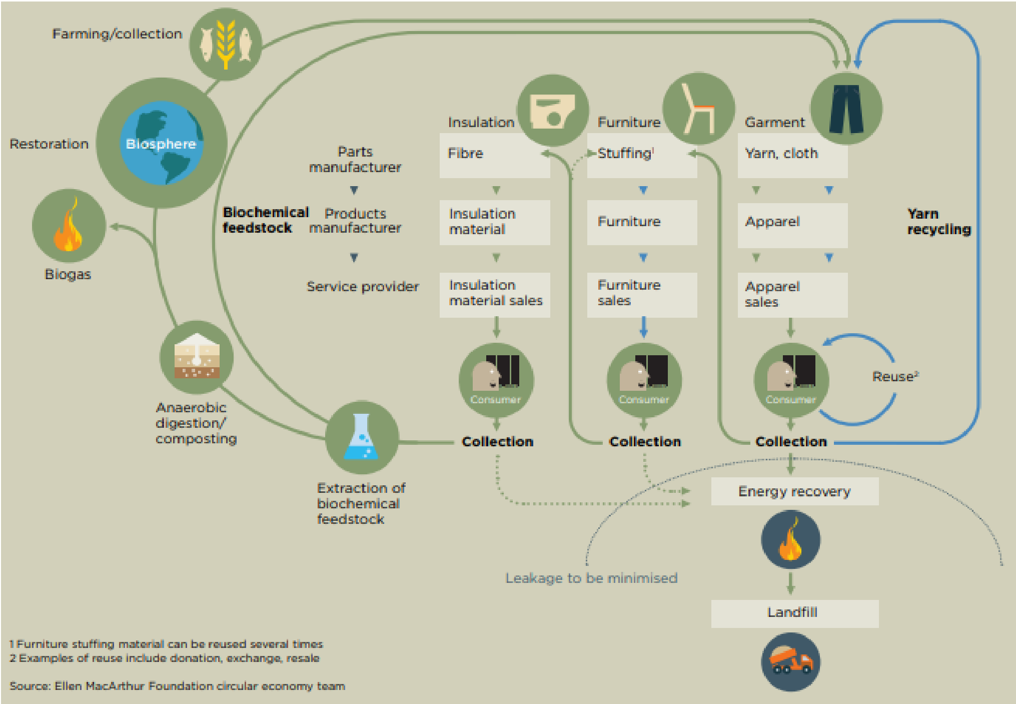

Figure 3 Cascading keeps materials in circulation for longer[6]

Textiles give the perfect example of the cascading opportunity. The consumption of clothing is determined by fashion rather than lifetime limitation. Instead of disposal at the landfill at the end of their use life, textiles can be reused multiple times.

The textile and clothing sector is characterized by unpredictable demand, short product life cycles, quick response time, large product variety, and a volatile, inflexible, and complex supply chain structure[7].

Topic 4.1.3.3 The benefits of circular economy

Moving to a circular economy could have benefits such as:

- protecting the environment,
- reducing greenhouse gas emissions,

[6] https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf

[7] Shalini Singh, Robinka Khajuria, *Penicillium Enzymes for the Textile Industry*, New and Future Developments in Microbial Biotechnology and Bioengineering, 2018, https://www.sciencedirect.com/topics/engineering/textile-and-apparel-industry

- raw materials´ supply transparency,
- avoidance of environmental damage caused by resource extraction,
- less pollution,
- stimulating innovation,
- increasing competitiveness.

Topic 4.1.3.4 The principles of a circular economy

Circular Economy is based on 3 main principles[8]:

1. **Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows.** This refers to designing out of waste and to reduce the use of non-renewable natural resources and encourage the use of renewable materials. This can be realized by:
    - *Dematerialisation*: Replace products, when possible, with a service (product service systems).
    - *Smart materials:* Choose materials that last and processes that consume little and renewable energy.
    - *Facilitate ecosystems*: Ecosystems are balanced by extracting and introducing nutrients at the right place and the right time.

    Real case example: Mud Jeans leasing product [9]

Scope	#Leasing #Brand #Industrial Partner #Close the loop #Recycled Cotton
Value added	MUD Jeans launched the pioneering lease system. This system ensures that they keep hold of their valuable fibers and that every garment comes back to them and it is recycled by their fabric supplier and industrial partner Tejidos Royo. Repairs are provided for free and the customers can keep the jeans for as long as they want.
More information	https://www.youtube.com/watch?v=0f70UMW0xfE

2. **Optimize resource yields by circulating products, components and materials in use at the highest utility at all times in both technical and biological cycles.** This means to produce products that can be repaired, remanufactured, recycled at the time when their performance or function is damaged. This principle also refers increasing

[8] https://www.ellenmacarthurfoundation.org/circular-economy/concept)
[9] https://thecurrentdaily.com/2018/10/31/9-brands-rethinking-textiles-for-the-circular-economy/

the useful life of the product or component/material in order to obtain good quality recycled products.

Real case example: Stella McCartney product based on regenerated cashmere[10]

Scope	#Brand #Sustainable product #Cashmere
Value added	Stella has been championing sustainable fashion since the formation of her namesake label, pushing the envelope of what circular textile innovation means for the industry at large. One stand-out circular textile from the brand is Re.Verso™, a regenerated cashmere made from post-factory cashmere waste in Italy. According to the brand's self-implemented Environmental P&L account, using this alternative material reduced its impact by 92%.
More information	https://www.youtube.com/watch?v=6oVK2pgR-G0&feature=youtu.be

3. **Foster system effectiveness by revealing and designing out negative externalities.** This principle refers to reducing the negative effects in health, education or food caused by the use of resources. This can be done by monitoring indicators such as land use, air and water quality, contamination by toxi«'c substances and (noise) nuisance.

Real case example: Denim fabric dyeing without water by Tejidos Royo

Scope	#Raw material #Denim without water #Textile industry.
Value added	TEJIDOS ROYO has managed to modify the process of conventional indigo dyeing, creating a unique dyeing process which dyes indigo without water in a very reduce space, minimizing drastically its environmental impact and obtaining a unique color in the market.
More information	http://www.tejidosroyo.com/en/post/_dry_indigo_el_futuro_de_denim_sostenible_ha_llegado

These 3 values presented before act as principles for action. So, Circular Economy is described by the following fundamental characteristics:

- Waste is "designed out" – in a circular economy waste is designed out by intention. The biological materials can easily be returned to the soil, while technical materials are designed to be recovered.
- Diversity builds strength - across many types of systems, diversity is a key driver of versatility and resilience.

[10] https://thecurrentdaily.com/2018/10/31/9-brands-rethinking-textiles-for-the-circular-economy/

- Renewable energy sources power the economy - in order to decrease resource dependence and increase systems resilience, the energy required to fuel the circular economy should be renewable by nature.
- Prices or other feedback mechanisms should reflect real costs – in a circular economy the prices should reflect the full cost in order to be effective.

4.1.4 Suggested readings

- Stahel W.R., Circular Economy, Nature. 531 (2016) 435-438
- Michael Lieder, Amir Rashid *Towards circular economy implementation: a comprehensive review in the context of manufacturing industry*, Cleaner Production Volume 115, 1 March 2016, Pages 36-51
- https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf
- https://www.ellenmacarthurfoundation.org/assets/downloads/publications/TCE_Report-2013.pdf
- https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Towards-the-circular-economy-volume-3.pdf

4.1.5 Quiz

Choose the correct option

1. What means circular economy?
   a. An economy where the products/services are treated in closed loops.
   b. An economy where the products/services are treated in opened loops.
2. Which are the circular economy principles?
   a. design out of waste
   b. design for biodegradability
   c. increase the life of the products
   d. regenerate the natural system
3. Which are the perspectives of circular economy?
   a. economic benefits
   b. environmental impact

   c. consumers choice
   d. resource scarcity
4. Which are the benefits of circular economy?
   a. protecting the environment
   b. reducing greenhouse gas emissions
   c. avoidance of environmental damage caused by resource extraction
   d. stimulating innovation
   e. increasing competitiveness.
5. What are the characteristics of textile and clothing sector?
   a. predictable demand
   b. long product life cycles
   c. large product variety
   d. complex supply chain structure.

Unit 4.2 Identification of environmental legislation regarding waste management

4.2.1 Introduction

The Waste Framework Directive includes basic concepts, definitions and rules related to waste management. EU waste legislation includes also other issues related with wastes, as for instance Landfill, Waste Incineration and Packaging and Packaging Waste.

4.2.2 Short description

Knowledge	**Skills**	**Competencies**
At the end of this unit the learner will:	*At the end of this unit the learner will be able to:*	*At the end of this unit, the learner will have acquired the responsibility and autonomy to:*
• Describe the national and European environmental legislation related to wastes management • Describe different types of waste and their final destination	• Select the most suitable methods to analyse the waste management options and the boundaries for the textile industry	• Apply the national and European legislation regarding Waste management; • Apply the principle of waste control to promote the separate collection;

• Define the European waste codes		• Implement the final supervision in the final waste destination.

4.2.3 Content unit

Topic 4.2.3.1 European environmental legislation related to waste management

Waste management refers to all the actions required to manage waste starting from the collection, transport, storage, recovery and final disposal. The EU legislation related to waste management aims to reduce the impact on the environment and human health created by waste.

The EU waste management policies contain many environmental action plans and framework of legislation about minimizing the negative impact on human health and on the environment. The European legislation includes Directive 2008/98/EC on wastes, Directive 1999/31/EC on the wastes landfill, Directive 2000/76/EC on the incineration of waste, Directive EU 2015/720, amending Directive 94/62/EC (which refers to packaging waste), regarding the consumption of lightweight plastic carrier bags. Some of them refer to:

- prevention (ensure an economic growth without creating more waste).
- recycling (encourage society to recycle; for example, the 7th Environment Action Programme[11] established targets for the EU Member States to recycle, among others, 50% of municipal waste and 70% of construction waste by 2020).

EU waste management policies aim to reduce the environmental and health impacts of waste and improve Europe’s resource efficiency. The long-term goal is to turn Europe into a recycling society, avoiding waste and using unavoidable waste as a resource wherever possible. The aim is to achieve much higher levels of recycling and to minimise the extraction of additional natural resources. Proper waste management is a key element in ensuring resource efficiency and the sustainable growth of European economies.

EU waste policy has evolved over the last 30 years through a series of environmental action plans and a framework of legislation that aims to reduce negative environmental and health impacts and create an energy and resource-efficient economy. The EU’s Sixth Environment Action Programme (2002- 2012) identified waste prevention and management as one of four top priorities. Its primary objective is to ensure that economic growth does not lead to more and more waste. This led to the development of a long-term strategy on waste. The 2005 Thematic Strategy on Waste Prevention and Recycling resulted in the revision of the Waste Framework Directive, the cornerstone of EU waste policy.

[11] https://ec.europa.eu/environment/action-programme/

The revision brings a modernised approach to waste management, marking a shift away from thinking about waste as an unwanted burden to seeing it as a valued resource. The Directive focuses on waste prevention and puts in place new targets which will help the EU move towards its goal of becoming a recycling society. It includes targets for EU Member States to recycle 50% of their municipal waste and 70% of construction waste by 2020. The Directive introduces a five-step waste hierarchy where prevention is the best option, followed by re-use, recycling and other forms of recovery, with disposal such as landfill as the last resort. EU waste legislation aims to move waste management up the waste hierarchy. In figure 4 is presented the waste hierarchy.

Figure 4 Waste hierarchy[12]

The waste hierarchy ranks waste management options according to what is best for the environment and includes 5 stages:

1. Prevention: using less material in design and manufacture; keeping products for longer, re use; using less hazardous materials.
2. Preparing for re-use: checking, cleaning, repairing, refurbishing, whole items or spare parts.
3. Recycling: turning waste into a new substance or product; includes composting if it meets quality protocols.
4. Other recovery: includes anaerobic digestion, incineration with energy recovery, gasification and pyrolysis which produce energy (fuels, heat and power) and materials from waste;
5. Disposal: landfill and incineration without energy recovery.

[12] http://ec.europa.eu/environment/waste/pdf/WASTE%20BROCHURE.pdf

Directive EU 2018/851 makes amendments to Directive 2008/98/EC on waste (The Waste Framework Directive) which provides the legislative framework for the collection, transport, recovery and disposal of waste. This Directive makes amendments in order to, among other things:

- increase targets for preparing for re-use and recycling of waste;
- remove substances intended for animal feed from the scope of Directive 2008/98/EC;
- add a number of new definitions;
- change cease to be waste conditions and requirements;
- set out exemptions for separation of waste collection;
- establish bio-waste separation;
- establish household hazardous waste collection; and
- update record keeping requirements.

The Directive makes amendments in some specific points related with textile wastes:

- Possibility to define specific criteria to the wastes declassification for textiles waste;
- Possibility of application of the extended producer responsibility to textile products;
- Encourage the re-use of products and the setting up of systems promoting repair and re-use activities, including textiles;
- Set up separate collection in urban wastes for textiles, by 1 January 2025.

The EC adopted the Circular Economy Package in order to encourage and help Europe's transition towards a circular economy. The Circular Economy Package includes action plans and Directives such as on the reduction of the impact of certain plastic products on the environment meant to reduce the quantity of waste and the negative impact on the environment and human health.

The EU Landfill Directive has an important role, developing the waste management policy and landfill restrictions. This Directive also defines the waste categories (municipal waste, hazardous waste, non-hazardous waste and inert waste) and presents the legislation and procedure for the acceptance of waste in a landfill.

The EU Waste Incineration Directive establishes the emission limit values for incineration and co-incineration plants and monitors the requirements for pollutants to air such as sulphur dioxide (SO_2), hydrogen chloride (HCl), dust, nitrogen oxides (NO_x) or heavy metals.

Topic 4.2.3.2 Type of waste and European waste codes

Waste management options for textiles are: reusing, extending the lifespan of the products; recycling – up-cycling and down-cycling, energy recovery – incineration, gasification, pyrolysis; and landfill.

Whether it is reused, recycled or landfilled, industrial waste management involves an environmental and financial cost. The first step is to collect the waste, next to sort and transport. After that, waste is being treated which can be expensive and, as a consequence, will generate greenhouse gas emissions and pollution of air, water and soil. The amount of waste contains a mix of materials, which can be hazardous or non-hazardous. Unfortunately a large amount of the waste generated is hazardous containing heavy metals and other toxins. Because of these substances the waste treatment requires special processes to deal with the hazardous components. The classification of hazardous and non-hazardous waste depends on the system for the classification and labelling of dangerous substances and mixtures defined in the scope of chemical substances legislation[13]. The classification of wastes, in terms of its hazardous characteristics is defined in the European List of Waste (Commission Decision 2014/955/EU[14]) and Annex III (properties of waste which render it hazardous) of the Directive 2008/98/C[15].

The role of waste codes is to classify different types of waste. This helps companies to identify the type of waste in a harmonized way, within the EU, in order to choose the best treatment option.

The nature of waste generated by the textile and clothing sector can be classified into two groups:

- Textile wastes: wastes generate during the different steps of the textile production, such as dust from the spinning process, selvedge from the weaving, remains of yarns from knitting process, side part of fabric from stenter process, small parts of fabric from the cutting process, etc.
- Other wastes: wastes generated during auxiliaries processes of textile and clothing companies, such as used packaging (cardboard boxes, rolls, containers, pallets, etc.), used oils, contaminated absorbents, metal scraps, out of use lamps, used batteries, etc.

Rules to identify wastes code

The different types of waste on the European List of Waste (Commission Decision 2014/955/EU) are fully defined by the six-digit code for the waste, which are directly related with the respective two-digit and four-digit chapter headings. This implies that the following steps should be taken to identify a waste code in the list:

- Identify the source generating the waste in Chapters 01 to 12 or 17 to 20 and identify the appropriate six-digit code of the waste (excluding codes ending with 99 of these chapters). Note that a specific production unit may need to classify its activities in

[13] https://echa.europa.eu/regulations/clp/understanding-clp
[14] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014D0955
[15] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02008L0098-20150731

several chapters. For instance, a car manufacturer may find its wastes listed in Chapters 12 (wastes from shaping and surface treatment of metals), 11 (inorganic wastes containing metals from metal treatment and the coating of metals) and 08 (wastes from the use of coatings), depending on the different process steps

- If no appropriate waste code can be found in Chapters 01 to 12 or 17 to 20, the Chapters 13, 14 and 15 must be examined to identify the waste
- If none of these waste codes apply, the waste must be identified according to Chapter 16.
- If the waste is not in Chapter 16 either, the 99 code (wastes not otherwise specified) must be used in the section of the list corresponding to the activity identified in step one.

In the European List of Waste exists a specific chapter for the textile and clothing industry, which includes the following type of wastes:

04 02	**waste from the textile industry**
04 02 09	wastes from composite materials (impregnated textile, elastomer, plastomer)
04 02 10	organic matter from natural products (for example grease, wax)
04 02 14*	wastes from finishing containing organic solvents
04 02 15	wastes from finishing other than those mentioned in 04 02 14
04 02 16*	dyestuffs and pigments containing hazardous substances
04 02 17	dyestuffs and pigments other than those mentioned in 04 02 16
04 02 19*	sludges from on-site effluent treatment containing hazardous substances
04 02 20	sludges from on-site effluent treatment other than those mentioned in 04 02 19
04 02 21	wastes from unprocessed textile fibres
04 02 22	wastes from processed textile fibres
04 02 99	wastes not otherwise specified

The European List of Waste has also chapters for wastes that can be generated in different industries. For example, the chapter 15 01 related with packaging wastes:

15 01	**packaging (including separately collected municipal packaging waste)**
15 01 01	paper and cardboard packaging
15 01 02	plastic packaging
15 01 03	wooden packaging
15 01 04	metallic packaging
15 01 05	composite packaging
15 01 06	mixed packaging

15 01 07	glass packaging
15 01 09	textile packaging
15 01 10*	packaging containing residues of or contaminated by hazardous substances
15 01 11*	metallic packaging containing a hazardous solid porous matrix (for example asbestos), including empty pressure containers

Beside the specific chapter for the textile and clothing industries (04 02), these companies can also generate wastes classified in the following chapters of the European List of Waste:

06	Wastes from inorganic chemical processes [wastes from the use of inorganic chemicals]
07	Wastes from organic chemical processes [wastes from the use of organic chemicals]
08	Wastes from the manufacture, formulation, supply and use (MFSU) of coatings (paints, varnishes and vitreous enamels), adhesives, sealants and printing inks
10	Wastes from thermal processes [only 10 01 - wastes from power stations and other combustion plants]
13	Oil wastes and wastes of liquid fuels (except edible oils, 05 and 12)
14	Waste organic solvents, refrigerants and propellants (except 07 and 08)
15	Waste packaging; absorbents, wiping cloths, filter materials and protective clothing not otherwise specified
16	Wastes not otherwise specified in the list
17	Construction and demolition wastes (including excavated soil from contaminated sites)
19	Wastes from waste management facilities, off-site waste water treatment plants and the preparation of water intended for human consumption and water for industrial use [only chapter 19 09 - wastes from the preparation of water intended for human consumption or water for industrial use -when a company has a treatment system for the industrial water]
20	Municipal wastes (household waste and similar commercial, industrial and institutional wastes) including separately collected fractions

4.2.4 Suggested readings

- EU Waste management, https://eur-lex.europa.eu/summary/chapter/environment/2004.html?root=2004
- http://ec.europa.eu/environment/waste/legislation/index.htm

- https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014D0955
- https://eur-lex.europa.eu/summary/chapter/environment/2004.html?root=2004
- https://echa.europa.eu/home
- http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=LIFE05_ENV_E_000285_LAYMAN.pdf
- Bianchi C., Birtwistle G., 2012, Consumer clothing disposal behavior. A comparative study. International Journal of Consumer Studies, 36, 335-341.

4.2.5 Quiz

1. What is included in the EU waste legislation?
   a. <u>Directive</u>
   b. Laws
   c. <u>Policies</u>
   d. <u>Regulation</u>
2. Which are the waste management options for textiles?
   a. <u>Reusing, extending the lifespan of the products</u>
   b. <u>Recycling – up-cycling and down-cycling</u>
   c. <u>Energy recovery – incineration</u>
   d. Landfill.
3. Which option for waste management is the most sustainable?
   a. Landfill
   b. <u>Recycling</u>
   c. Incineration
   d. Reusing
4. It is important to respect the waste codes in a company?
   a. No, it is not necessary
   b. <u>Yes, to classify different types of waste in order to choose the best treatment option</u>
5. There are legislation to control textile waste?
   a. <u>Yes</u>
   b. No

Unit 4.3 Circular Economy in the textile sector

4.3.1 Introduction

The EU clothing production industry focuses on adding value to products improving the design, comfort, quality, materials to respect the environmental rules. The EU has always been a significant provider of high-quality clothing to the world market.

4.3.2 Short description

Knowledge	**Skills**	**Competencies**
At the end of this unit the learner will:	*At the end of this unit the learner will be able to:*	*At the end of this unit, learner will have acquired the responsibility and autonomy to:*
• Discuss sustainability and supply chain; • Describe the clothing production chain, materials properties and technologies which are used in the textile industry to re-orientate the company business to a model which is based on the preservation of resources • Discuss recycling process (fibres, materials, products, etc.)	• Design a framework for implementing the principles of Circular Economy in the company. • Test the capacity of changing the current linear model of value chain into a closed loop.	• Use flexible supply chains or create new ones to reduce the stocks; • Apply alternative ways of transportation, logistics and communication; • Select a suitable supplier (local) who can supply eco-friendly materials.

4.3.3 Unit content

Topic 4.3.3.1 Concept of sustainability

Beyond its conventional definition, the sustainability concept reflects the contemporary social concerns for the environmental impact produced by human activities, through unwise consumption of natural resources and extensive pollution.

Sustainable development, according to the European Commission, means meeting the needs of the present whilst ensuring future generations can meet their own needs[16]. Sustainable development has been mainstreamed into EU policies and legislation, via the EU Sustainable Development Strategy[17], the EU 2020 Strategy, and through the EU's Better Regulation Agenda. It is reflected in sectoral policies such as the 7th Environment Action Programme. These efforts have gone hand in hand with a high level of engagement of Member States and stakeholders, which is a prerequisite for successful implementation.

The EU was instrumental in shaping the global 2030 Agenda[18]. The Agenda is fully consistent with Europe's vision and has now become the world's blueprint for global sustainable development. The EU will continue to be a frontrunner in implementing the 2030 Agenda and the SDGs, together with its Member States, in full respect of the principle of subsidiarity. The 2030 Agenda includes:

- No poverty
- Zero hunger
- Good health and well-being
- Quality education
- Gender equality
- Clean water and sanitation
- Affordable and clean energy
- Decent work and economic growth
- Industry, innovation and infrastructure
- Reduced inequalities
- Sustainable cities and communities
- Responsible consumption and production
- Climate action
- Life below water
- Life on land
- Peace, justice and strong institutions
- Partnerships for the goals

Sustainability can be defined in many ways, it depends on the intended use. Officially, sustainability as a concept was defined in the Brundtland report in 1987 and then adopted by the United Nations World Commission on Environment and Development: “sustainability

[16] http://ec.europa.eu/trade/policy/policy-making/sustainable-development/
[17] https://ec.europa.eu/environment/sustainable-development/strategy/index_en.htm
[18] https://ec.europa.eu/environment/sustainable-development/SDGs/index_en.htm

means being able to satisfy current needs without compromising the possibility for future generations to satisfy they own needs”[19].

Sustainability in textile sector

Sustainability, according to the World Summit on Social Development[20], covers three main pillars: environmental, social, economic. From an economic point of view, the sustainable development of the European textile industry can be achieved through competitiveness, to be one step ahead of the competition.

The environmental impact of textiles varies significantly depending on the type of fibre and industrial processes used. However they include[21] :

- energy use, greenhouse gas (GHG) emissions, nutrients releases (leading to eutrophication) and ecotoxicity from washing (water heating and detergents) and dyeing of textiles;
- energy use, resource depletion and GHG emissions from processing fossil fuels into synthetic fibres, e.g. polyester or nylon;
- significant water use, toxicity from fertiliser, pesticide and herbicide use, energy use and GHG emissions associated with fertiliser generation and irrigation systems related to production of fibre crops, e.g. cotton;
- water use (20% of industrial fresh water pollution comes from textiles treatment and dyeing), toxicity, hazardous waste and effluent associated with the production stage, including pre-treatment chemicals, dyes and finishes.

In terms of chemicals used in textile and clothing company’s one of the most relevant legal issues is the REACH Regulation[22]. Based on that Regulation, for textiles produced in Europe, substances incorporated in the textiles, need to be registered. For all textile articles, producers or importers, need to inform the client if a textile article contains any of SVHC (substances of very high concern) in the candidate list in a concentration above 0,1% (w/w). And besides that, the company (producer or importer) has to notify ECHA if the total annual quantity of a SVHC (in concentration > 0,1% in the article) is greater than 1 tonne. Consumers also have the possibility to ask retailers if products contain SVHC in a concentration above 0,1% and the retailer has 45 days to answer. All the textile articles in EU (produced or imported) must comply with the restrictions defined (in annex XVII of REACH Regulation) and with the authorizations (annex XIV of REACH Regulation).

[19] World Commission on Environment and Development (1987). *Our Common Future*. Oxford: Oxford University Press. p.27. ISBN 019282080X.
[20] https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_60_1.pdf
[21] http://susproc.jrc.ec.europa.eu/textiles/stakeholders.html
[22] https://echa.europa.eu/regulations/reach/understanding-reach

Topic 4.3.3.2 Supply chain – definition

A sustainable value chain may reduce the ecological and social impacts of the company and the activities across the supply chain. A sustainable supply chain helps to create brand value and loyalty among the consumers and shareholders.

The supply chain represents the steps it takes to a company to get the product or service from its original state to the consumer (figure 5). It can be defined as a network[23] or a system of activities, organizations, information and resources involved in moving a product/service from supplier to consumer.

Scientific literature shows that companies have recognized the benefits of their supply chain members in managing the environment[24] on one hand, and they are also responsible for the environmental performance of their partners and suppliers [25] on the other hand.

Another important aspect in a sustainable supply chain is traceability. Traceability, as defined by ISO (in ISO 9001:2015 standard), is "the ability to identify and trace the history, distribution, location, and application of products, parts, materials, and services. A traceability system records and follows the trail as products, parts, materials, and services come from suppliers and are processed and ultimately distributed as final products and services". In general, a traceability system can be used to access information related to all involved actors, activities, and products including raw material components, processing conditions, logistics movements, carbon footprints, etc.

Traceability in textile supply chain is partially adopted by brands to share information related to their sustainability aspects in the form of green certifications, eco-cotton labels, carbon footprint data, or supplier details. Steps are required to promote traceability and develop consensus among the textile supply chain partners for the implementation of a single and complete traceability system that can record and share information related to each supply chain stage in a standardized format[26].

Supply chain traceability means organizations have the ability to follow material and production flows from raw material extraction until it reaches the customer (UNECE 2017). The ability to trace a product throughout its life cycle supports risk management, fraud mitigation, quality assurance, worker rights, informed management decisions, and establishes direct responsibility for each link in the product life cycle. To determine which phases in a particular product life cycle have the greatest impact, a life-cycle sustainability assessment (LCSA) can be carried out.

[23] https://www.investopedia.com/terms/s/supplychain.asp
[24] Vachon, S., 2007. Green supply chain practices and the selection of the environmental technologies. International Journal of Production Research 45 (18-19), 4357-4379;
[25] Koplin, J., 2005. Integrating environmental and social standards into supply management – an action research project. Research methodologies in supply chain management
[26] Tarun Kumar Agrawal, Rudrajeet Pal, *Traceability in Textile and Clothing Supply Chains: Classifying Implementation Factors and Information Sets via Delphi Study,* Sustainability 2019, 11, 1698; doi:10.3390/su11061698

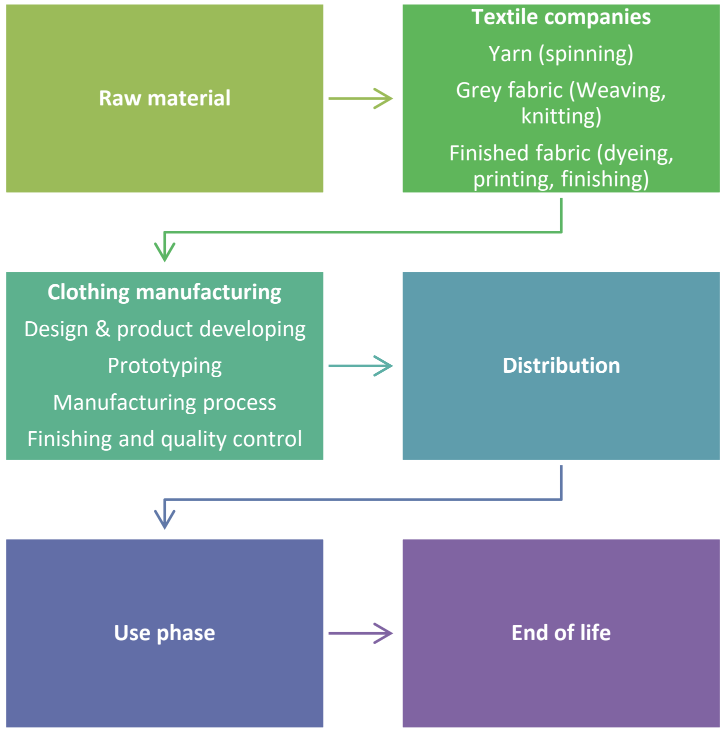

Figure 5 Supply chain for fashion industry

Raw material

There are two main sources of textile raw materials: natural fibre and man- made fibre. There are three sub types of natural fibres: plant or vegetable, animal fibre and mineral. Typical examples of plant fibres include conventional and organic cotton, linen, hemp, jute, ramie and sisal. Wool, silk, mohair, cashmere, angora and alpaca are the main constituents of the animal fibre category. There are two types of man- made fibres: artificial and synthetic. The moist relevant artificial fibres used in textile industry are regenerated cellulosic fibres, which are produced from the transformation of natural polymers. The fibres in this category include viscose rayon, acetate rayon, lyocell and modal. Synthetic fibers are made of polymers, produced entirely from chemicals to create fabrics like polyester, polyamide, acrylic, carbon, etc.

The production of raw materials is responsible for a large share of the environmental impact of textile and clothing industry. According to the 2017 Pulse of the Fashion Industry report, natural fibres have the highest environmental impact, with wool contributing to greenhouse gas emissions, silk having an effect regarding depletion of natural resources and global warming, and cotton contributing to water scarcity.

Textile companies

Raw material preparation is the first step in the life cycle of textile products, with the conversion of raw material to yarns. Depending on the fibre type, different spinning processes can be applied. The yarn, through knitting or weaving processes is transformed in fabrics. In textile process the finishing steps (dyeing, printing, chemical finishing and mechanical finishing) can be applied in the textile different stages, that means, in the fibre stage, in the yarn stage, in the fabric stage and even in the clothing stage. The main environmental impacts to be considered in the textile process are related with raw material, water, energy and chemicals used as well as the emissions from the processes, manly wastewater, by-products and wastes, but also air emissions. The relevance of each of the environmental aspects depends on the industrial process step. For instance in a weaving process the most relevant environmental aspects are the raw material and energy consumption as the wastes generated.

Clothing production

This consists of various operations: spreading or laying, cutting according to the pattern, sewing, and attaching interlining components to garments by heat pressing, ironing and packaging. The points to be considered in environmental impact assessment are:

- transportation type and distance from finishing factory to garment manufacturing factory;
- internal transportation type and distance between different departments of the finishing factory;
- energy used in the garment manufacturing operations;
- procurement of different accessories – distance and means of transport;
- dealing with scraps of fabric from various operations, especially waste from cutting;
- percentage of garments rejected;
- production of steam from boiler and associated impact (such as procurement, storage and burning of firewood);
- other consumables such as lubricants, packaging materials, transportation and disposal issues.

Distribution

This phase involves transport from the factory to the customer via the retailing process. The major impacts of this stage arise from the means of transportation and the distance involved.

Use phase

In the case of textiles, the use phase makes the largest contribution to the total environmental impact over the lifetime of a material. This will increase as the life span of the product increases. The significant factors in the use phase are:

- type of care needed for maintenance of the textiles;
- washing and drying methods;
- amount of water and chemicals used in washing;

- temperature of washing and drying;
- energy consumed in washing and drying;
- necessity of ironing and the energy consumed;
- frequency of washing.

End of life

The end of life options is mainly influenced by consumer behavior coupled with the functional and ecological properties of the textile products, such as:

- reuse for primary and/ or secondary purposes;
- recycling;
- incineration with or without energy recovery;
- disposal to landfill.

All actors along the supply chain have a role to play in reducing the environmental footprint of textile products. First of all producers, because as explained above, considerable impacts might be generated during the fibre production, dyeing, printing and finishing; but also consumers as considerable environmental impacts occur during the use phase.

Topic 4.3.3.3 Textile recycling process

According to the JRC[27] quoted estimates by the Textile Recycling Association that only between 15 % and 20 % of textiles disposed of were collected for reuse or recycling in 2005.

According to EPRS 2019[28] it is still unclear what proportion of the clothes collected is reusable and how much is non-reusable. Depending on the EU Member State, the collection of clothes is organised by municipalities or charities and other civic organizations. Some companies, such as H&M and Marks and Spencer, also operate collection schemes for textiles, both reusable and non-reusable.

Clothes can be recycled using two technologies (figure 6):

- **Mechanically recycling**: clothes are cut up and shredded which means that the obtained fibres are shorter with a lower quality. Wool garments are sent to other firms that make fibre reclamation to make yarn and fabric. Cotton clothes are recycled and used for paper manufacture, automotive, and mining industries and various other uses. Some old clothes are being reused in a creative way by fashion

[27] http://publications.jrc.ec.europa.eu/repository/bitstream/JRC85895/impro%20textiles_final%20report%20edited_pubsy%20web.pdf
[28] EPRS European Parliamentary Research Service 2019 - http://www.europarl.europa.eu/RegData/etudes/BRIE/2019/633143/EPRS_BRI(2019)633143_EN.pdf

designers to make fashionable garments and bags. Fibres made from recycled PET plastic bottles are used in the active sportswear market.

- **Chemical recycling**: virgin fibres of a high quality are available for polyester and nylon. In the future it will become available for cotton and blends. Cotton can be chemically recycled into man-made cellulosics, for example Refibra, Re:newcell, Infinited Fiber or ioncell.

	**MECHANICAL** 	**CHEMICAL** 
Process	High Value Recycling Downcycling	High Value Recycling
Input Fibre	Plant Based Animal Based Petroleum Based	Plant Based Petroleum Based
Output	Non-Wovens New Yarn	New Yarn

Figure 6 General process of inputs and outputs of the recycling types, adapted[29]

Textile recycling helps to protect the environment. Four categories of recycling technologies exist and include, primary, secondary, tertiary and quaternary approaches, summarized as follows:[30] [31]

Primary: recycling material in its original form for recovery of equal value.

Secondary: processing post-consumer product usually by mechanical means into product with different physical and/or chemical properties (mechanical recycling).

Tertiary: processes such as pyrolysis and hydrolysis, in which waste is converted to basic chemical constituents, monomers, or fuels (chemical recycling).

Quaternary (recovery): waste-to-energy conversion processes such as incineration of solid waste, or utilization of heat generated.

[29] GreenBlue Institute, "Chemical Recycling - Making Fiber-to-Fiber Recycling a Reality for Polyester Textiles," Patagonia and Steelcase, 2017.
[30] Y. Wang, "Fiber and Textile Waste Utilization," Waste Biomass Valor , vol. 1, p. 135–143 , 2010.
[31] Interreg Europe, "Recycling in textile and waste disposal," in Agora, Alcoi, 2016.

Mechanical processes are categorized as a secondary recycling approach. Processes include: cutting of sorted fabrics for use as wiper rags, shredding and pulling of textile materials into fibres, re-bonding or respinning into new yarns or fabrics, melting and re-extruding, reblending (may include proportions of virgin material)[32][33].

Real case example: Textile waste to produce insulation by Regeneracija company.

Scope	#Textile Waste #Recycled #Textile Industry
Value added	Regeneracija lies in recycling of textile waste from surrounding textile industries to produce insulation for construction and automotive industry, protective floor coverings, filtration, and furniture industry. The company collects 35% of household textile waste, 15% of industrial textile waste while 50% of textile waste is imported.
More information	https://www.regeneracija.hr/index.php/en/about-us-3

Real case example: Textile waste back into fibres to new materials and products

Scope	#Textile Waste #Recycled #TextileIndustry
Value added	Dafecor is one of the few companies utilising textile waste on an industrial scale in Finland. Dafecor takes the leftover materials from textile production and waste textiles from the public sector, laundries and consumers. Using a mechanical recycling process, the company transforms the textile materials back into fibres and uses these to manufacture new materials and products for various uses. Dafecor's products are mainly used in industrial maintenance to prevent or rectify environmental damage. In addition, the company manufactures insulation products for construction, as well as products suitable for the furniture industry and gardening. Typical end users include companies in the metal and paper industries.
More information	http://dafecor.fi

Chemical processes are categorized as a tertiary recycling approach, and include processes in which the chemical structure of the material is either broken down partially or fully (depolymerization), followed by re-polymerization to virgin material, or through the

[32] Oakdene Hollins, "Apparel and Footwear Recycling Innovation," Sustainable Apparel Coalition, 2014.
[33] A. Peterson, "Anna Peterson, PhD Thesis: Towards Recycling of Textile Fibres: Separation and Characterization of Textile Fibers and Blends," Master's Thesis: Chalmers University of Technology, 2014

dissolution and melting processes, from which the material is drawn or extruded into re-usable fibre[34].

Real case example: Ecoalf brand for products with recycled plastic from oceans

Scope	#Brand #Recycled Polyester #Ocean waste
Value added	Sustainable fashion brand created in 2009, which creates clothing and accessories made entirely from recycled materials with a campaign to use recycled polyester from Oceans PET bottles waste.
More information	https://www.youtube.com/watch?v=boV_TkmBtho

Textile recycling is a complex process. Figure 7 presents an overview of reuse, recycling, or waste options for textiles. Mechanical recycling processes for cotton and wool fibres are well established, but are low volume, and most recycled polyester fibres are derived from mechanically recycled PET bottles. Chemical recycling of cellulosic fibres has been developed with ongoing advancements in technology towards scale-up, while the recycling of synthetics (nylons and polyesters) include some full-scale developments.

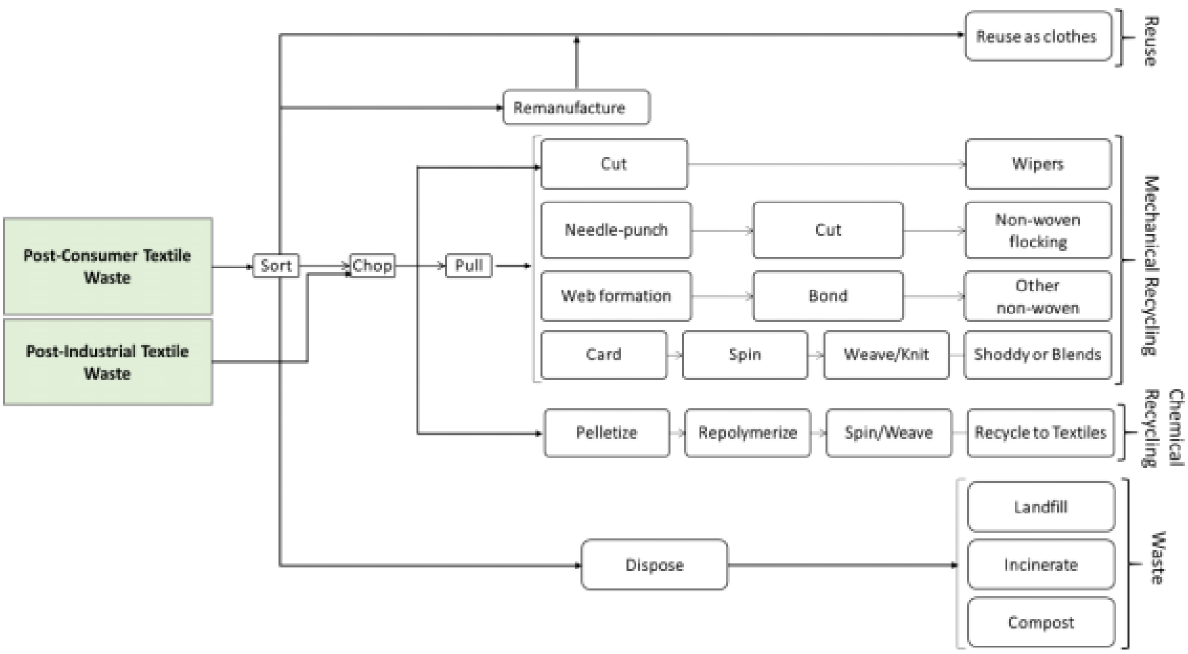

Figure 7 Possible overview of post-consumer and post-industrial textile waste flows, adapted[35]

[34] Boston Consulting Group and Global Fashion Agenda, "Pulse of the Fashion Industry," 2017
[35] P. Thompson, P. Willis and N. Morley, "A review of commercial textile fibre recycling technologies," WRAP, 2012

Requirements for a textile material recycling chain include stakeholders involved in the various processes along the chain from the organization of collection, sorting, and to subsequent reuse, recovery, or regeneration processes of materials. Efficient recycling methods require technologies to separate and manage the various textile waste streams, which includes the characterization, identification and separation of constituent components (i.e. trims, buttons, zippers, threads), fibre blends, as well as dyes and chemicals from finishing treatments, from which final fibre quality is not diminished.

Real case example: Recycled plant for converting waste into reusable polymer by Antex

Scope	#Textile Waste #Recycled #Textile Industry
Value added	Antex is a Spanish private equity textile group founded in 1968, and acts as a partner to several companies converting waste into reusable polymer by: - Internal waste from spinning and texturing process. - Customer fabric or finished product waste (100% mono material). - Post-consumer recycling (bottles, films, etc.)
More information	https://www.antex.net/index_es.php#processes

Collaborative industry efforts from raw materials, design, collection, and recovery technologies are essential to obtain environmental, economic, and social benefits from a textiles recycling chain.

4.3.4 Suggested readings

- Caniato, F., Cardi, M., Crippa, L., Moretto, A., 2011. Environmental sustainability in fashion supply chains: An exploratory case-based research. International Journal of Production Economics 135, 659-670
- Vachon, S., 2007. Green supply chain practices and the selection of the environmental technologies. International Journal of Production Research 45 (18-19), 4357-4379;
- Pagell, M., & Wu, Z. (2009). Building a More Complete Theory of Sustainable Supply Chain Management Using Case Studies of 10 Exemplars. Journal of Supply Chain Management, 45(2), 37–56. Http://doi.org/10.1111/j.1745- 493X.2009.03162.x
- MucellaGuner and OnderYucel , 2005. Environmental Protection and Waste Management in Textile and Apparel Sectors. Journal of Applied Sciences, 5: 1843-1849. DOI: 10.3923/jas.2005.1843.1849

- World Commission on Environment and Development (1987). Our Common Future. Oxford: Oxford University Press. p. 27. ISBN 019282080X.
- Department for Environment, Food and Rural Affairs (DEFRA) Sustainable Clothing Action Plan (update Feb 2010) Department for Environment, Food and Rural Affairs, London, U.K (2011) http://www.defra.gov.uk/environment/consumerprod/products/clothing.htm
- https://sustain.ubc.ca/sites/sustain.ubc.ca/files/Sustainability%20Scholars/2018_Sustainability_Scholars/Reports/2018-25%20Textile%20Recycling%20Technologies%2C%20Colouring%20and%20Finishing%20Methods_Le.pdf

4.3.5 Quiz

Choose the correct option

1. Which are the pillars of sustainability?
   a. <u>Social</u>
   b. <u>Economic</u>
   c. Financial
   d. <u>Environment</u>
2. Which of the following statements is true?
   a. <u>Each company sets its own supply chain</u>
   b. A sustainable value chain doesn't reduce the ecological impacts of the company
   c. <u>Usually post-consumers textiles are discarded in landfills</u>.
3. What is traceability?
   a. <u>The ability to identify and trace the history, distribution, location, and application of products, parts, materials, and services</u>
   b. Can be used to access information related to all involved actors, activities, and products including raw material components, processing conditions, logistics movements, carbon footprints
4. A general supply chain for fashion industry includes six chains. Which option is correct?
   a. Textile companies, raw material, clothing production, distribution, use phase, end of life.
   b. <u>Raw material, textile companies, clothing production, distribution, use phase, end of life.</u>

c. Raw material, clothing production, textile companies, distribution, use phase, end of life.

5. Which are the recycling options for textile waste?

a. Composting

b. <u>Chemical</u>

c. Regeneration

d. Non-woven technology.

Unit 4.4 Eco-design

4.4.1 Introduction

To obtain an ecofriendly product, the most important phase is the design "70% of a product environmental impacts are determined in the design stage"[36].

4.4.2 Short description

Knowledge	**Skills**	**Competencies**
At the end of this unit the learner will:	*At the end of this unit the learner will be able to:*	*At the end of this unit, the learner will have acquired the responsibility and autonomy to:*
• Discuss methods for reducing material consumption and waste generation • Discuss eco-friendly materials; • Describe Eco-certification and Eco-label. • Discuss the value chain textile sector	• Design products with minimum types of materials, number of pieces to minimize waste production. • Design/ re-designed products with reused/ recycled or recovered elements/ pieces • Use of 3D technology to reduce the number of	• Select proper materials to produce the model with minimum waste ; • Select suitable eco materials to replace the others (protect the environment, reduce material use); • Use computer design tools to re-design the Eco-product.

[36] Niinimäki, K., 2011. *Sustainable consumer satisfaction in the context of clothing.* In: Vezzoli, C., Kohtala, C., Srinivasan, A. (Eds.). Product-Service System Design for Sustainability LeNS publication, Greenleaf, Sheffield.

	physical prototypes.	

4.4.3 Content unit

Topic 4.4.3.1 Concept of eco-design

The eco-design approach aims to integrate environmental criteria from the product, good or service, design phase with the goal to reduce its negative environmental impact throughout its whole life cycle. Within circular economy, the design approach is more comprehensive, being referred as circular design or design for circularity.

According to Ellen MacArthur Foundation (in 2012 book: Towards the Circular Economy Vol. 1) Circular design is focused in improvements in material selection and product design (standardisation/ modularisation of components, purer material flows, and design for easier disassembly) and is the heart of a circular economy.

Design for Environment (DfE) or Eco-design is defined as the integration of environmental aspects in the product design process during its life cycle (Directive 2009/125/EC). Eco-design can be applied with different goals depending on the product life-cycle stage, which must be improved[37].

The principles of eco-design were formally published in 2002, ISO/TR 14062:2002 - Environmental management -- Integrating environmental aspects into product design and development - describes concepts and current practices relating to the integration of environmental aspects into product design and development.

An eco-design approach involves the organization that extracts materials as well as manufacturing. All the people and structures involved along the rest of a product's lifecycle, such as retailers or consumers, are also included. All the processes along a product's value-chain are covered too. Design for Recycling (DFR) and Design for Disassembly (DFD) are two interrelated approaches of eco-design that are largely applied in the product and industrial design definition phases, with the explicit objective of facilitating the recycling of products, their components and end-of-life materials.

Real case example: recyclable carpets by Niaga.

Scope	#carpet #recyclable #sustainable product
Value added	Carpet manufacture has been re-imagined by Niaga. According to Niaga (the word 'again' spelled backwards) adding more and more complex combinations of materials to everyday products will not solve today's product performance, health and

[37] *Introduction to the Eco-Design Methodology and the Role of Product Carbon Footprint*. Available from: https://www.researchgate.net/publication/276266304_Introduction_to_the_Eco-Design_Methodology_and_the_Role_of_Product_Carbon_Footprint

	environmental challenges. That's why they developed a carpet production technology to make carpets out of one material only, or two materials bound together with an adhesive that can decouple on demand. This allows carpet producing companies to sell or lease carpets that can be 100% recycled to new carpets after use.
More information	https://www.dsm-niaga.com

According to the DFR principles[38], the priority of preferences for maximizing recycling potential goes to:

- white fabrics which allow easy dyeing;
- natural fibres that are easier to extract and are more versatile;
- good quality fibres (length and fineness), which can be processed on faster machines
- pure, unblended fibres that require less processing than fibre mixtures, guaranteeing reliable results and efficiency in the recycling process.

Another eco-design approach is "zero waste pattern cutting" - During the traditional production in making the final garments or goods, there is a loss of first quality material, in particular the cutting phase of the patterns generates waste and scrap material. In the production of clothing the cutting phase is the one in which the losses of good quality material are greater. In fact, in the traditional method, the fabric is rolled out and the pattern pieces are cut out while the space around the shapes remains unused and discarded because it cannot be reused. Typically, waste varies between 10% and 20% of the fabric depending on the efficiency of the final layout. Some designers and stylists have tackled the issue of waste reduction, called "Zero Waste Pattern" (ZWP), this is a design approach aimed at eliminating the resulting waste. The designer adapts the shape of each component of the model in order to "fit it like a puzzle", until it uses 100% of the useful surface. Currently, some software facilitates positioning, development and also allows simulating the finished garment aesthetic.

Real case example: Zero waste pattern Cutting by Timo Rissanen and Holly McQuillan. [39]

Scope	#Ecodesign #Zero Waste Pattern
Value added	Timo Rissanen and Holly McQuillan worked on and investigated alternative formats of configuration, positioning and construction of patterns of shapes. They intervene on the layout and shape of the single pieces, modifying them as if they were an Escher framework to reduce to zero any waste of material during

[38] http://www.ecosign-project.eu/wp-content/uploads/2018/09/TEXTILE_UNIT09_EN_lecture.pdf
[39] http://www.ecosign-project.eu/wp-content/uploads/2018/09/TEXTILE_UNIT09_EN_lecture.pdf

	the cutting process.  Waste pattern Cutting by Holly McQuillan
More information	https://hollymcquillan.com/category/patterns/

Topic 4.4.3.2 Eco materials

Eco materials are the ones that boost environmental improvement throughout their entire life cycle, without compromising their performance.

An eco-material should contribute to reduce the environmental negative impacts through its entire life cycle and, according to Professor Yagi in 2000[40], should at least achieve one of the ten superior properties compared to conventional materials. The 10 superior proprieties are:

- Energy saving ability
- Resource saving ability
- Reusability
- Recyclability
- Structural reliability
- Chemical stability
- Biological safety
- Substitutability
- Amenity
- Cleanability

Material selection involves the use of materials with low environmental impact and a reduction in their use. The materials selection must then give priority to materials with the lowest energy consumption and environmental impacts, replacing the most energy-intensive with materials with low overall impacts.

Another important aspect is the optimisation of materials in order to reduce their overall consumption volumes and the waste generated during the production process, on one hand and to eliminate unnecessary parts by optimising product design on the other hand.

Real case example: Patagonia products.

[40] Yagi, K. (2002). Concept and Development of Ecomaterials. Proceedings of International Workshop on Eco-materials, Tokyo, Japan, National Institute for Materials Science

Scope	#Ecomaterials #Brand
Value added	Patagonia's products are fabricated in an environmental manner. They use e-fibres such as: hemp, organic cotton, REFIBRA™ LYOCELL, recycled nylon, recycled polyester, recycled wool, YULEX®, TENCEL® LYOCELL.
More information	https://www.patagonia.com/materials-tech.html https://www.patagonia.com/blog/2017/10/from-shirt-to-dirt-thoughts-on-the-patagonia-design-philosophy/

The MADE-BY organization has stablished an Environmental Benchmark of textile fibre (figure 8), which organize them from class A (better) to class E (worst):

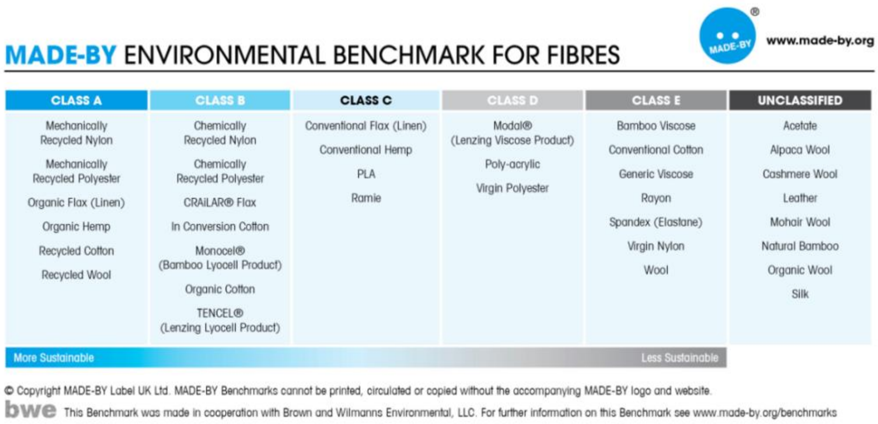

Figure 8 Environmental Benchmark of textile fibre

This classification is based on life cycle analysis which means that it takes into consideration the carbon footprint starting from raw material extraction, yarn production, garment manufacturing to end of life.

Figure 9 Eco friendly textiles classification, source [41]

The eco friendly textiles classification is presented in figure 9. Organic cotton can play a crucial role in moving towards sustainable textiles. Rather, synthetics are taking the lead globally due to their affordability while cotton industry faces many challenges in terms of competition with polyester[42]. In figure 10 are presented the characteristics of conventional and organic cotton from a sustainable point of view.

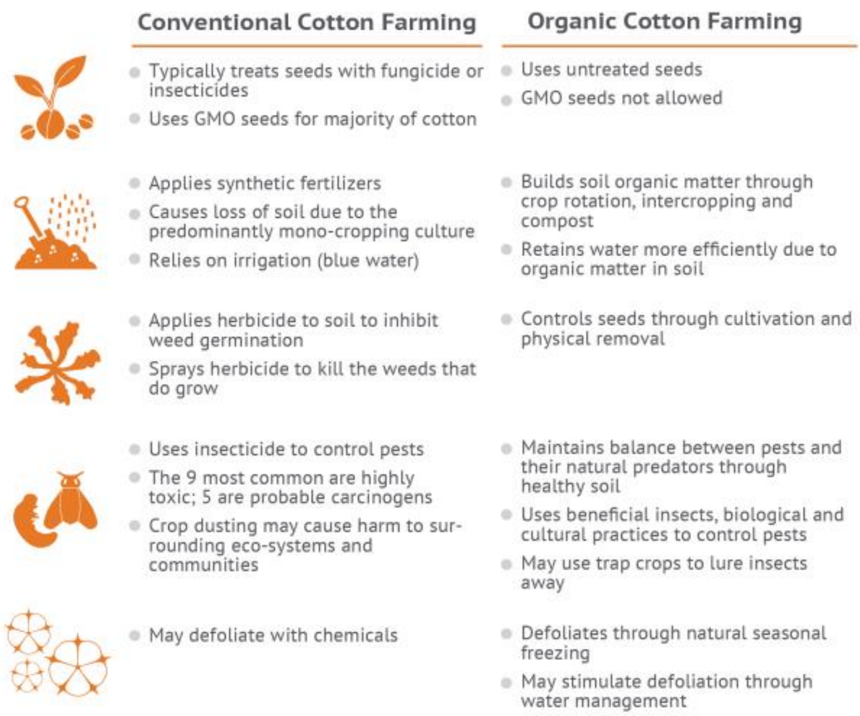

Figure 10 Characteristics of conventional and organic cotton[43]

Another eco material is hemp. It requires way less pesticides and herbicides than cotton when grown on a large scale. The ecological footprint is considered to be low in hemp fibres when compared to other fibres. It is rapidly renewable, requires little or no pesticides, grows without fertilizer, requires minimum attention and doesn't deplete soil nutrients.

Soy silk/cashmere is a good alternative for silk and cashmere and it's machine washable and wrinkle resistant. This fabric is made from soy protein fibre left over after processing

[41] https://www.researchgate.net/publication/327498497_Eco_friendly_Textiles
[42] http://www.cotton.org/news/meetings/2013annual/ecout.cfm
[43] https://hej-support.org/wp-content/uploads/2018/06/HEJ_Sustainable-textiles.pdf

soybeans into food. The liquefied proteins are extruded into fibres, which are then spun and used like other fibres. The high protein content makes it receptive to natural dyes[44].

Wool is renewable, fire-resistant and doesn't need chemical inputs. Organic wool is increasingly becoming available as it is produced using sustainable farming practices. Wool is a very useful textile with many important properties that make it attractive. One of the major benefits of wool is that it can absorb moisture well by drawing moisture into the core of its fibres.

Linen is made from cellulose fibers that are commonly derived from flax plants. This fabric is durable, linen can endure 20 years of wear. The flax plant does not require much energy or water resources to produce and the entire plant is used to make linen, leaving no waste footprint. Linen clothing is naturally biodegradable and recyclable.

Bamboo fabric is among the most environmentally friendly materials, is biodegradable, highly sustainable, and in no need of pesticides, it's a better alternative to typical cotton fabrics.

Among natural fibres available cotton, wool and silk are the most commonly used fibres for making fabrics. Among artificial fibres rayon, nylon and polyester are popular. Difference between cellulose and synthetic fibres[45] are presented in the next table (figure 11).

Cellulosic fibres	Synthetic fibres
Low resiliency: Fabric wrinkles unless any finishing is given	High resiliency: Less wrinkles after washing and wearing
High water absorbency: Comfortable for summer wears, good for towel, hand kerchief and diapers.	Low moisture absorption: Easily washable and easy spot removing.
Good conductors of heat.eg: Cotton is a better conductor of heat but less than that of rayon.	Good conductors of heat they melt with hot or ironic touch with hot objects.
Identification: Cellulose fibres ignite quickly, burns freely with smoke and have an after glow and after burning forms and a grey feathery ash.	Identification: Readily burns and melts giving a distinct plastic burning odour.
High affinity for dyes.	Low affinity for dyes.
Resistant to moth but less susceptible to mildew hence damp clothes should not be stored.	Highly resistant to moths, mildew and insects.
Need ironing at low temperatures. Ex: wool	Are adjusted with high heat settings. Hence

[44] *Eco friendly Textiles*. Available from: https://www.researchgate.net/publication/327498497_Eco_friendly_Textiles
[45] http://bieap.gov.in/Pdf/CGTPaperII.pdf

	it is good for embossed designing and easy for plant setting.
Susceptible to strong mineral and organic acids stains that require acid treatment should be rapidly removed.	Get readily damaged due to acids. Ex.: Nylon

Figure 11 Difference between cellulose and synthetic fibres

Topic 4.4.3.3 Eco-certification and Eco-label

Eco certification is related with the certification of companies in terms of their environmental performance based on the criteria defined in specific standards. Eco-label is related with the labelling of products that meet environmental criteria defined in specific reference documents.

The textile sector uses natural resources, chemical products and energy, making environmental sustainability a fundamental aspect of materials production and also of the textile and clothing processes.

The International Organization for Standardisation (ISO) has identified three types of labels, that are presented in three standards:

- Type I, in ISO 14024: Environmental labels and declarations - Type I environmental labelling -- Principles and procedures: A Type I label is a third-party assessment of a product based on a number of criteria involved in the environmental impact of a product or material throughout its life cycle. The objective of this type of environmental labelling programme is to contribute to a reduction in the environmental impacts associated with products, through the identification of products that meet the specific criteria of a Type I programme for overall environmental preferability.
- Type II, in ISO 14021 Environmental labels and declarations -- Self-declared environmental claims (Type II environmental labelling): specifies requirements for self-declared environmental claims, including statements, symbols and graphics, regarding products. It also describes selected terms commonly used in environmental claims and gives qualifications for their use and presents a general evaluation and verification methodology for self-declared environmental claims and specific evaluation and verification methods for the selected claims.
- Type III, in ISO 14025: Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures: Environmental Product Declaration (EPD), is a voluntary international certification aimed at providing relevant, verified and comparable information about the environmental impact of an activity gathered by examining the whole production chain.

There is also some specific standards oriented for certain environmental impacts, like ISO 14067 (Greenhouse gases -- Carbon footprint of products -- Requirements and guidelines for quantification) , which specifies principles, requirements and guidelines for the quantification and reporting of the carbon footprint of a product (CFP), in a manner consistent with International Standards on life cycle assessment (ISO 14040 and ISO 14044).

4.4.4 Suggested readings

- http://ec.europa.eu/growth/industry/sustainability/ecodesign_en
- https://www.researchgate.net/publication/266483128_Ecodesign_and_Textiles
- http://www.circular-design.eu/automatisch/
- http://circulardesigneurope.eu/
- https://www.circulardesignguide.com/methods
- Ceschin F., Gaziulusoy I., Evolution of design for sustainability: From product design to design for system innovations and transitions, Design Studies, Volume 47, November 2016, Pages 118-163, http://dx.doi.org/10.1016/j.destud.2016.09.002
- https://www.textileschool.com/154/eco-friendly-fibers/
- https://www.fibre2fashion.com/industry-article/7250/eco-textile-dyeing-and-finishing
- Sustainable Textiles - Life Cycle and Environmental Impact, Woodhead Publishing Series in TextilesBook, 2009, ISBN 978-1-84569-453-1
- http://www.d4s-sbs.org/MH.pdf
- https://www.google.pt/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&cad=rja&uact=8&ved=2ahUKEwizwsqi-tHhAhVwzoUKHUKlDtIQFjAEegQICBAC&url=https%3A%2F%2Fwww.mdpi.com%2F2071-1050%2F10%2F7%2F2524%2Fpdf&usg=AOvVaw2AGBgvFTQPi0PTQweMyO0I
- https://www.commonobjective.co/article/made-by-environmental-benchmark-for-fibres
- Eco label http://ec.europa.eu/environment/ecolabel/
- https://globalecolabelling.net/what-is-eco-labelling/
- https://www.iso.org/standard/72458.html
- https://www.iso.org/standard/66652.html
- https://www.iso.org/standard/38131.html
- https://www.iso.org/standard/71206.html
- https://www.oekotex.com/en/business/certifications_and_services/ots_100/ots_100_start.xhtml

- https://www.oeko-tex.com/en/business/certifications_and_services/leather_standard/leather_standard.xhtml
- https://www.oeko-tex.com/en/business/certifications_and_services/mig/mig_start.xhtml
- https://www.global-standard.org/
- https://textileexchange.org/integrity/
- https://www.bluesign.com/
- https://www.c2ccertified.org/
- https://www.oeko-tex.com/en/business/certifications_and_services/step_by_oeko_tex/step_start.xhtml
- https://www.iso.org/iso-14001-environmental-management.html
- http://ec.europa.eu/environment/emas/index_en.htm

4.4.5 Quiz

Choose the correct answer

1. What statement about eco-design is true?
    a. <u>Refers to design a product taking into consideration the environmental impact of materials</u>
    b. <u>Use sustainable materials</u>
    c. Is not applied to the entire lifecycle of a product
2. What are the characteristics of eco materials?
    a. Green resource profile
    b. Low recyclability
    c. <u>Energy/resource saving ability</u>
3. Eco materials are the same with natural materials?
    a. Yes
    b. <u>No</u>
4. Eco materials have the same properties like ordinary materials?
    a. <u>Yes</u>
    b. No
5. What statement is true?
    a. <u>Eco-certification helps companies to gain the trust of the customers</u>.

b. Eco-label refers only to products without services.

Unit 4.5 Circular business models for the textile sector

4.5.1 Introduction

In scientific literature business models refers to as 'the rationale of how an organization creates, delivers and captures value', 'describes the design or architecture of the value creation, delivery and capture mechanisms employed'[46].

4.5.2 Short description

Knowledge *At the end of this unit the learner will:*	**Skills** *At the end of this unit the learner will be able to:*	**Competencies** *At the end of this unit, the learner will have acquired the responsibility and autonomy to:*
• Define circular business models; • Describe new concepts: system thinking, cradle to cradle, resource recovery.	• Test the capacity of changing the classic business model into a circular one.	• Organize a work team, manage and supervise it; • Apply the Circular Economy framework principles to build a Business Model; • Analyze the opportunities and challenges along each stage.

4.5.3 Unit content

Topic 4.5.3.1 Circular business models (CBM) definition

"Value" is the central factor within the circular economy and circular business model. Roberta De Angelis defines circular business models as "business models where enhanced customers' value is produced as a result of more comprehensive 'circular offerings'" such as ecological performance, higher convenience, or superior durability.

According to Accenture[47] CBM is defined as 5 keys: circular suppliers, resource recovery, product life extension, sharing platforms and product as a service. CBM requires a good communication and collaboration between actors/stakeholders.

[46] Teece David, Business Models, Business Strategy and Innovation, Long Range Planning 43 (2010) 172e194 http://www.businessmodelcommunity.com/fs/Root/8jig8-businessmodelsbusinessstrategy.pdf

The governance, regulations and business models will play a crucial role in order to support the transition to the circular economy. More importantly circular business models would allow the retention of an asset at its highest value over time and support enhancement of natural capital according to Ellen Macarthur Foundation[48].

Different CBM will be required at different stages of a lifecycle of an asset and may work independently or collaboratively. Successful implementation of these business models will require action from designers, suppliers, service providers, contractors and end-of-life companies by sharing materials, systems, energy, as well as information and services[49].

According to Ellen Macarthur Foundation new business models would allow[50]:

- Greater control of resource streams through the value chain, in order to identify and capture the added value,
- Innovation through the whole supply chain so new entities can be generated such as business in waste handling, refurbishment and reverse logistics,
- Enhanced collaboration within the supply chain among all the actors,
- Creation of services that capture valuable products or resources.

CBM is a business model that reach for[51]:

- using less materials and resources for making products and/or services;
- extending the life of current products and/or services through refurbishment and remanufacturing;
- closing the loop of products' life by recycling.

CBM strives to reduce, retain and recycle. The circular economic system avoids waste and tries to preserve the inherent value of products as long as feasible[52]. The main goal is to reduce the consumption of resources by recycling materials and/or energy after the use phase in order to avoid leakage out of the system.

Real case example: Natural fiber from pineapple leaves by Piñatex.

Scope	#Raw material #Vegan

[47] https://www.accenture.com/t20150523T053139__w__/us-en/_acnmedia/Accenture/ConversionAssets/DotCom/Documents/Global/PDF/Strategy_6/Accenture-Circular-Advantage-Innovative-Business-Models-Technologies-Value-Growth.pdf
[48] https://www.ellenmacarthurfoundation.org/assets/downloads/ce100/CE100-CoPro-BE_Business-Models-Interactive.pdf
[49] idem 48
[50] Idem 26
[51] https://www.ellenmacarthurfoundation.org/publications/a-new-textiles-economy-redesigning-fashions-future
[52] https://www.researchgate.net/publication/324617908_Business_models_and_supply_chains_for_the_circular_economy [accessed Sep 05 2019].

Value added	Piñatex (Pineapple Leather) Made from pineapple leaf fibre, this innovative fabric thought up by Ananas Anam is not only a natural, biodegradable product – it also reduces waste and provides additional income to farmers who were otherwise throwing pineapple leaves away and reduce the soil destinated to harvest textile because the farmers harvest to obtain pineapple.
More information	https://www.ananas-anam.com/

Resource recovery models tries to recycle waste into secondary raw materials, thereby diverting waste from final disposal while also displacing the extraction and processing of other virgin natural resources.

The role of product life extension models is to extend the life of the existing products, to slow the flow of constituent materials through the economy, and to reduce the rate of resource extraction and waste generation.

Real case example: Recovering textile consumer waste to create a second life for clothes

Scope	#Textile Waste #Post consume textile #NGO
Value added	Humana People to People Federation that includes 30 organizations worldwide. In Spain they have 5,000 containers that are used for the collection of used clothing. These containers are available to the public through established partnerships with 2.000 municipalities and institutions and private companies. In addition, they have 52 shops that sell second-hand clothing: 20 in Barcelona and its metropolitan area, 1 in Reus (Tarragona), 25 in Madrid, 3 in Seville, 1 in Granada and 2 in Valencia in order to give a second life, the rest of the textile is recycled by different upcycling and downcycling proposes.
More information	https://www.humana-spain.org/?&lang=en

A possibility to reduce the demand for new products on the market is sharing models witch facilitate the sharing of under-utilised products.

This business models aim at providing planning and design for components, systems and ultimately the full asset in order to improve its service life. Figure 12 presents a strategic plan of process through the value chain is required for this business model to increase the reuse potential and recyclability of products, by-products and waste streams[53].

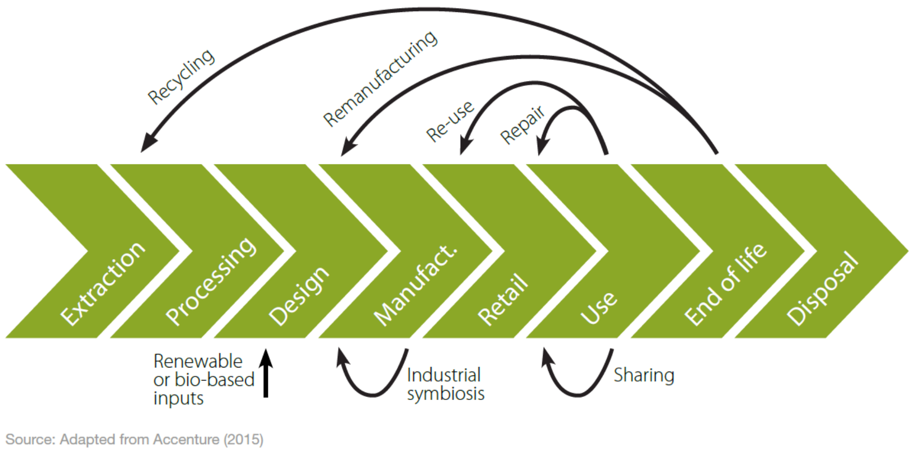

Figure 12 Circular business models operate in different parts of the value chain[54]

CBM should be implemented on the whole value chain, that's why the value chain requires a new way of thinking. In order to achieve it, it should be followed some facts[55] such as:

- **Circular supplies** - It is based on supplying fully renewable, recyclable, or biodegradable resource inputs that support circular production and consumption systems. The value suggestion focuses on the substitution of fossil, critical and scars materials.
- **Access and performance** - is concerned with providing the capability or services to satisfy the consumers needs without owning physical products. The value suggestion includes the offering of Product-Service-Systems, which is a combination of products and services that seek to provide functionality for customers.
- **Extending product value** – refers to exploiting residual value of products and delivering high-quality, long-lasting products based on design for durability, upgradability, reparability and modularity. Values that would otherwise be lost through wasted materials are instead maintained or even improved by repairing, upgrading, refurbishing, remanufacturing or remarketing products.
- **Bridging** - promotes platforms for collaboration among producers and consumers, either individuals or organizations. The value suggestion focuses on enabling

[53] https://www.ellenmacarthurfoundation.org/assets/downloads/ce100/CE100-CoPro-BE_Business-Models-Interactive.pdf
[54] https://www.oecd.org/environment/waste/policy-highlights-business-models-for-the-circular-economy.pdf
[55] https://sustainabilityguide.eu/methods/circular-business-models/

interaction between different but interdependently players and bring together supply and demand.

Some of the business model strategies[56] are:

- Provide and Perform – giving the capability or services to satisfy consumer needs without needing to own physical products.
- Extend product value - Exploiting residual value of products – from manufacture, to consumers, and then back to manufacturing.
- Long - life - Business models focused on offering long-product life, based on design for durability and repair for instance.
- Encourage sufficiency – active ways to reduce end-user consumption through principles such as durability, upgradability, warrantees, service, reparability and a non-consumerist approach to marketing and sales.
- Extend resource value - Exploiting the residual value of resources: collection and sourcing of otherwise “wasted” materials or resources in order to turn these into new forms of value.

Real case 2: Collect postconsumer garments by Inditex and H&M

Scope	#Close the loop #brands
Value added	To ensure the correctly postconsumer garment waste management two of the most important retailers of the world were creating a project in order to correctly garment post consumer management.
More information	https://www.inditex.com/es/comprometidos-con-el-medio-ambiente/closing-the-loop https://hmgroup.com/sustainability/Planet/recycling.html

- Industrial Symbiosis - A process-oriented solution, interested in using residual outputs from one process as feedstock for another process, which benefits from geographical proximity of businesses.

Using circular business models the model of product and material flows through the economy will be modified in order to reduce the environmental side-effects resulting from the extraction, use, and in the end disposal of natural resources[57].

[56] https://sustainabilityguide.eu/methods/circular-business-models/
[57] https://www.oecd.org/environment/waste/policy-highlights-business-models-for-the-circular-economy.pdf

Topic 4.5.3.2 Concept of "system thinking", "cradle to cradle", "resource recovery"

System thinking can be defined as a design approach which highlights interdependence between and collective evolution of system players. There are a lot of instruments to related to system thinking such as behaviour over time, graphical function, structure-behavior relationships, causal loop, policy structure[58].

Another definition of Systems thinking refers as "a holistic approach to analysis that focuses on the way that a system's constituent parts interrelate and how systems work over time and within the context of larger systems"[59]. There is a difference between the system thinking approach and the traditional analysis because the last one studies systems by dividing them into individual parts.

Systems thinking approach can be used and applied to many areas of research such as the study of medical, economic, political, environmental, human resources and educational systems and many others.

Systems thinking show systems in a holistic manner and offer an overview of a system by highlighting the linkages and interactions between the parts that include the entire system[60].

Cradle to Cradle® is a design concept that was developed for the first time in the 1990s by Prof. Dr. Michael Braungart, William McDonough and other scientists of EPEA in Hamburg. It militates for innovation, obtaining a quality product and describes many possibilities for endless use of materials in cycles.

Real case example: Cradle to cradle certified products.

Scope	#Sustainable products #certification
Value added	Cradle to Cradle Certified™ is a globally recognized measure of safer, more sustainable products made for the circular economy by a certification process in order to ensure a third-party verification according to a guideline with Circular Economy principles. Examples: • Apparel for Biological Cycle by Cotton Blossom – Gold • GOTS Organic Knit Wool clothing – Silver • C&A designed to be recycled Pacific Jeans garment – Bronze
More information	http://www.cotonblossom.org https://www.ramblersway.com http://www.c-and-a.com/uk/en/corporate/company/

58 https://www.ceguide.org/Strategies-and-examples/Design/Systems-thinking
59 https://searchcio.techtarget.com/definition/systems-thinking
60 http://learningforsustainability.net/systems-thinking/

Another definition of Cradle to Cradle® is a design concept inspired by nature, in which products are created according to the principles of an ideal circular economy[61].

Cradle to cradle "C2C" can be defined as a design framework centered on eco-efficiency and eco-effectiveness. C2C is based on 5 principles[62]: Material Health, Material Reutilization, Renewable Energy, Water Stewardship, Social Fairness. The goal of Cradle to Cradle is to ensure that the products remain in a continuous circuit so that no waste remains. Cradle to Cradle should be applied on the entire supply chain, starting to the design phase by choosing the right materials and production process. Another important aspect of C2C is that the companies should also focus on environmental and social factors not only the economics[63].

According to EPEA[64] Cradle to Cradle® design is a concept which makes the difference between the biological and the technological cycles for materials. For example, the waste materials from an old product will become materials for new products. Figure 13 presents the Cradle to Cradle approach.

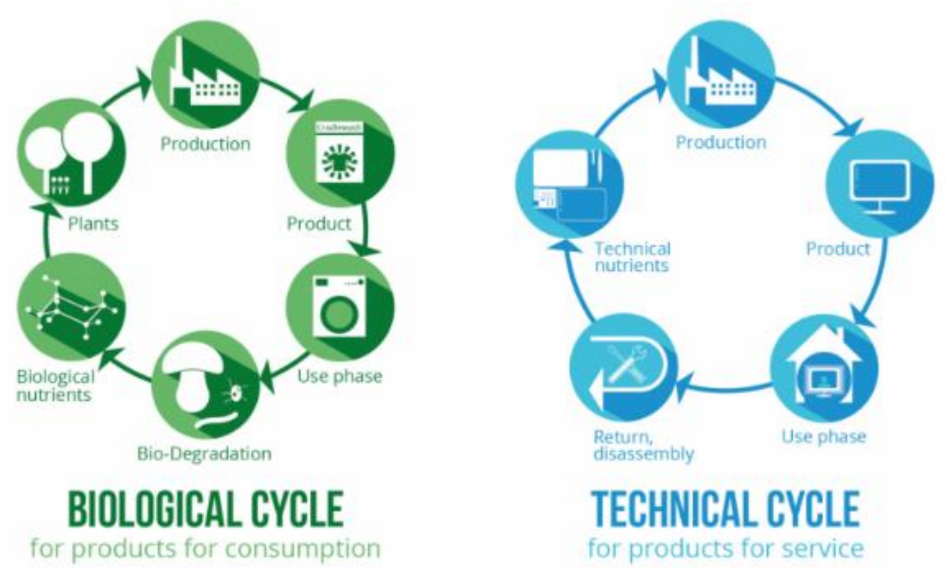

Figure 13 Cradle to Cradle approach, source EPEA[65]

In case of biological cycle the materials are returned to the biosphere as compost or other nutrients, from which new materials can be obtained.

[61] https://epea-hamburg.com/cradle-to-cradle/
[62] https://www.ceguide.org/Strategies-and-examples/Design/Cradle-to-Cradle-R
[63] http://www.c2c-centre.com/news/cradle-cradle-fashion-industry
[64] https://epea-hamburg.com/cradle-to-cradle/
[65] https://epea-hamburg.com/cradle-to-cradle/

In case of technical cycle the materials that are not used during use in the product can be reprocessed to allow them to be used in a new product.

Resource recovery is one of the main aspects of waste management. Resource recovery refers to the routes on recirculating post-consumer materials or waste. In the economic system of CE resource recovering refers to extracting the maximum value of resources or raw materials for many times to be processed, used at any scale and ends up in life cycle to regenerate. Circular economy resource recovery routes concentrate on waste prevention, recovery (reuse, repair, remanufacturing) and reprocessing (upcycling, recycling, downcycling).

4.5.4 Suggested readings

- https://thesystemsthinker.com/systems-thinking-what-why-when-where-and-how/
- https://www.cradletocradle.com/
- https://www.c2ccertified.org/
- http://www.ecap.eu.com/take-action/increasing-clothing-recovery-rates-2/
- Fontell P., Heikkila P., Model of circular business ecosystem for textiles, https://circulareconomy.europa.eu/platform/sites/default/files/model-of-circular-business-ecosystem-for-textiles-11-2017.pdf
- https://www.ceguide.org/Strategies-and-examples

4.5.5 Quiz

Select the right answer

1. Which element is the key factor in business models?
   a. Money
   b. <u>Value</u>

2. Circular business models can be applied in different sectors?
   a. <u>Yes</u>
   b. No

3.Which statement is true?
   a. <u>CBM modify the pattern of product and material flows through the economy</u>.
   b. Can’t reduce the adverse environmental side-effects resulting from the extraction, use, and eventual disposal of natural resources and materials.

4. Why is important to apply the Circular business model in textile industry?

   a. <u>Helps to manage better post-consumer textiles</u>
   b. Provides complex products to costumers

5. Why resource recovery models are necessary?

   a. Divert waste from final disposal while also displacing the extraction and processing of virgin natural resources.
   b. <u>Extract the maximum value of resources or raw materials for number of possible times to be processed</u>.
   c. Are not necessary.