Co-funded by
the European Union

From Sustainable to Circular Materials

License and Terms of Use

Sustainability:
avoiding the depletion of natural resources to maintain ecological balance

Co-funded by the European Union

Sustainability

In 1987, the United Nations defined sustainability as “meeting the needs of the present without compromising the ability of future generations to meet their own needs”.
This envisions a holistic focus on environmental health, social equity and economic vitality.

Co-funded by
the European Union

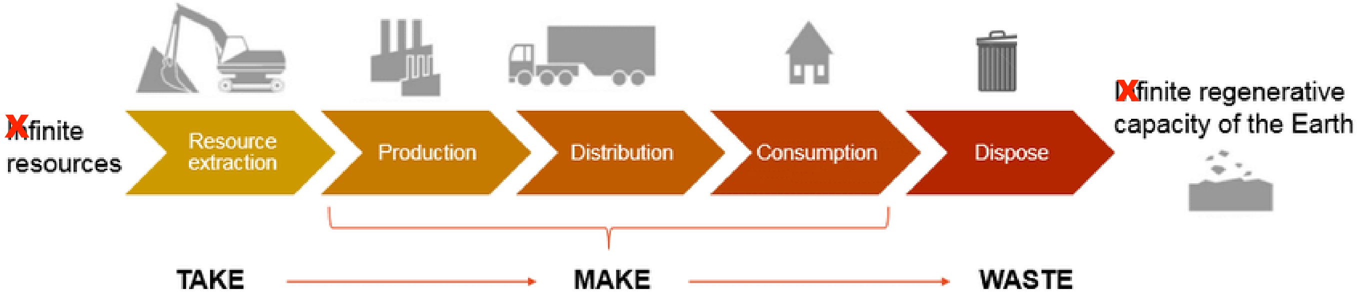
Unfortunately, sustainable ambitions are not enough!

“Instead of doing **less damage** to the environment, it is necessary to learn how we can participate with the environment” - Bill Reed, 2007

Our patterns of consumption tend to follow a ‘take-make-waste’ model meaning that **we are still extracting too many resources and not using the things we already have enough.**

Co-funded by the European Union

A Linear Economy

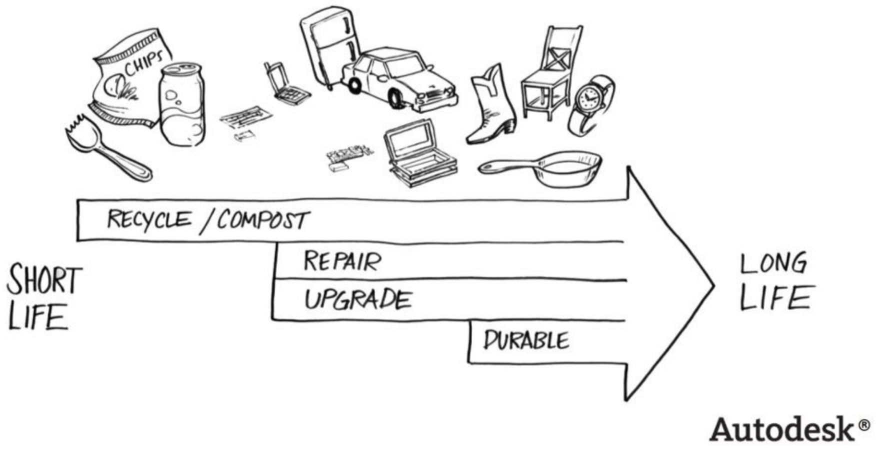


Traditional manufacturing has followed a linear process for a long time, where finite resources (such as fossil fuels) are extracted to make materials, and power the process of making them. They are then shipped around the world using the same kinds of finite resources, to distribute them among consumers.
This does model does not have a long term view of the health and needs of future generations, as it treats resources like they are in-finite. The market drives trends, competition and low pricing - which feeds the overconsumption of products, encouraging consumers to only use them for a very short time, where replacing things very quickly, buying multiple versions of the same thing, and discarding things is the 'norm'.

A Sustainable Product in a linear economy?

Even when a product is made sustainably, using fair labour practices, renewable materials (such as bio-based or recycled materials) and renewable energy (such as wind or solar), **there is still a big sunk energy cost for planet and people.** A sustainable product is only sustainable if it remains in use and of high value. This means different things for different products, such as single use items vs. Clothing.

To move away from this model means we need to encourage a shift from being **consumers** of a product to **users** of a **product, service or system**.



Circularity:
from linear to circular

Co-funded by the European Union

Circularity

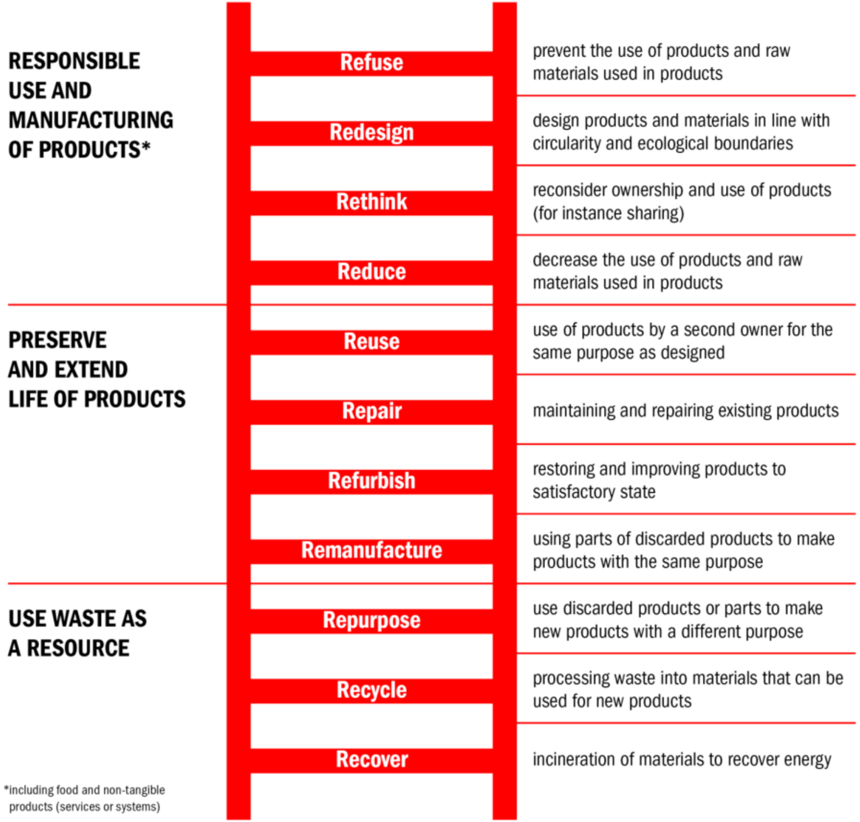
"The circular economy is a system where materials never become waste and nature is regenerated. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting. The circular economy tackles climate change and other global challenges, like biodiversity loss, waste, and pollution, by decoupling economic activity from the consumption of finite resources."

Ellen MacArthur Foundation

The R-ladder

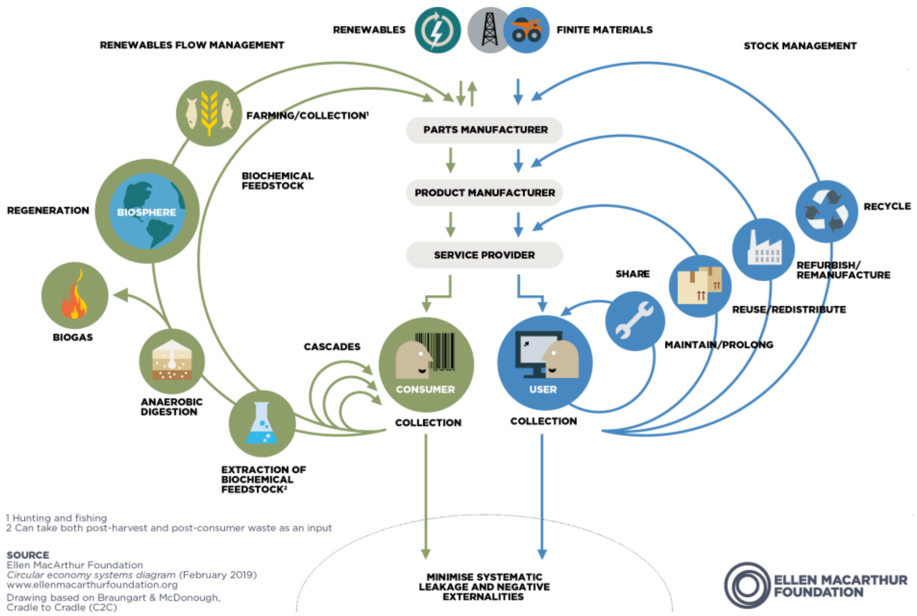
The circular economy requires us to move from a take-make-waste model. This means we need ways to **keep products in use for as long as possible**. This requires **behaviour change** on behalf of designers and users, as identified by the top 4 rungs: refuse, redesign, rethink and reduce.

Other forms of behaviour change and alternative actions are described by the next 4 rungs: resue, repair, refurbish and remanufacture are actions that can often be taken by users themselves, given the correct education and access to resource, but also represents opportunities for growing the service economy, in which jobs are created for roles such as repairing, refurbishing, remanufacturing and upcyling.



Source: What Design Can Do

Resource use in a circular economy



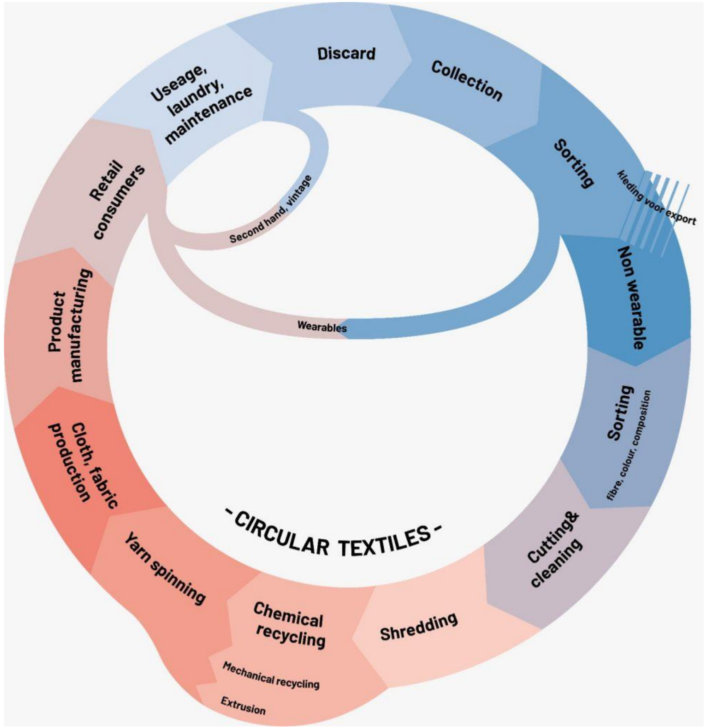
The last 3 rungs of the R-Ladder are repurpose, recycle and recover. These are the final actions to take when all of the other processes have been carried out, ideally a number of times. They are at the bottom of the ladder, because they represent the highest investment of energy and resources to execute.

The Ellen MacArthur Foundation use the Butterly diagram to illustrate the different paths for finite and renewable materials. These different groups require different methods for processing and reuse. Finite materials can often go through greater levels of reprocessing and recycling, whilst renewable materials will inherently break down faster, and need to be well managed to make sure they are reaching the correct systems for decomposition and redistribution.

Learning from:
REFLOW Amsterdam

In fashion and textiles, there are specific routes that need to be considered when aiming for circularity.

- Products need to be designed with circularity in mind, so they can be easily repaired, sorted, cleaned for reuse
- Products should also be designed for their end of life where they need to be recycled, either through chemical or mechanical recycling processes.
- We need systems for good collection and sorting and redistribution of used items
- We need infrastructure to process used items for recycling
- We need infrastructure for re-manufacture: spinning, weaving, knitting, product assembly
- We need alternative models and services to traditional consumption, such as rental



Circular textile wheel, reflowproject.eu transitions

Co-funded by
the European Union

Sustainable – Circular Materials

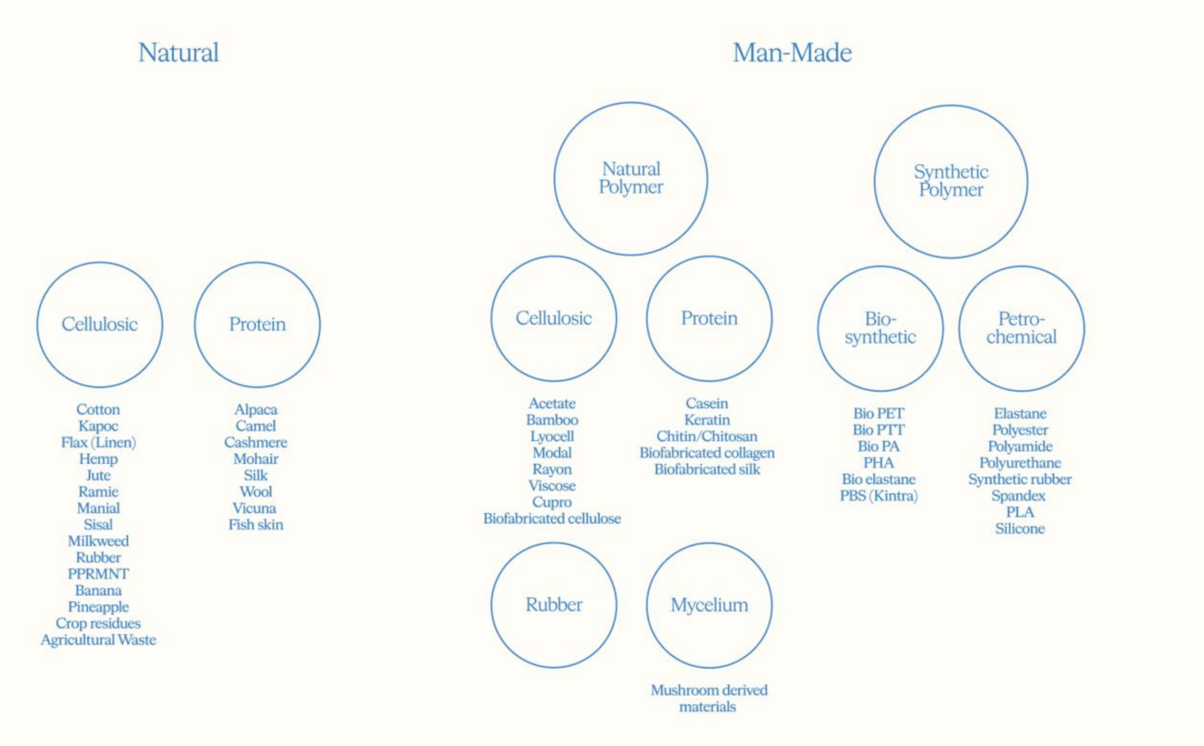
Co-funded by
the European Union

Material Choices

Following the Ellen MacArthur butterfly diagram, understanding material groups and properties is essential for designing and successful recovery of fibres for reuse, or decomposing.

Mixing of different fibre groups is problematic for future use as it creates blends that do not follow the same material cycles, meaning they cannot be separated easily.

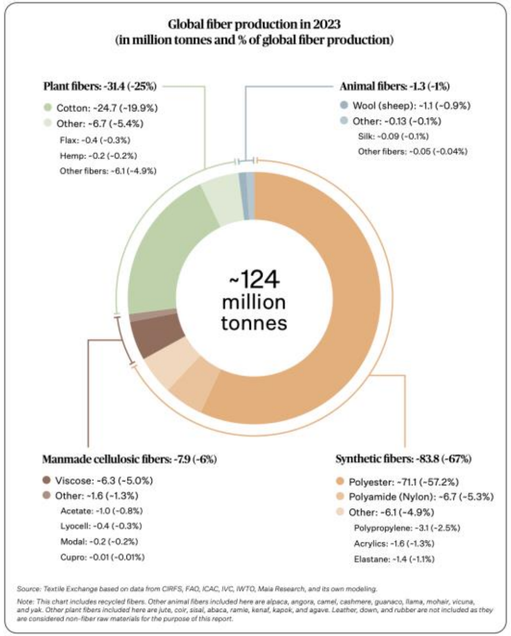
This is why designing for recyclability, by following mono-material or disassembly principles is important.



Material Choices are context dependent

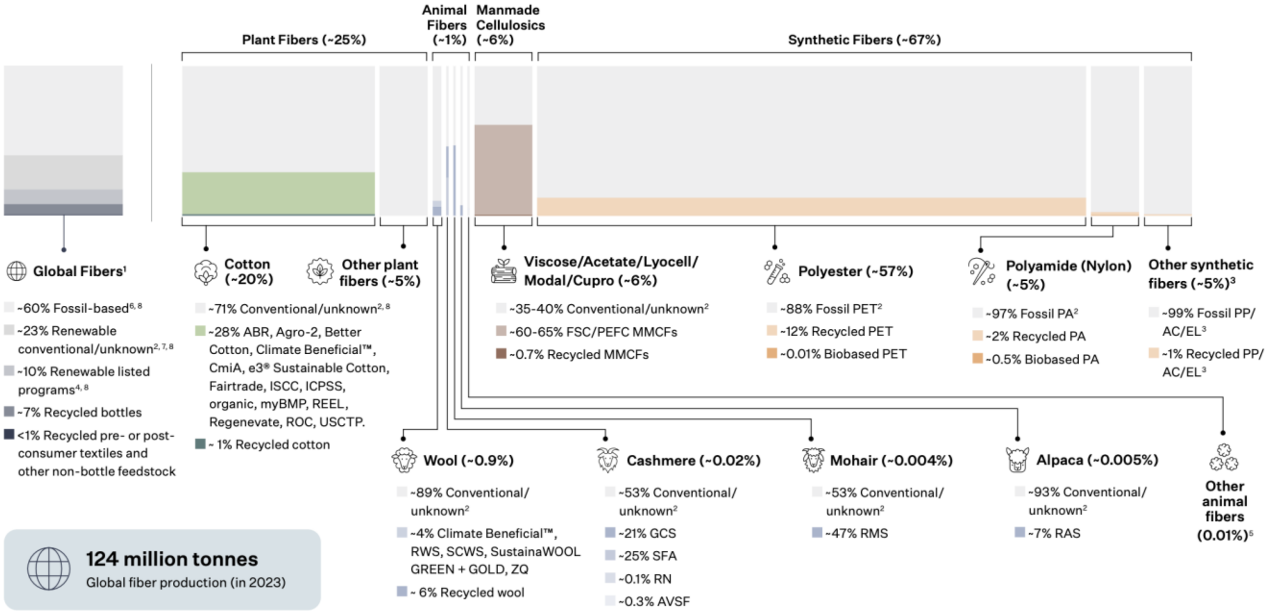
Only since the 2010s, the dominant fibre group used in fashion and textiles has been synthetics. These are Polyester, Acrylic, Polyamide (Nylon) and Elastane derivatives. They are efficient and reliable, in that they are not dependent on land use and farming to produce the raw material, however they are directly linked to the rise of fast fashion and microplastic pollution. The raw material for these fibres are fossil fuels, which the use of creates greenhouse gas emissions, which cause global warming and climate change.

Overuse of cheap synthetics drives the production and consumption of fast fashion, and they are being used where they don't need to be used.
Synthetics have great technical properties, such as being lightweight and fast drying, and the possibility to be readily recycled - as long as they are not blended with other material groups or chemical compounds. However, they are not needed in things like sweaters - where pure cotton or wool would be a better natural solution.



Textile Exchange Materials Market Report 2024

The global fiber market 2023: Program overview



1 This graph aims to inform the industry about global total fiber production volumes and the shares covered by different programs.
2 'Conventional/unknown' includes volumes of programs for which data is not accessible or available.
3 Other synthetic fibers include polypropylene (PP), acrylics (AC), and elastane (EL).
4 Renewable listed programs include here all the programs listed in this chart apart from the recycled fibers.
5 Other animal fibers include here angora, camel, guanaco, llama, vicuna, yak, and silk.
6 Fossil-based is calculated as the synthetics total excluding recycled and biobased synthetics.
7 Renewable conventional/unknown is calculated as the global fiber total excluding fossil-based, the renewable listed programs, recycled bottles and recycled pre- or post-consumer textiles and other non-bottle feedstock.
8 Revised January 2025. See methodology for further information.

Textile Exchange Materials Market Report 2024

Co-funded by the European Union

Market dominance of virgin fibres

Most of the fashion and textile industry relies heavily on the use of virgin

- Synthetics
- Cotton
- Regenerated (Man-Made) Cellulosics
- Other plant fibres (such as flax)
- Wool

"After years of growth, the market share of recycled fibers decreased from 7.9% in 2022 to 7.7% in 2023. 7.0% of all fibers produced were recycled polyester made from plastic bottles. **Overall, less than 1% of the global fiber market was from pre- and post- consumer recycled textiles in 2023. Virgin fiber production volumes increased** from 107 million tonnes in 2022 to 115 million tonnes in 2023, **primarily driven by the increase in new virgin fossil-based fibers** from 67 million tonnes in 2022 to 75 million tonnes in 2023."

- Textile Exchange Materials Market Report 2024

Co-funded by the European Union

Recycling Textiles for circularity

"Recycling is the process of transforming waste into reusable material. This step is taken when a product is no longer usable, cannot be refurbished or remanufactured, or isn't suitable for those processes. Recycling ensures that the materials of the product are kept in use, preventing them from becoming waste. While the embedded value of a product—the time and energy spent making it—is lost in recycling, the value of the materials themselves is preserved."

Closed-loop recycling for circularity in fashion involves recycling textiles and clothing into new products of the same type and quality as the original. This system aims to create a continuous cycle of reuse, maintaining the integrity and properties of the materials.

There are two methods currently used, **mechanical** and **chemical.**

Co-funded by the European Union

Challenges of Closed-Loop Recycling

Material Complexity: Many garments are made from blended fabrics (e.g., cotton-polyester blends), making it difficult to separate and recycle the different fibres effectively.

Quality Retention: Repeated recycling can degrade fibre quality, making it challenging to maintain the original properties and performance of the materials.

Technological Limitations: High-quality closed-loop recycling often requires sophisticated and expensive technology to efficiently separate, clean, and process textiles. Current recycling technologies may not be advanced enough to handle all types of textiles effectively, limiting the scope of closed-loop recycling.

Economic Factors: The process of closed-loop recycling can be more expensive due to the need for advanced technology and specialized processes. Moreover, the market for recycled textiles can be volatile, with fluctuations in demand and price affecting the economic viability of recycling initiatives.

Logistical Challenges: Efficiently collecting and sorting used textiles is logistically challenging and resource-intensive. A robust infrastructure is required to support the collection, transportation, and processing of textiles for closed-loop recycling, which may not be well-developed in all regions.

Environmental Impact: While closed-loop recycling aims to reduce waste, the processes involved can still be energy-intensive and resource-demanding, potentially offsetting some environmental benefits.

Consumer Behaviour: Consumer awareness and willingness to participate in recycling programs are crucial.

Co-funded by the European Union

Mechanical Recycling

Mechanical recycling has been used since the 1800s in Prato, Italy for recycling high value wool. It's a multi-step process, reliant heavily on the initial phase of **collecting and sorting high quality textiles**. This is primarily done by hand, although some machines, such as Fibersort Technologies are being piloted.

The process is as follows: fabrics are mechanically shredded or cut into small pieces or fibers. The resulting fibers are cleaned and reprocessed into yarn or nonwoven fabrics.These recycled fibers are used in new textiles (like insulation, stuffing, felt or new yarns), though are typically lower-quality than virgin fibers.

There are many challenges associated with recycling textiles, many of which can be alleviated through decisions made at the design stage. Most textiles are made from mixed fibers (e.g., cotton-polyester), which are hard to separate mechanically - therefore **mono-material designing** can be implemented. Accurately identifying and sorting different fibre types requires advanced (and often expensive) technology, however **use of Digital Product Passports** could help with traceability. Many designs have contaminants, such as zippers, dyes, labels, and other non-textile materials which complicate the process and reduce yield., however **designing for modularity and disassembly** could help this.

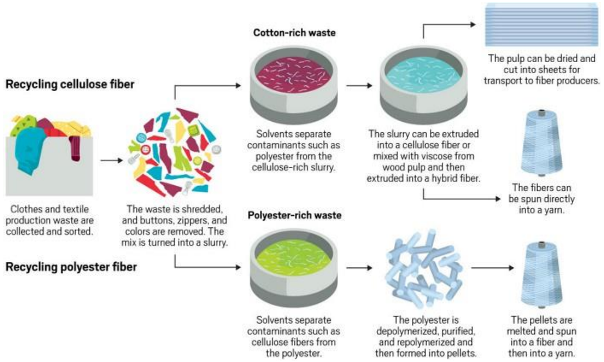
Chemical Recycling

Chemical recycling is a comparatively new process. It focuses on breaking down a fibre to its base chemicals or cells, and rebuilding them up into new fibres. The process is as follows:

Sort & Pre-Treat: Textiles are sorted by fibre type and contaminants are removed. Fibres are then broken down into their base chemicals (e.g. monomers) through depolymerisation. Extracted chemicals are then purified to remove dyes, additives, and impurities. Purified materials are rebuilt into new fibres (e.g., PET, cellulose) through depolymerisation. This advanced process can produce fibres comparable to virgin material.

Whilst this process achieves a very high level of recycling, it faces similar and additional challenges to mechanical recycling. The process also works best with single-fiber fabrics (e.g., 100% polyester or cotton), and separating mixed fibers is technically difficult and costly. Some methods have large environmental footprints through high energy and chemical use. The technology is relatively new and often under NDA, so only a few large-scale chemical recycling facilities exist.

The cost of chemical recycling often exceeds that of using virgin materials, so it is difficult to convince suppliers that they would want to use this, when prices are always trying to be driven down.



Source: c&en

Co-funded by
the European Union

Chemical Recycling Case Study: Circulose

Chemical recycling opens up new possibilities for reusing **post-consumer textiles** whilst maintaining value.

The benefits of this method mean that we can t**arget used cotton clothing, towels and bedsheets**: Circulose®, takes post-consumer cotton and turns them into a new raw material. The process transforms worn-out textiles into a **cellulose pulp**, which can replace virgin cotton in the production of **viscose, lyocell, or modal** fibers. Unlike mechanical recycling, which weakens fibres, Circulose retains fiber integrity by breaking cotton down chemically into **pure cellulose**. This allows garments to be recycled into new garments – closing the loop on cotton-based textiles.Major brands like H&M, Levi's, and Zara have started incorporating Circulose into their products, proving scalability.

The process still has some challenges, where it needs **cotton-rich** inputs – blended fabrics (like poly-cotton) are still problematic. Global **sorting and collection systems** for post-consumer waste need major improvement, and s**caling production and the investment required to meet demand** is still underway.

Co-funded by the European Union

Natural Fibres: Biodegradability

Natural fibres like cotton, flax, wool and hemp break down naturally at end-of-life, unlike synthetics (e.g., polyester), which persist for hundreds of years and require external energy to recycle. Natural fibres don't shed harmful microplastics into waterways when washed. Unlike synthetics, which are derived from oil; natural fibres grow from the earth and animals, and can be farmed in healthy, regenerative ways that give back to the planet, supporting biodiversity and flourishing. In addition, they're more breathable and less irritating on the skin than many synthetic alternatives and can be dyed using natural processes, rather than chemically-dependent processes.

Natural Fibres: Cultivation

Whilst many natural fibres can also be mechanically and chemically recycled, in addition to biodegrading under the right conditions, the way they are grown is also important. Exemplary practices of this are listed below.

Regenerative Cotton is grown using techniques that restore soil health, enhance biodiversity, and sequester carbon, such as crop rotation and intercropping. Regenerative growing also reduces need for chemical inputs and improves long-term farm resilience.

Flax (Linen) grows well in certain parts of Europe with cooler climates, specifically France, the Netherlands and Belgium. It requires little water, generally surviving from annual summer rainfall, no pesticides and can thrive in poor soil conditions. In addition, it is naturally antibacterial and durable.

Hemp Is one of the most sustainable crops: fast-growing, needs minimal water and no pesticides. It improves soil structure and sequesters carbon well. Produces strong, long-lasting fibre ideal for both clothing and industrial building uses.

Wool fibres naturally insulate in cold and wick moisture in heat — making garments wearable year-round. Wool's natural lanolin and structure help resist odor and bacteria buildup. The crimped fiber structure gives wool resilience and shape retention, ideal for long-lasting fashion. When disposed of, wool breaks down in soil within months, enriching it with nutrients like nitrogen.

In addition, sheep can be rotationally grazed, their movement mimicing wild herds, encouraging soil regeneration and plant diversity. Healthy grasslands store more carbon in the soil — regenerative grazing helps draw down atmospheric CO_2. This in turn leads to Improved root systems that enhance the land's ability to retain water and support wildlife.

Co-funded by the European Union

Biobased Materials

As the fashion industry seeks sustainable alternatives to fossil fuel-based materials, bio-based innovations are emerging as game-changers — offering renewable, biodegradable solutions that reduce environmental impact and open up new creative possibilities for manufacture.

Mushroom Leather (Mycelium)
Made from the root system of fungi (*mycelium*), grown on agricultural waste. Biodegradable and leather-like in texture — soft, durable, and flexible.Uses far less water and energy than animal leather or synthetics.
Commercial examples: Mylo™ (by Bolt Threads), Reishi™ (by MycoWorks).

Bacterial Cellulose
Produced by fermenting bacteria (often from kombucha cultures).
Forms a non-woven, leather-like sheet that's strong, breathable, and biodegradable.
Can be grown into shape, reducing cutting waste.
Still early in scaling but promising for small accessories and experimental fashion.

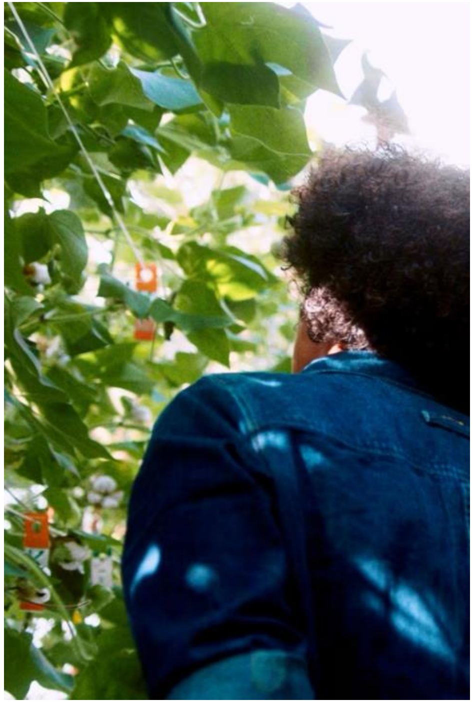
Algae-Based Bioplastics
Derived from algae biomass, used to create films, coatings, or flexible plastics.Fully biodegradable and can be home-compostable, unlike petroleum-based plastics. Can be used in trims, packaging, and even as fibres when blended with other materials. Algae farming can absorb CO_2 and filter water, offering additional environmental benefits.

Co-funded by the European Union

Increase Local Natural Fibre Production

The market reliance primarily on synthetics, cotton, and regenerated (Man-Made) Cellulosics such as Tencel and Modal is a global issue - as many of these fibres are needed for production in places where they do not come from or grow. Global imports and exports of cotton, MMRF and wool create long and complicated supply chains that increase the likelihood of misinformation, poor work practices, unfair pay and waste.

A renewed focus on local materiality is suggested to help tackle some of these issues. Examples of pilot projects include G-Star's 'Homegrown Cotton' which saw the controlled cultivation of cotton in greenhouses in the Netherlands. Whilst heavy infrastructure is required, the pilot study showed that growing cotton in this way, compared to traditional mono-crops that are dependent on heavy water and land use, could improve yields, extend the growing season, provide weather protection, help control pest management, water efficiency, soil protection, and enables localised production.



G-Star 'Homegrown Cotton'

transitions