REFLOW AMSTERDAM

Circular Textiles Pilot

A Primer On Textile Recycling

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

REFLOW AMSTERDAM CIRCULAR TEXTILES PILOT

A PRIMER ON TEXTILE RECYCLING

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PREFACE

Laurie Skelton

There is no denying that the environmental impact of the textile industry is enormous. From the pesticides and fertilisers used in cotton production to the fossil fuels used in fabric manufacturing, the textile industry's current practices have dire consequences for our planet and our health. With the looming threat of climate change, we need to rethink the way we create and consume textiles more than ever.

The Amsterdam Reflow Pilot aims to address some of these issues through a grassroots initiative focusing on discarded consumer textiles. Each year, over 11,000 tonnes of textiles are improperly discarded and end up in landfills or incinerators, while only 2,500 tonnes end up in recycling facilities. By empowering Amsterdam citizens with new knowledge and skills, the pilot programme aims to improve the way textiles are discarded, reused, and brought back into the material flow.

The purpose of this publication is to assemble knowledge and educate stakeholders at every stage of the textile industry's cycle. Firstly, we aim to extend the life of textiles currently in use through encouraging people to reduce consumption and repair or reuse items. Secondly, when items must be discarded, we want to encourage people to do so correctly and responsibly. Finally, we want to educate and encourage citizens, designers, retailers, and manufacturers to think sustainably when creating or buying new products.

To enact real change and move towards a circular economy and a circular textile industry, we cannot act alone. We hope the knowledge collected here encourages and empowers you to do your part in moving towards a more sustainable world.

INTRODUCTION

Reflow is a project funded by the European Union's Horizon 2020 programme that focuses on researching methods and policies to improve circularity in six European cities, including Amsterdam. The Amsterdam Reflow project focuses specifically on the circularity of textiles used within the city and executes its initiatives in cooperation with the Amsterdam Metropolitan Area (MRA).

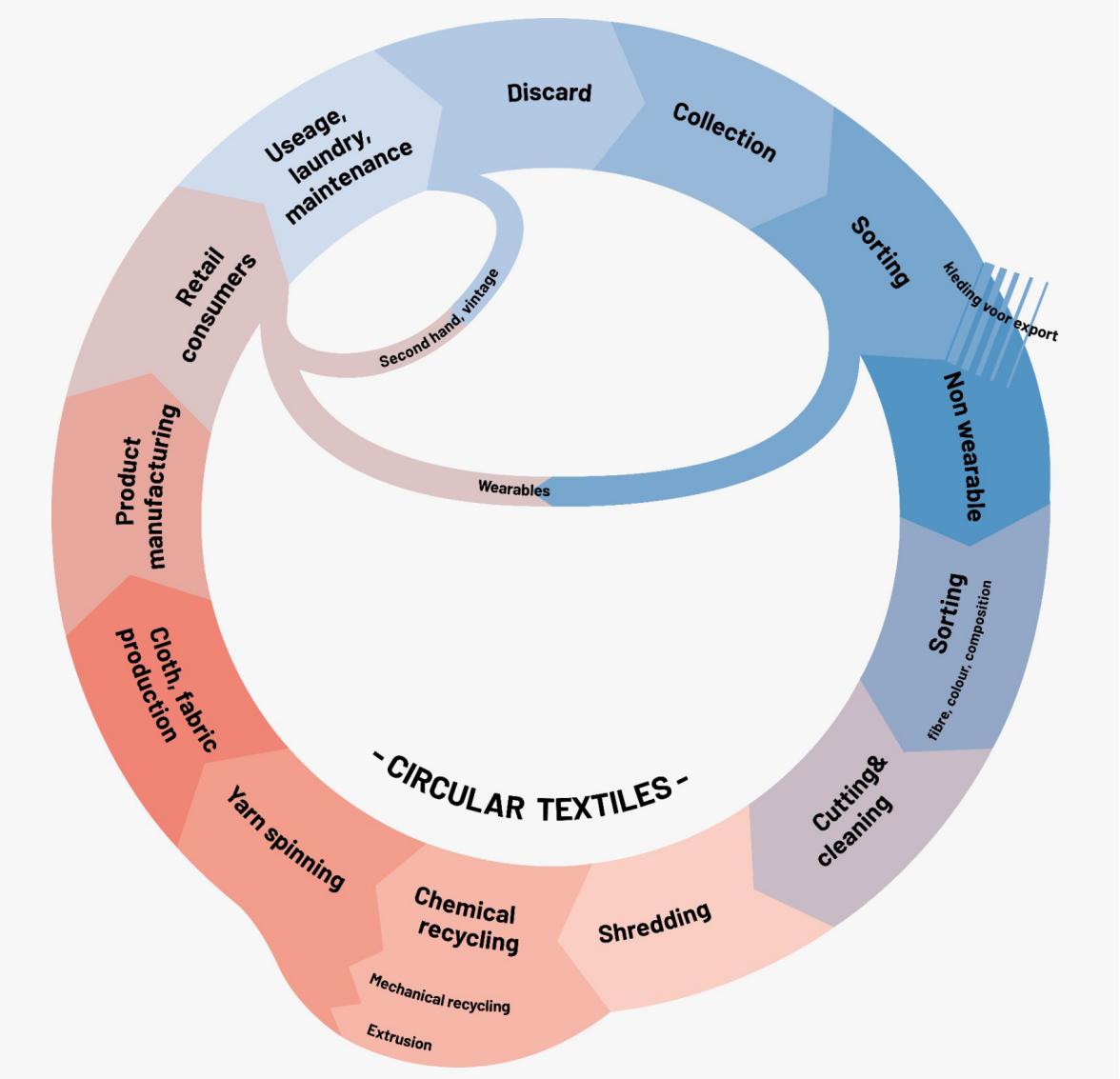
The field of textiles is ripe with potential for increasing circularity. To summarise how we envision moving from a linear to a circular textile flow, we developed the "Textile Wheel," an infographic identifying the 16 stages of circular textiles (see next page). In this booklet, we describe these 16 stages in more detail and provide background on important issues crucial to developing a successful local circular textile economy in Amsterdam.

Within the wheel, you may notice several loops, which represent the reuse of products (e.g. swap-shops, thrift stores, vintage outlets, etc.). These loops of discarded clothing are important in facilitating a circular textile economy. Consumers of textile products have an important role in this stage of the wheel because the way they discard their textiles directly affects the health of the circular system in Amsterdam. Awareness and engagement amongst citizens is crucial to increasing the amount of textiles collected and the success of the programme.

This booklet describes all of the stages of product use, reuse, collection, sorting, and recycling in detail. Many of the issues we touch upon in this booklet were further elaborated during the execution of the Reflow Amsterdam project and disseminated through webcasts.

We would like to thank the Amsterdam Reflow Team in assisting us in preparing this booklet and the actions they took in order to establish a good base for a circular textile economy in Amsterdam. We would also like to extend a special thanks to the project lead organisation, Waag (Cecilia Raspanti, Isabel Berentzen, Ista Boszhard, Margherita Soldati, Maritt Kuipers, Beatriz Sandini, Gijs Boerwinkel, Lucas Evers, Stefano Bocconi, Taco van Dijk); the City of Amsterdam (Roosmarie Ruigrok, Stef Le Fèvre, Danielle Schouten); and Pakhuis de Zwijger (Thomas van de Sandt, Fenno Verdaasdonk) for their inputs, suggestions, and comments. And lastly, a special thanks to Ellen van den Adel for being a great moderator during the Reflow livecasts at Pakhuis de Zwijger.

THE CIRCULAR TEXTILE WHEEL



Above: *The Circular Textile Wheel. There are several loops within the wheel that represent the reuse of products (e.g. swap-shops, thrift stores, vintage outlets, etc.). These loops of discarded clothing are important in facilitating a circular textile economy. Consumers of textile products have an important role in this stage of the wheel because the way they discard their textiles directly affects the health of the circular system in Amsterdam.*

CHAPTER 1
DISCARDING TEXTILES

Do’s & Don’ts

INTRODUCTION

The textile industry has a high environmental impact, whether it is through the production of the fibres, the processes of making a fabric or textile product, or the use of the final product (e.g. washing, drying, or ironing). In the context of global climate change, it is more important than ever to ensure that the amount of energy we put into the textile industry is not wasted.

A simple way to conserve energy in the industry cycle is to use one's textile products for as long as possible. Of course, there may also be times where you no longer want to keep the product. In cases like these, you have several options for prolonging the use of the product (and the materials from which it's made) to reduce the environmental impact. Here are a few easy ways to extend the life of your textiles (while also helping people and the planet).

REUSE

There are a lot of ways you can reuse old textiles. You could, for instance, give old pieces away to friends; organise a closet sale at home; or sell your old clothing on places like Marktplaats, Vinted and other apps. Alternatively, you could discard your old items at one of the many textile containers in the city (this is the most anonymous way to give your textile product a second life). If you do choose to discard your textile products in one of these containers, they will then be collected, sorted, and (if they are in a reasonable condition) used again. Do not, however, throw away textile products in a waste container. If you do, the fabric will be incinerated, and everything invested in the material will be gone forever!

REPAIR

If your textile is damaged, you might be able to repair it yourself. A missing button, for instance, can be replaced quite easily. More difficult repairs, like replacing a broken zipper, can be done at one of the numerous tailoring or alterations shops in Amsterdam. Alterations shops also often repair things like torn trousers and holey sweaters. If you're feeling adventurous, however, you can also find beautiful DIY solutions for these problems on YouTube.

REFURBISH

Another option to prolong the life of a garment is to make something creative from a textile product you no longer want or need. There are many examples of creative upcycling on the internet. You could, for example, turn your old jeans in a shopping bag, make them into a denim rug or use them to upholster a chair. With upcycling, the possibilities for customisation are endless. For inspiration, use your favourite search engine or services like Pinterest to look up crafts using old clothing.

SECONDHAND

To make the most impact, don't stop at donating your old clothing items—buy secondhand items yourself! You can find plenty of great pieces at vintage and secondhand shops, or by searching Marktplaats and other apps. By buying secondhand textile products, you reduce your personal environmental impact considerably.

TEXTILE CONTAINERS
WHAT YOU SHOULD KNOW

If you must discard your textile product, please drop them in a textile container. There are plenty of these containers in the City of Amsterdam. If you live in Amsterdam, you can find locations listed on the amsterdam.nl website.

THE BASICS
When disposing of textile products, please remember these rules:

- The item must be clean and dry
- The item should be in a plastic bag (so it stays dry and clean and won't become contaminated by other products that don't belong in the container)
- The item should not be too bulky

WHAT CAN YOU DISCARD?
With your help, we can realise a circular textile economy and reduce our environmental impact. Your textiles deserve a second life! You can discard the following in a textile container:

- Clothing (even if it is worn out or broken)
- Household textiles (e.g. towels, tea towels, etc.)
- Sheets and blankets
- Fabrics and knitting yarns
- Curtains
- Shoes (but please attach them in pairs)
- Bags and accessories
- Hats and caps
- Cuddly toys

WHAT SHOULD YOU NOT DISCARD?
Please be aware that it only takes a tiny amount of waste to spoil the entire contents of a textile container. Please do not dispose of the following:

- Duvets and quilts
- Mattresses
- Pillows
- Carpets
- Textiles soiled with oil and paint
- Non-textile waste like: vegetables, (rotten) fruit, meat (and meat bones), diapers, food packaging, glass, etc.

CHAPTER 2
COLLECTING DISCARDED TEXTILES

Do’s & Don’ts

INTRODUCTION

After textiles have been used, they are usually discarded and the systems that take care of collecting old textiles come into play. The collection of discarded textiles marks the beginning of the textile waste processing sequence. The collector usually gathers the discarded textiles as part of a textile processing business and then passes on the discarded materials to the next step in the chain: the sorting company. While the collection phase is only one link in the recycling chain, the benefits of collecting discarded textiles are obvious for both the people and the planet.

SECONDHAND AND HAND-ME-DOWNS

Ideally, textiles would pass through several hands before being handed off to a collector so that the time of use for a textile product is prolonged and the carbon footprint is reduced. Buying secondhand products is one of the easiest ways to reduce the carbon footprint of your closet.

You can find secondhand items on websites like "Marktplaats", purchase vintage pieces through Vinted and other apps, see if your friends and family might offer you some hand-me-down items, or browse vintage and secondhand shops. After you've given the product a second home and are ready to let it go, it may still be good enough for someone else to enjoy. So, if it looks fit for a third home, sell it or give it away. If you're certain no one can use it, then discard it through the proper channels (see chapter 1).

THE RAG MAN

In the not so distant past, textiles were considered very valuable materials and their use was sustained as long as possible. During this era, a designated "rag man" would drive through the streets and collect old, discarded textiles. In fact, the threadbare textiles he gathered were still considered valuable enough that the rag man would even pay a small fee to those he collected from.

After collection, the rag man would then sort and sell the collected material to processors who could turn these discarded textiles into other products (e.g. non wovens). The advantage to this system was that the rag man provided a clear, human connection between textiles, their use and their second life.

Today, the rag man has been replaced by secondhand shops, where you can drop off your discarded textile products. If these shops could expand their services to collecting textiles from your home (an app could be the first contact), the rag man could return to the streets of Amsterdam.

One of the goals of the Reflow programme is to investigate if this method of textile collection could be organised in Amsterdam, and whether or not it could be a business model for smart, young entrepreneurs.

COLLECTING TEXTILES
THROUGH TEXTILE CONTAINERS

In many regions, textile waste is collected in a top-down, organised manner. The City of Amsterdam, for instance, has contracted the company Sympany to collect textile waste from textile containers. These containers can be found in many locations all over Amsterdam. Click here to find one close to you.

Once full, the contents of these containers are picked up by trucks and transported to the sorting centers.

To maximise the value of the collected textile waste, the following rules apply:

- Keep it clean and dry.
- Avoid contamination with non-textile materials or waste.
- No bulky products. Keep the textile waste manageable so that manual sorting is possible.
- Bulky products (like mattresses, furniture, and carpets) are collected from the municipal waste yard.

To reduce your carbon footprint, help keep collected textile waste clean and dry. And please remember that it only takes a tiny amount of waste to spoil the entire contents of a textile container.

CHAPTER 3
SORTING TEXTILE WASTE

Who & How

INTRODUCTION

Most people know that when they no longer need their textile products, they can drop them into a textile bin. However, it's not often clear what happens to products after they are donated to charity organisations (e.g. Sympany, Reshare/Salvation Army, Sam's Kledingactie) or to commercial textile collectors (e.g. Curitas).

While the collection of discarded clothing falls under the jurisdiction of waste collectors (e.g. Twente Milieu, ROVA, Circulus Berkel) in some municipalities, the collected textile products are always sorted for reuse and recycling.

It's a common misconception that discarded textile products are given to poor people in Africa and Asia, but that's not the case. Most of the collected textiles are sold. Charity organisations then use those profits to support initiatives in both The Netherlands and developing countries.

In fact, homeless shelters operated by the Salvation Army may well be paid by the revenue generated from the collection of discarded textiles!

SORTING TEXTILES IN SORTING CENTRES

Discarded textiles are always sorted to maximise the value of the collected items. Sometimes the organisations that collect the textiles also do the sorting, but more often than not, sorting is done by specialised sorting centres.

The sorting process is completed by skilled workers who are trained to recognise and separate valuable products suitable for reuse from products that must be recycled.

The first step is always to separate non-textile waste from textile waste. Unfortunately, the amount of non-textile waste disposed of in textile containers is increasing. Never put non-textile waste into textile waste bags or textile containers.

The second step is to separate and sort the products into 20 or more groups of reusable items and into at least 10 groups of non-reusable products.

In the third step, these groups are further sorted into different quality grades, which we will touch upon in the next section.

SORTING REUSABLE
PRODUCTS & THEIR DESTINATIONS

All reusable materials are sorted into more than 200 categories, reflecting the needs of the final customers who will purchase these products. For reusable products, there are at least 3 quality grades: crème, first quality, and second quality.

- **Crème quality** products are sold at the highest prices to second hand and vintage shops in Western Europe. Crème products might include branded clothing like Levi's jeans or a Tommy Hilfiger sweater.
- **First quality** products are exported to countries in Eastern Europe like Romania, Ukraine, and Belarus. They are sold to traders who then sell the products to local shops. Due to the weather conditions in these countries, products in this group might primarily be composed of winter clothing, jackets, and workwear.
- **Second quality** products are predominantly exported to African countries (e.g. Ghana, Tanzania, and Uganda) and Asian countries. Once there, the products are sorted in further detail before they are sold on markets and in shops. This merchandise consists mainly of summer clothing, sports clothing, and trousers.

The export of reusable products to developing countries has reached its limit. Many Eastern African countries have decided to reduce the imports of these products to stimulate the production of textiles and clothes in their own counties. Nevertheless, it is estimated that 80% of African people regularly wear second hand products from Western Europe and North America.

SORTING NON-REUSABLE
PRODUCTS & THEIR DESTINATIONS

Some collected products cannot be reused, due either to their low quality or to market conditions. For instance, one can sell only a limited amount of winter clothing to developing countries. There is also always a mismatch between clothing collection and sales: winter clothing is usually collected in spring, but demand doesn't begin to rise until autumn. For this reason, goods often must be stored for 5-6 months. These products are sorted into a number of categories based on material composition (e.g. wool, cotton, polyester, blends of cotton and acrylic, etc.); structure (e.g. knitted or woven); and product category (e.g. bed linen or jeans).

The sorted groups are then sold to textile waste processors. Bed linen is predominantly sold to the wiper industry. Jeans are used (after they are shredded and processed through non-woven production) in the automotive industry for heat and noise insulation. Woolen products might be sold to Italian firms specialising in wool recycling (Prato is famous for this). Acrylic products are mainly exported to India, where they shred the product and use it to produce coarse yarns for blankets.

Above: *The Reflow team visited Sympany, a Dutch company that collects discarded textiles. They collect millions of kilos of discarded textiles each year. Once textiles have been collected, they must be sorted. As you might imagine from the photo above, this is no small task!*

ECONOMIC BENEFITS OF TEXTILE SORTING

There's a market for almost all the collected textile products. Only a small percentage of the collected products is too spoiled or contaminated and must be rejected as useless waste.

Due to the enormous amounts of textiles we use and the limited uptake of second hand textiles by developing countries, the financial margins of textile sorters are very thin. The focus, therefore, must be not only on recycling materials, but also on reducing the use of new textile products and on prolonging their use.

This is where the Reflow project comes in. We advocate the reduction, reuse, repair, and recycling of textile products!

CHAPTER 4
SORTING FOR RECYCLING

What & How

INTRODUCTION

Non-reusable textile products might not make great clothes, but they can still be used as recycled materials.

Because there are several recycling methods (each with their own material-specific demands), the sorting process must be adapted depending on the process. In most cases, sorting is done manually, but a lot of progress has been made in the field of automated sorting.

Automated sorting has the potential to be much more precise and will lead to more consistent batches of sorted materials. Precision is important in this instance because better sorting means a more optimised recycling process.

COMMON SORTING CATEGORIES

Post-consumer textiles are a blend of materials, colours, structures and chemical components (e.g. dyes and finishes). When materials are sorted manually for recycling, sorters only use a few broad categories (like composition, colour and structure to separate textiles).

In the world of material recycling, 100% pure materials have a higher value than blends. For this reason, sorted groups include categories like 100% cotton, 100% wool, 100% polyester and 100% acrylic. After these categories, sorters identify the most commonly used blends, such as cotton-polyester, polyester-wool and wool-acrylic.

When sorting based on colour, white products have a higher value compared to coloured ones (because white products can be dyed). Colour sorting might include categories like white and black; the three primary colours (i.e. red, yellow, and blue); and some secondary colours like green or purple.

When it comes to fabric structure, products are sorted into categories like wovens and knits. Within these categories, one might separate fabrics with a loose, open structure from the more tightly woven and knit fabrics.

If you'd like to know more about sorting categories, further processing, and potential end-products, ECO-TLC in France has produced a nice overview, which can be found on the Refashion website here.

AUTOMATED SORTING

RECENT DEVELOPMENTS & THE FUTURE

A recent development in the recycling industry is the automated sorting of post-consumer textiles. Currently, there are a few automated textile sorting machines in operation, like the Fibersort by Wieland Textiles and the Siptex system in Malmö (Sweden) operated by a consortium of Swedish companies.

In the automated sorting process, the textile product is analysed by Near Infrared Technology. After this analysis, in theory, the resulting parameters can be used as sorting criteria. When combined with optical inspection by a human, most sorting categories obtained during manual sorting can be reproduced by automated sorting.

Because the technology is still under development, it is expected that the number of sorting criteria will be expanded to include criteria that cannot be identified by manual sorting (like the chemical composition of the dyes used and the chemical nature of finishes present on the textile product). These criteria are important for improving the recycling process and especially for the chemical recycling of post-consumer textile waste.

RECYCLING

DIFFERENT METHODS & THEIR LIMITATIONS

Non-reusable textiles must be sorted both in order to improve the quality of the end product and to make certain recycling processes possible. For instance, the recycling of thermoplastic fibres like polyester and polypropylene by extrusion is only possible if the input exclusively contains these thermoplastics. Cotton and other non-meltable fibres will only clog the system.

In mechanical recycling, the quality of the resulting fibres is much higher when a well-sorted, narrowly defined stream is used as input. The mechanical recycling of jeans is quite well established for this reason. Knowing which dyes and finishes are present in sorted groups makes this process even easier.

Recycling technologies, their limitations regarding input, and the characteristics of what is produced will be described in more detail in other chapters of this series.

Above: *Textile waste must be sorted by colour and composition before recycling. Sorting is usually done manually, but technological advancements mean that automatic sorting will be more prevalent in the future.*

WANT TO KNOW MORE?

Have we piqued your curiosity? If so, you can check out some of the resources below to find out more about how textiles are sorted for recycling.

SOME SORTERS

- Boer groep (https://www.boergroup.eu/)
- Wieland Textiles (https://www.wieland.nl/)
- Circulus Berkel / Reshare (https://www.reshare.nl/english)
- Regionaal Textielsorteercentrum Twente (joint venture of Het Goed en De Beurs)

MORE INFORMATION

- Fibersort (https://www.wieland.nl/en/innovation-fibersort/)
- Automated sorting Malmö: (PDF)
- The sorting process (in Dutch): (https://www.wieland.nl/gebruikte-textiel-sorteren/)

CHAPTER 5
CUTTING AND CLEANING
How & Why

INTRODUCTION

Whether it was an outdated pair of jeans or a sweater full of holes, you've likely dropped unused clothing into a collection bin. Once donated, your old clothing is either resold, recycled, or thrown away.

Fortunately, there's a market for almost every textile product collected. Only a small percentage of collected textiles must be thrown away due to spoilage or contamination.

REMOVING NON-TEXTILE MATERIALS

After the collection and sorting phases, there are inevitably things that cannot be sold. Fortunately, these waste products can often be recycled into new textile materials.

However, donated items are often a combination of different types of fabric, various buttons, fasteners and other closures. To salvage the waste textile material, the product must go through several steps.

The first step is removing any non-textile fasteners, closures, and accessories attached to a product. During this stage, we must first remove:

- zippers
- rivets (i.e. on jeans, or nails for fastening things like belts)
- buckles
- buttons
- chords
- stickers and PVC plastisol prints
- labels
- embroidered threads or metallic filaments
- printed ornaments
- gems (usually glued)

CUTTING & CLEANING

TEXTILE WASTE IN SORTING CENTRES

Before non-wearable textile waste can be recycled, it must first be processed. Ornaments and auxiliaries are usually removed manually using electric scissors and knives. The metal parts, like nails and buckles, are sold as metal scrap. Miscellaneous parts, like stickers and labels, are discarded as waste and incinerated.

If textile products are fitted with embroidered logos or PVC-plastisol prints, then these are cut out of the textile and discarded as well.

A key aspect of this stage is to ensure that the textile product is small enough for further processing, which means cutting it into manageable pieces. One usually uses a cutting machine for this phase, paying special attention to thick, strong seams.

Depending on the recycling process, these thick seams can cause problems when cutting the textiles down to a practical size. Sometimes they create such a problem that the textile must be cut along the seams, creating thick, multilayer strips that are then disposed of and incinerated.

WASTE PROCESSING

WHY IT'S IMPORTANT

While this work may seem labour-intensive, this step is necessary to make non-wearable textiles fit for the next stage of the recycling process: shredding. The cutting and cleaning phase of the process is essential to the cycle of textile recycling and ensures a higher quality output.

A large part of textile waste processing is recycling the waste into new fibres and yarn. The success of turning textile waste into new fibres is largely determined by the quality of cutting and cleaning. Thus, this stage of the process is vital for producing high-quality recycled materials.

The Reflow project aims to encourage reduction, reuse, repair and recycling within the textile industry. If we want the industry to use recycled products, we must ensure these products are worth using. For this reason, producing high-quality recycled textiles is crucial to building a healthy, sustainable textile industry.

CHAPTER 6
SHREDDING FOR RECYCLING

How & Why

INTRODUCTION

Before recycling can begin, non-wearable textile waste must go through several preparatory processes.

In the previous chapter, we discussed the first step: cutting and cleaning. Once all accessories have been removed and the fabric has been through the preliminary cutting stage, textile waste can move to the next phase of recycling: shredding.

Because standard recycling processes are not usually equipped to handle large pieces of intact textiles (e.g. bedsheets, overalls, coats, etc.), materials must be shredded into smaller pieces. The process of shredding has several benefits, which we will discuss more thoroughly later in the chpater.

SHREDDING TO PREPARE FOR RECYCLING

As we discussed in chapter 5, ornaments, closures and accessories are usually removed by skilled workers using electric scissors and knives. A key aspect of this stage is to ensure that the textile product is small enough for further processing, which means cutting it into manageable pieces. During this process, one usually uses a textile cutting guillotine machine (click here the see an example) and a shredding machine.

Much like a common paper shredder, industrial textile shredding machines are made up of a series of sharp blades mounted on rotating shafts. From thin jersey to thick denim, these machines are equipped to shred a wide variety of textiles. To see what this process looks like, you can watch this video or this video on YouTube.

SHRED IT!

WHY SHREDDING IS IMPORTANT

While shredding textiles is an essential part of the recycling process, this step is important for a variety of reasons. For instance, many people wear uniforms in sensitive professional situations (e.g. security guards, police, etc.). Uniform shredding can, therefore, keep unauthorised persons from stealing discarded uniforms. Thus, this process not only provides recycled materials for the textile industry, but it also guards against the possibility of fraud or deception.

Branded textile products that have been removed from the shelves or have fallen out of fashion are also prime candidates for shredding. Instead of selling these items at a discount or discarding these products into the open textile waste system, they can be destroyed and recycled.

RECYCLING

WHAT HAPPENS AFTER SHREDDING

Once shredded, materials and textiles are recycled as often as possible. While shredded textiles may not always be recycled into new clothing, they are almost always recycled into other useful materials that reduce our impact on the planet.

If you send your old uniforms straight to a landfill, you are not only contributing to pollution and waste, you might also be risking the security of your business if all information and logos have not been properly removed.

We encourage reduction, reuse, repair and recycling within the textile industry for a variety of reasons. In this case, recycling not only helps to ensure the welfare of the planet, but also your safety.

Above: *Once shredded, textile waste is almost always recycled into new materials. Shredded material might not always end up as new clothing, but reusing and recycling materials reduces our impact on the planet.*

WANT TO KNOW MORE?

Have we piqued your curiosity? If so, you can check out some of the resources below to find out more shredding textiles for recycling.

SOME SHREDDING VIDEOS

- Small textile and old cloth shredder (https://www.youtube.com/watch?v=YeIT6GBLBmg)
- How to shred uniforms and clothing (https://youtu.be/FRvlj-y3nPE)

REFERENCES

- What Happens To Shredded Fabric?. (2016, May). Greenway Group. Retrieved June 2020 from https://www.greenawaygroup.co.uk/happens-shredded-fabric/

CHAPTER 7
INTRO TO CHEMICAL RECYCLING

What & How

INTRODUCTION

Once textile waste has been sorted, cleaned, cut and shredded, the material moves on to the next stage: recycling. The best-known recycling technologies are chemical and mechanical recycling and extrusion. While the extrusion process can only be used on thermoplastic materials like polyester, chemical and mechanical recycling can be used for most textile materials. In this chapter, we will discuss chemical recycling.

RECYCLING CHEMICAL FIBRES

To understand the chemical recycling process, it is useful to know that textiles are made of long molecules called polymers. Polymers are formed by the reaction of small molecules, called monomers. During the recycling process, these long chain-like polymers are broken down into their constituent monomers, which can then be polymerised to generate new polymers. Thus, no additional fossil resources are needed when using this method.

Unfortunately, chemical recycling currently requires high energy demands and is sensitive to contamination, which results in higher costs compared to plastics derived from fossil resources. However, the general textile industry consensus is that chemical recycling will become the most important recycling technology because its results are just as good as virgin fibres made from oil.

NYLON

Nylon is a synthetic polymer material widely used for various textile applications. In fact, around 5% of textiles are made of nylon. The main commercial applications for nylon include textile fibres for technical applications, for sport and outdoor applications, and for carpet.

Also known as Polyamide (PA), nylon is a polymeric material made up of one or two smaller entities called monomers. We won't delve too deep into the chemistry behind this, but it may be useful to know that nylon 6 is made of one monomer (caprolactam) and nylon 6,6 is made of two monomers (hexamethylenediamine and adipic acid). When nylon is recycled chemically, the long nylon chains are broken down into the monomers and other intermediates. These monomers, or reactive building blocks, can subsequently be re-polymerised into new long chains: new virgin nylon. The closed-loop recovery of Nylon-6 has been widely used in the carpet industry.

However, this method of recycling is both expensive and requires a substantial amount of energy. Current research focuses on making this recycling process more economical and energy efficient. While the chemical recycling of Nylon-6,6 is not yet performed commercially, the recycling of Nylon 6 is. You might have seen recycled Nylon 6 advertised as textiles from old fishing nets (see an example here).

POLYESTER

Polyester (also known as polyethylene terephthalate, or PET) is the most widely used synthetic polymer material. This material is used for a wide variety of textile applications. PET is used in almost every textile application imaginable, from fashion to technical to automotive to building and construction. In fact, around 60% of all textiles are made of polyester!

Because it's a thermoplastic material, polyester melts when heated (for more information, refer to chapter 9). Unfortunately, the environmental impact of polyester is significant because the raw materials for PET are usually derived from oil. There are, however, also examples of biobased raw materials.

Polyester is produced by combining two monomers: ethylene glycol and terephthalic acid. Chemical recycling pathways for PET include processes that break down the polymer into its components (monomers and other intermediates). Chemical treatment in the recycling process may also help separate PET from other materials, such as blended fibres (e.g. elastane or cotton), dyes, or chemical finishings. For fibre-to-fibre recycling, we must produce the main monomer constituents of PET (ethylene glycol and purified terephthalic acid) to reproduce virgin quality PET.

Globally, there are many commercial and R&D level activities focusing on polyester recycling. For example, the Dutch start-up company, Ioniqa, currently focuses on recycling PET bottles, but is now also investigating recycling PET from textile waste. Issues hindering chemical PET recycling include: the cost of recycling compared to the cost of producing virgin fibres and the environmental impact of chemical processes involved in recycling PET. Currently, there is no economic benefit and only a small environmental benefit to chemical recycling.

IN SUMMARY

Both nylon and polyester are synthetic textile materials that are broken down into their constituent monomers during chemical recycling. These monomers are then resynthesised into polymers and extruded into filaments, which are subsequently further processed and spun into yarns. In the next section, we will discuss the chemical recycling of cellulose fibres.

CHEMICAL RECYCLING
CELLULOSE FIBRES

COTTON
Cotton represents about 25% of textile materials, totalling an impressive 25 million tonnes per year. Recycling cotton will help resolve issues around water usage, arable land use, fertiliser use, and pesticide use. Without diving too deep into the chemistry behind the process, it is useful to know that cotton is made of a single large molecule: cellulose. This cellulose is formed by plants and trees and is, consequently, quite different from the synthetic materials described above. For this reason, the recycling process is completely different.

PULP MAKING
To begin the recycling process, cotton textile waste must be separated and shredded as described in the previous chapters. After shredding, the next step is grinding the cotton into a coarse powder. This powder is then chemically treated to remove all the non-cellulosic constituents. Due to the type of chemicals and the conditions of the process, dyes and most of the finishing materials are also removed.

This cotton is often blended with polyester or elastane. If we are dealing with blends, the polyester can be removed by breaking it down and rinsing it away (this polyester may then be recycled as well). Unfortunately, this process does not work for elastane. Therefore, if elastane is present, the cotton cannot be recycled. Solving this issue is the subject of a few research projects.

After removing all these constituents, we must check the length of the cellulose chain. If this cellulose chain is too long, then the recycling process becomes more difficult. For this reason, we also reduce the length of the cellulose chain during this purification step. If everything looks satisfactory, we dry it. The resulting fibrous material is called the **pulp**. Once we have the pulp, we move on to the next step in the process.

CHEMICAL RECYCLING

WET SPINNING: CELLULOSE FIBRE PRODUCTION

Wet spinning of cellulose fibres is nothing new. The former ENKA used wet spinning to produce rayon fibres in the early 1950s.

To wet spin, the pulp produced during the previous step is dissolved using an appropriate solvent. It is during this step that the length of the cellulose chain becomes very important. If the chain is too long, it will not dissolve. If the cellulose chain is the correct length, then it dissolves and the resulting solution (called "dope") is injected into a spin bath full of water.

Once the solution of dissolved cellulose is exposed to the water, the cellulose solidifies into a gel state first and then into a fibre similar to viscose. This process is similar but not completely analogous to the viscose process. Unfortunately, even low percentages of polyester or elastane block the spinneret and render the wet spinning process unfeasible, which is a real problem.

Once the cellulose fibre has been precipitated in the bath, we can then collect it, rinse it, dry it, and collect it on a bobbin. Now, we have a spool of recycled cellulose filament from cotton.

The next step is chopping this filament into short pieces called staple fibres. These staple fibres are then spun into cellulose yarn, a process that will be described further in the following chapters.

Currently, a number of projects and investment programmes are working to produce chemical recycled cotton on a commercial scale. Fortunately, there is great interest in chemically recycled cotton. Mud Jeans has announced that they will produce jeans made from 100% recycled cotton with the help of chemically recycled cotton. Check out the Mud Jeans website for more information.

WHAT DOES IT LOOK LIKE?

Have we piqued your curiosity? Watch this video to get an idea of what the wet-spinning process looks like.

Above: *SaXcell is an example of a new material made from chemical recycled domestic cotton waste. The fibres are made from 100% cotton, which is a great step towards building a more sustainable apparel industry.*

DO'S AND DON'TS

- Always donate discarded cotton and cotton/polyester blends for recycling.
- Avoid mixing or blending cotton with other fibres, particularly elastane. Until elastane removal is solved, it is better to buy cotton clothes without stretch.
- Support these recycling initiatives where possible.

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CHAPTER 8
INTRO TO MECHANICAL RECYCLING

What & How

INTRODUCTION

In the last chapter, we discussed the complex process of chemical recycling in the textile industry. In this section, we will describe the much simpler process of mechanical recycling. Unlike chemical recycling, mechanical recycling requires little water and no chemicals to transform textiles back into fibres.

FACTS

- Growing cotton requires 7,000 litres of water, 3.5 kg of CO2-eq, and between 5-10 m2 of agricultural land. Mechanically recycling cotton requires little to no water, no agricultural land and only 0.36 kg CO2-eq.
- Mechanically recycled fibres can be used in most textile products. In fact, mechanically recycled fibres can make up around 10-20% of a product without impacting quality.
- Mechanically recycled textile fibres are already widely used in the textile industry. Industrial textile waste is often used for this purpose. In fact, you may own products made with mechanically recycled fibres without realising it!

MECHANICAL RECYCLING

Mechanical recycling is the process by which fabric (woven, knitted or non-woven) or yarn is broken back down into fibres using mechanical action. This process is performed in machines containing several pinned rollers of varying sizes that rip the textile pieces apart.

As it moves through the machine, textile waste is shredded into finer and finer pieces. Rollers further along in the production line are equipped with a much higher number of finer pins than those on the first rollers. The last roller might be equipped with sawtooth-like pins to better break down the yarn into fibres. While no chemicals are needed for this process, oil or water is occasionally used to reduce the friction between the fibres, resulting in gentler processing.

Mechanical recycling is still the most widely used technology for recycling textiles. The resulting fibres are predominantly used for low-quality applications, like sound and thermal insulation. Mechanical recycling remains the most popular method because any material and blend of fibres can be processed this way at a relatively low cost. This technology is not only low cost, but has also been used for over 100 years to recycle industrial textile waste.

The mechanical recycling of post-consumer waste, however, is a much more recent phenomenon. Because post-consumer waste involves a wider variety of textile materials and the demand for higher quality recycled fibres is growing, mechanical recycling technology must be improved considerably in the near future. This broader spectrum of post-consumer textile waste is also why advancements in sorting technology are becoming increasingly important.

INPUT TEXTILES
FOR MECHANICAL RECYCLING

Theoretically, mechanical recycling machines can process any type of discarded textile. However, in order to attain a useable final product, it is better to exclude certain types of textiles:

- Coated textiles, like rainwear or blackout curtains, are very difficult to process because the yarns and fibres in the fabric are glued together by a coating.
- Products with PVC content, like PVC plastisol printed T-shirts and jackets, should be avoided as users of the end-product (like companies that manufacture non-wovens) reject these materials.
- Products with down and feathers, like cushions and duvets, are difficult to process because a large part of these products are not made of textiles.
- Polyester multifilament products, like sportswear and (polyester) microfibre jackets, are best recycled using extrusion or chemical recycling. The mechanical recycling of multifilament products will only result in a fluffy material not suitable for further processing.

The better defined the input for mechanical recycling, the higher the quality of the output. The higher quality the output, the more applications the final recycled product will have.

THE OUTPUT
OF MECHANICAL RECYCLING

The desired output of mechanical recycling are long textile fibres, preferably of one colour and in large amounts. The quantity is important because the greater the volume, the cheaper the processing will be.

However, mechanical recycling often results in shorter fibres mixed with different yarns. This output is well suited for the production of the non-woven materials used in sound insulation, thermal insulation, and pressure distribution. You find these kinds of nonwovens in cars (e.g. door panels, dashboard, rear dash, and trunk), in washing machines, refrigerators, dishwashers, mattresses, chairs, and in carpet underlayments. With such a wide variety of uses, there's a fair chance you're already using a tremendous amount of recycled textile fibres.

THE FUTURE
OF MECHANICAL RECYCLING

The future of mechanical recycling will be not only to provide fibres for the non-woven industry, but also for the textile yarn spinning industry.

For yarn spinning, recycled textile fibres must meet much more stringent guidelines regarding purity, the presence of foreign particles, and reproducibility (i.e. the same quality must be met every time). Foreign objects, like pieces of metal from zippers, can destroy the fragile card clothing in the spinning preparation. The average fibre length must also be higher because longer fibres produce stronger yarn and allow finer yarns to be spun. These finer yarns fetch a higher price and can be used in more applications.

The mechanical recycling of denim jeans is relatively popular because of their ubiquity and uniformity. An enormous amount of jeans is sold each year and nearly all of them are dyed indigo blue! As a result, more and more fibres from recycled jeans are used in the production of new jeans.

Fibres from recycled jeans, mixed with either virgin cotton fibres or polyester fibres from PET-bottles, can comprise up to 40% of the materials used in new jeans. Mud Jeans is very transparent about their production process and their use of recycled fibres (click here for more information).

The Alliance for Responsible Denim (ARD), based in Amsterdam, is also promoting the use of post-consumer recycled denim in their products. Here is a video providing some insights into the process. The goal of ARD is to produce over a million pairs of jeans with at least 20% recycled content in 2021.

Above: *Mechanical textile recycling machine at Frankenhuis. (Photo by Alcon Advies)*

DO'S AND DON'TS FOR MECHANICAL RECYCLING

- Reuse, repair, and refurbish textile products as often as possible.
- Buy second-hand textile products in shops and through apps.
- Always drop off your discarded textiles at a textile collection bin.
- Support recycling initiatives where possible and buy textile products with post-consumer recycled content. They are labeled with the GRS certificate and/or with the REMOkey.

For more information about REMOkey, see www.remokey.com.

CHAPTER 9
RECYCLING BY EXTRUSION
What & How

INTRODUCTION

Now that we've discussed the basics of chemical recycling and mechanical recycling, we will now move on to extrusion. While chemical and mechanical recycling can be used for most textile materials, extrusion can only be applied to thermoplastic materials (e.g. polyester, polyamide, and polypropylene).

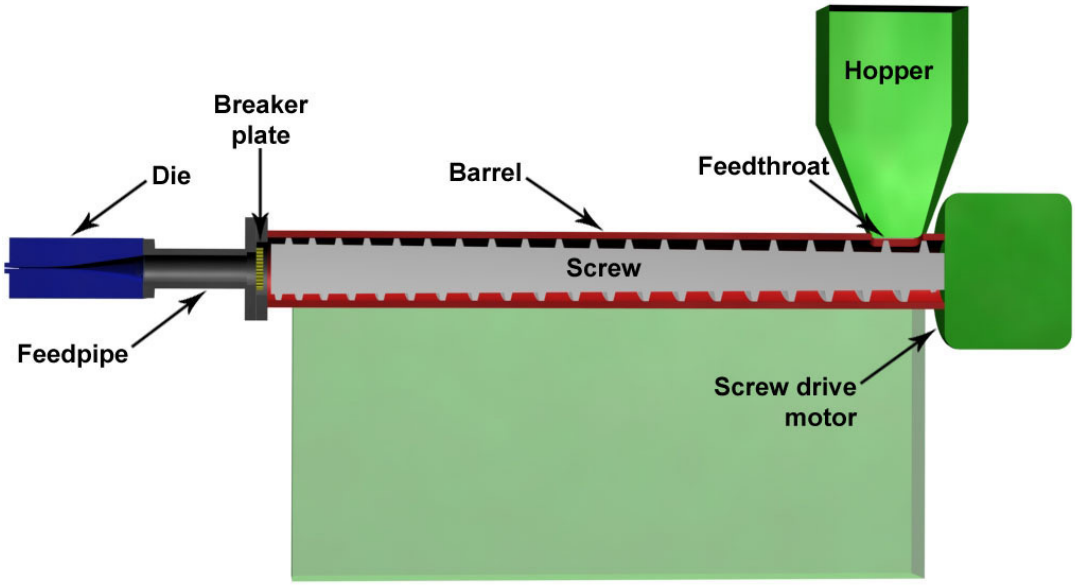
In essence, extrusion is the process of forcing a pliable material through a hollow die with a fixed shape. This versatile technique is used for everything from the industrial manufacture of pipes to the creation of certain types of pasta. Because plastic is a malleable material when heated, extrusion is frequently used in the plastic industry.

RECYCLING PLASTIC BY EXTRUSION

The recycling process begins by converting meltable polymer waste materials into plastic granules. An extruder, the machine that performs the extrusion process, is made up of the following basic elements:

- a feeder (also called a hopper)
- a screw, which transports the material through the extruder
- a heating system to melt the thermoplastic material
- a slot die (by which the material leaves the extruder)

An example of a simple extruder is shown in the drawing below.



Above: *A sectional view of a plastic extruder. Plastic granules are melted and then fed into the hopper. The melted plastic is then fed through the barrel and extruded through a die. Photo was released into the public domain by its author and was retrieved from Wikipedia in June of 2020.*

INPUT TEXTILES
FOR RECYCLING BY EXTRUSION

Recycling by extrusion is only possible using pure thermoplastic fibres (e.g. polyester, polyamide, and polypropylene). Blends of thermoplastic fibres cannot be processed if the flow properties of the molten materials and/or their melting temperatures are too far apart (they must fall within a range of approximately 10-20 °C).

The thermoplastic fibre waste should be clean and free from non-meltable contaminants. Metal components (e.g. zippers, push buttons and rivets) should, therefore, be removed before the product can be extruded. Examples of textile waste that can be recycled by extrusion include:

- women's polyester blouses
- polyester sportswear (mostly 100% polyester multifilament, which cannot be processed by mechanical recycling)
- polyamide workwear (like Cordura, which is a polyamide 6,6 fibre)
- fishing nets
- polypropylene nonwovens (often used in disposable protective clothing)

Recycling textile waste by extrusion is not an option for natural fibres (e.g. cotton, wool and viscose), for most textile blends, or for coated fabrics.

PRETREATMENT
FOR RECYCLING BY EXTRUSION

Recycling by extrusion requires well-prepared input material. The input material must be entirely composed of specific thermoplastic fibre. Non-meltable materials (eg. natural fibres, coatings, and metal parts) must not be present.

Because extrusion takes place at high temperatures (well above the melting point of the thermoplastic fibre), special precautions must be taken to avoid undesirable side effects during the process. The most important preventative measure is ensuring that the material is dried to a very low level of residual moisture (0.1 gram water per kg) before extrusion. Water at high temperatures will decompose most thermoplastic polymers during extrusion (due to depolymerisation).

Before being fed to the extruder, the textile waste material has to be cut in small pieces and turned into small compressed balls or pills. Otherwise, a special kind of extruder, called double-screw extruder, must be used.

THE EXTRUSION PROCESS

In the first part of the extrusion process, the thermoplastic material is melted. The screw in the extruder then slowly transports the material through the extruder while also mixing and homogenising the material. The colours of the input material are also mixed during this phase.

Sorting materials based on colour will result in a homogeneous colour, but colour variations often occur. By adding master batches of concentrated coloured thermoplastic material, a more uniform (but darker) coloured re-granulate can be obtained. For polyester, other reactive agents (e.g. chain extenders, which repair broken molecules) might be added to the extruder to improve the quality of the output.

At the end of the extruder, the material is cooled down to just below its melting point before leaving the extruder through the slot die. The shape of the opening of the slot die (usually circular) determines the shape of the recycled thermoplastic string that comes out of the extruder. The resulting string is then cooled down further using either air or water.

THE OUTPUT OF THE EXTRUSION PROCESS

The output of an extruder is a string of thermoplastic material with a diameter of a few millimetres, which is then chopped into small pieces a few millimetres in length. This material is called the regranulate and can be used for further processing. Further processing might include the extrusion of textile monofilament yarns (with a diameter of 100-500 micrometres), but this is only possible if the regranulate is very pure (without any foreign particles) and has a diameter bigger than half the diameter of the monofilament.

More often, the regranulate is used in the extrusion of larger products (like pipes and rods), or in injection moulding wherein the molten regranulate is pressed into a mould. The shape of the mould determines the end-product. Regranulate thermoplastic materials are used to produce products like flowerpots, crates, toys, plastic chairs and more.

In conclusion, only very pure thermoplastic textile waste materials can be recycled by extrusion. The method is well suited for discarded textile products made out of 100% pure thermoplastic material (like multifilament polyester shirts). Thermoplastic fibre recycling resembles the recycling of plastics in many ways. The resulting regranulate can only be used to produce thermoplastic textile fibres under special circumstances in which the input materials are sorted very precisely.

THE DO'S & DON'TS
OF TEXTILE RECYCLING

- Reuse, repair and refurbish textile products as often as possible.
- Buy second-hand textile products in shops and through apps.
- Always discard unwanted textiles at a textile collection bin. Make sure your donated items are clean and dry.
- Textile waste is always suitable for recycling, but it is not always possible to reuse textile waste in the textile industry.

DID YOU KNOW?
SUSTAINABILITY & EXTRUSION

Although limited to thermoplastic fibres, extrusion is quite sustainable as a recycling technology. Did you know that most recycled polyester textiles are not actually made from recycled textiles, but recycled PET bottles?

Every hour, millions of these bottles are discarded worldwide. When these bottles are recycled by extrusion, the resulting regranulate is good enough for the production of textile fibres. Many fleece jackets and vests are made from these recycled PET bottles.

Above: *Thermoplastic textile waste must be sorted prior to recycling by extrusion. Sorting materials based on colour will result in a more homogeneous colour, but colour variations often occur.*

WANT TO KNOW MORE?

Have we piqued your curiosity? If so, you can check out some of the resources and references below to find out more about recycling by extrusion.

RESOURCES

- Manufacturing of fabric by recycling plastic bottles - an article from Textile Focus.
- Making Shirts Out Of Recycled Water Bottles - a video from Sand Cloud, a sustainable fashion brand, about making fabric from PET bottles

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CHAPTER 10
SPINNING RECYCLED YARN

How & Where

INTRODUCTION

Once we have used extrusion, mechanical recycling, or chemical recycling techniques to produce fibres and filaments from used textiles, we must move to the next step in the recycling process: spinning yarn.

Spinning is one of the most complex and demanding parts of the textile production chain. While approaches to spinning are similar, there isn't a one-size-fits-all solution. For instance, the material produced by chemical recycling can be spun into yarn using well-known standard yarn spinning techniques, but mechanically recycled material must use adapted methods.

When we are able to spin a high quality yarn, we are able to produce high quality textile products. Millions of spinning machines around the globe produce millions of kilograms of yarn each day. As one might imagine, spinning technology is a broad and complex subject, so we will only focus on the highlights.

THE BASICS OF YARN SPINNING

Yarn spinning is the activity of making yarn from staple fibres (i.e. fibres short in length). Spinning involves bringing the staple fibres in close contact with each other, twisting them around each other while simultaneously stretching the fibre bundle (known as the sliver) to the required diameter or thickness.

You can get a basic idea of the process by watching the following video about the ancient drop spindle technique (here). An up-to-date overview of various aspects of yarn spinning can be seen in the document here. This document also describes how specific spinning techniques influence yarn properties.

INTERMEZZO YARN NUMBERING

The diameter or thickness of yarn is not trivial. The yarn number indicates the thickness (diameter) of the yarn. Because the diameter is difficult to measure, this measure is indicated as the ratio of the mass (weight) and length of a piece of yarn. There are 2 systems to determine the yarn number:

- weight numbering: determined by measuring the weight of a fixed yarn length
- length numbering: determined by measuring the length of a fixed yarn weight

For weight numbering, tex is technically the only official numbering, but in practice tex is usually only used for filament yarns. Tex is the weight in grams of 1,000m of yarn. Prefixes such as dtex and ktex are used with this unit. For example, 13.5 tex is 135 dtex, so dtex is the weight in grams of 10,000m of yarn.

Length numbering is the numbering that was traditionally used. These are still in use in the Netherlands and use the abbreviations Ne (number English) and Nm (number metric). As the names indicate, Ne works with imperial sizes and Nm with metric sizes. In length numbering, the relationship between yarn thickness and yarn number is inversely proportional: a thicker yarn has a lower number.

YARN SPINNING

SPINNING PRE-PROCESSING

The object of spinning, and the processes that precede it, is to transform the single fibres into a workable, continuous length of yarn. In the case of natural fibres, the processing involves opening, blending, carding (and in some cases combing), drawing, and roving to produce the material for the spinning frame.
This is followed by the spinning itself.

The steps are as follows:

- Bales with staple fibres are brought into the blending chamber and are opened. Depending on what the requirements of the final product are, different kinds of staples may be mixed at this stage. Cotton staple fibres are often mixed with polyester staple fibres to produce polyester/cotton yarns. This process is known as intimate blending.
- After thorough mixing, the fibre pack is transported through a system that removes tiny fibres and other impurities to improve the quality of the final yarn.
- In order to produce the sliver, fibres must first be cleaned and untangled using a process known as carding. Carding on an industrial scale involves feeding fibres between two drum rollers covered in small pins. This process separates the fibres and arranges them into a uniform, parallel mesh known as the **sliver**.

The resulting sliver can then undergo all kinds of treatments like making it denser, stretching it, or combining several slivers into a new, thicker sliver.

SPINNING METHODS

Once the staple fibres have been processed, the resulting sliver is then fed into the spinning machine. There are a few different spinning techniques, which differ in the way the sliver is manipulated and transformed into a yarn. Most recycled textiles can be processed into new yarn by using the technologies described below. However, mechanically recycled textiles require further processing.

OPEN-END / ROTOR SPINNING

The first technique is known as **open-end** or **rotor spinning**. The first functioning rotor spinning machine was developed in 1967. Rotor spinning is a more recent method of yarn formation compared to techniques like ring spinning. The sliver is fed into the machine, combed, and individualised by the opening roller. The fibres are then twisted together by the spinning action of the rotor, and the yarn is continuously drawn from the centre of the rotor.

The resulting yarn is cleared of any defects and wound onto packages. Rotor spun yarns are more even, somewhat weaker, and have a harsher feel than ring spun yarns. Yarns spun in this fashion have several end uses, which include a variety of products like: denim, towels, shirts, and more.

RING SPINNING

The second technique is known as **ring spinning**. Ring spinning is a method of spinning fibres (e.g. cotton, wool, flax, etc.) by drawing sliver (also called roving) through a series of rollers, spinning the material into yarn, and then winding the material around a rotating spindle within a ring flyer. For a more detailed explanation, check out this article by Textile School.

AIR JET SPINNING

One of the latest developments in spinning technology is a process known as **air jet spinning**. In this method, a sliver is first fed into a drafting system. The drafted sliver then enters a spinning unit and, once inside, the fibres are twisted using air. However, the fibres are not always uniformly twisted.

FRICTION SPINNING

Another new development is a method called **friction spinning**, which is related to the open-end spinning process. In friction spinning, the fibres must first be fed through an opening roller before being gathered into a suction area. The yarn is then twisted using the friction between the fibre and two spinning perforated drums. This method of spinning allows for an especially high twist rate in the resulting yarn.

SPINNING CHEMICALLY RECYCLED TEXTILES

The chemical recycling process produces filaments: extraordinarily long thin threads, collected on bobbins. Occasionally, several of these thin filaments will be twisted together to produce sewing thread. To be used in industrial scale yarn spinning, filaments produced by chemical recycling are chopped into pieces measuring between 30mm (for cotton fibres) and 40 or 50mm length. These pieces, called the staple, are then spun into the yarns we use to produce garments.

SPINNING MECHANICALLY RECYCLED FIBRES

Spinning high quality yarn from mechanically recycled fibres is quite difficult. Mechanically recycled fibres are often much shorter than virgin fibres. Due to the various sources of post-consumer textile waste, these fibres also have a much broader range of length (from short dust fibres to the length of virgin fibres) and thickness. For these reasons, virgin fibres are almost always added when spinning mechanically recycled yarns (except in the case of wool, which has much longer fibres compared to cotton).

Recycled PET fibres (from bottles) are the most frequently used, but virgin cotton and viscose may also be blended with the recycled fibres. In some cases, renewable, sustainably grown hemp and linen are added to mechanically recycled cotton fibres. In the future, they will be blended with chemically recycled fibres, like SaXcell, to obtain 100% recycled cotton products.

Due to the variation in fibre length, open-end spinning technology is used predominantly in spinning mechanically recycled fibres, as this technology is the most versatile. However, when the fibre length of the mechanically recycled fibres is longer, ring spinning is also an option. The fibres produced from blends of mechanically recycled fibres and virgin fibres are not as fine as yarns produced from entirely virgin fibres (mostly between Nm 5 and 40). Therefore, the range of potential applications for these yarns is not as broad.

Mechanically recycled fibres used for spinning mostly come from industrial waste. On average, between 10-20% of the material used in spinning, weaving, and clothing production is waste. Fortunately, this large volume of waste material can be reused for recycling. Many specialised spinning companies (particularly in Italy, Spain, and many Asian countries) use mechanically recycled fibres. These include companies like:

- Comistra and Fil3 in Italy, using recycled wool
- Recover in Spain, using recycled cotton
- Belda Llorens in Spain, using recycled cotton

Many of these companies have already been using mechanically recycled fibres for a long time, but did not use sustainability as a unique selling point until recently. These companies have adapted their spinning systems (especially the pre-spinning processes) in such a way that they are able to produce high quality yarn for products like business suits, jeans, and T-shirts.

THE PROBLEM WITH BLENDS

Blending fibres is a well-developed technique for producing yarn (and ultimately textile products) with specific, predictable properties. In fact, the current practices within the textile industry are such that a world without blending is almost unthinkable.

But this presents us with a problem: recycling blended materials is very difficult! Fortunately, there is a lot of research going into developing processes for recycling textiles that take blends into account. With the current SaXcell recycling process, it is possible to separate cotton from polyester and to then use each in further recycling processes.

Elastane, however, is still a big problem. Although research is underway to solve this issue, textiles that contain elastane cannot currently be chemically recycled. Because of these issues, blends currently reduce recycling efficiency and are, therefore, not good for the environment.

Above: *Spinning is one of the most complex and demanding parts of the textile production chain. Spinning involves bringing the staple fibres in close contact with each other, twisting them around each other while simultaneously stretching the fibre bundle.*

QUICK FACTS

- Currently, around 2.5 million tonnes of recycled fibres per year are taken from various stages of the textile manufacturing chain and fed back into the spinning system. See this article for more details.
- Mechanically recycled fibres, often from industrial waste, are already present in a wide variety of textile products. It is even possible that you own products containing these fibres—you just never noticed!

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CHAPTER 11
MAKING & FINISHING TEXTILES

What & How

INTRODUCTION

Once we have turned our discarded textile products yarn, we then use this yarn to produce cloth, or fabric, which is then used to make textile products. To make fabric, there are three main production methods: weaving, knitting, and nonwoven technology. We will briefly describe these three methodologies in the following sections. Without finishing, however, no textile product is ready for use. In the final section of this chapter, we will discuss finishing techniques like dyeing and printing.

Before we begin, however, we must provide a brief disclaimer. These areas of cloth production are huge industries. The amount of knowledge, technology, and variation in production methods is such that we cannot cover all of it. We will only discuss the basic principles in this chapter and leave out the more detailed information.

KNITTING

Knitting is a traditional way of creating fabric and garments by using needles to loop yarn into a pattern of interconnected stitches. These stitches are then joined together in a series of rows, which eventually form a mesh (the fabric). Garments are usually made up of a large number of stitches (often more than a few hundred). Knitting needles hold the initial row of stitches in place (so it does not unravel) while subsequent loops are pulled through the first row using the working needle. This process is repeated until the garment is complete.

Knitting is a versatile technique that can be used to create a wide range of diverse and varied fabrics. Factors such as needle size, stitch pattern, fibre type, and yarn weight can all affect the properties of the final product. Open lace patterns worked in a lightweight cotton yarn, for instance, will not retain as much heat as denser stitch pattern knit in a yarn made from wool.

One can knit a garment by hand, by using a small hobby machine, or by using large industrial machines. Flatbed knitting and circular knitting are the two main techniques used in industrial knitting. The following videos provide a good visualisation and cursory explanation of how machine knitting works:

- Knitting Technology / Loop/Stitch Formation by Elias Khalil
- Single Jersey Circular Knitting Machine's Needle Action by Textile School

Virtually all textile materials can be knit, but wool is the dominant material in knitting. Wool is quite often blended with nylon and acrylics to make the wool stronger or more wear-resistant. Obviously, as we discussed in previous chapters, blends are not particularly well-suited to recycling.

INDUSTRIAL CIRCULAR KNITTING

Knitting allows for a broad range of patterns suited to a variety of uses, from jersey knits (suitable for t-shirts) to 3D knitwear (suitable for technical and interior applications). Industrial circular knitting is a technique by which one knits on a circular needle bed. In this process, yarn is fed into a series of latch hook needles arranged in a circular needle bed that rotates to create a tube of fabric. For a more thorough explanation, see this video. Once the tube is knit, it must be cut open for further use.

Industrial circular knitting machines are advantageous because they have a high output capacity and can produce very fine knits. However, the size of the knit fabric is limited to the size of the circular knitting machine. As a result, the material created from these industrial machines must often be cut and sewn together to form a completed garment.

INDUSTRIAL FLATBED KNITTING

Industrial flatbed knitting machines use a carriage to draw yarn across a flat needle bed. See this video for a good visualisation of the process.

Because flatbed knitting machines don't have the same output capacity as circular machines, they are best used for individual garment creation rather than large quantities of knitted fabric.

There are two main types of flatbed knitting machines currently in use in the textile industry: hand flat machines and computerised Jacquard machines. Both of these machines have specific applications, but a detailed description of their place in the textile ecosystem is beyond the scope of this article.

Fully fashioned knitting machines are a particularly important piece of technology because they have the ability to produce an entire garment. Arms and collars, which would usually be knit and sewn on separately, can be produced from one skein on a single fully fashioned knitting machine.

DID YOU KNOW?

Knitted products are recycled on a large scale. Because the structure of knitted fabrics can be easily unravelled, recycled yarn can be harvested at scale. The collected yarns are then sorted by thickness, material, and colour before being sold to produce new knitted products.

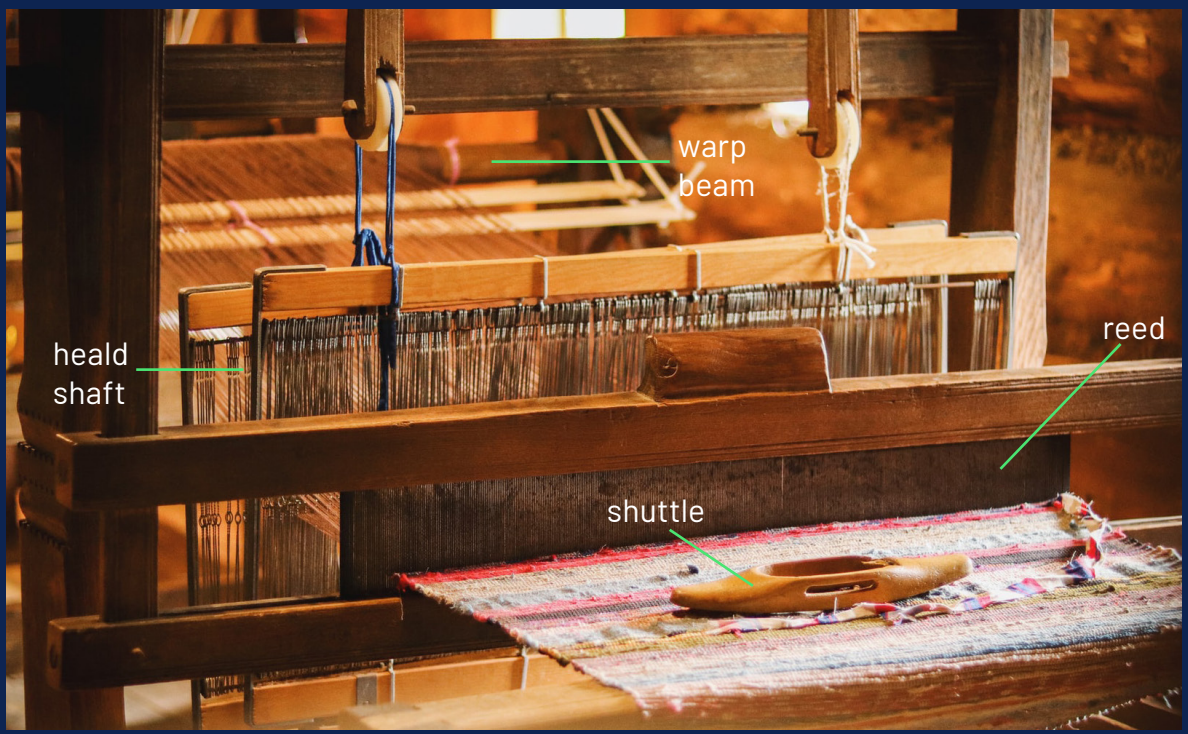
WOVENS
HOW WEAVING WORKS

In weaving, two different threads (or yarns) are interlaced to form fabric. Threads running lengthwise are referred to as the warp, while the threads running laterally are known as the weft. The cloth's properties are affected by the way in which these threads are woven together. Weaving normally takes place on a loom, a machine that holds the longitudinal threads in place as the weft threads are woven between them. Threads can be woven through each other in a variety of ways. The manner in which the threads are woven together is referred to as the weave.

INDUSTRIAL WEAVING

Most industrial woven products are created using three basic weaves: satin, plain weave, or twill. Woven cloth can either be plain (e.g. woven in a single colour or using a simple pattern), or it can be woven in a decorative or artistic design. The basic principles of industrial weaving can be seen in this video.

One of the key features of weaving is that the warp is wound onto the warp beam and the warp threads are carefully guided through the reed. This, in conjunction with the healds, determines the fineness of the cloth. The reed acts as a guide for the shuttle, which passes from one end of the loom to the other, while also helping maintain the position of the warp threads. In fact, it is the reed that determines the number of threads per cm. The heald shafts are the parts that move up and down. They determine the design, or pattern, in a fabric. The heald shaft is also useful in identifying broken warp threads during the weaving process.



Above: *A traditional loom with the warp beam, heald shafts, reed, and shuttle labeled. Photo by Zuzana Kacerová published August, 2019 and was retrieved from Unsplash in June of 2021.*

JACQUARD WEAVING

Another technology used within the industry is known as Jacquard weaving. In Jacquard weaving, a pattern is produced using programming with the Jacquard hard/software system. Jacquard weaving makes it possible to produce large figure patterns by controlling each warp yarn separately at any pick. When using the Jacquard shed or Jacquard shedding, you can produce a high quality, expensive fabric. To see how this works, check out the following videos:

- For modern Jacquard technology, watch this video.
- For the archiac, traditional form of Jacquard weaving, see this video.

To recycle a woven textile, it must go through all the steps described in the previous parts of this series. Needless to say, blending and using different types of yarn or yarn compositions in woven fabrics makes recycling them more difficult.

NONWOVENS

WHAT & HOW

Nonwovens are made from either short staple fibres or long fibres, which are then bonded together by chemical, mechanical, heat, or solvent treatments. This process bears some resemblance to paper making. Nonwoven fabrics can be broadly defined as a web of structures bonded together by entangling fibres mechanically, thermally, or chemically. Because they are flat, porous sheets made from fusing separate fibres together, they do not require yarn.

Nonwovens are typically manufactured by fusing small fibres together to form a sheet, and then binding them either mechanically (e.g. as in felt making), with an adhesive, or thermally (i.e. by applying binder in the form of powder, paste, or polymer melt and then melting the binder onto the web). There are also special types of nonwovens, like meltblown or spun bonded nonwovens. In the production of spun bonded nonwovens, melted thermoplastic material is sprayed directly from an extruder onto a cylinder or belt. After cooling, the nonwoven is ready for use (see this video for more information).

There is usually a certain amount of recycled fibres and oil-based materials present in staple fibre nonwovens. The amount of recycled fibres depends largely on the desired properties and intended use of the material. Because some nonwoven fabrics can be recycled, they are considered by some to be more environmentally friendly in certain contexts. For instance, fields and industries that must use disposable products (e.g. schools, hospitals, and nursing homes). For an overview of nonwoven production technology, watch this video. To get an idea of the size of the machine used in this process see, watch this video.

APPLICATION & IMPACT

Nonwoven fabrics can be engineered to embody a variety of characteristics (e.g. softness, resilience, absorbency, etc.) and perform a variety of functions (e.g. insulation, cushioning, filtration, etc.). Producers of nonwovens can create fabrics that balance cost effectiveness with durability and are suitable for a variety of applications. When combined with other materials, nonwovens allow for a wide variety of products with diverse properties.

Applications for nonwoven materials include: medical products, surgical masks, household cleaning wipes, and filtres. While any type of staple fibrous material can be turned into nonwoven material, thermoplastic polypropylene (PP) is the most commonly used fibre for medical applications because it is water and dirt repellent and easy to recycle.

How is Reflow connected? Nonwovens have long been the subject of environmental debate. Because they are most often used as disposable products, their environmental profile is dubious. Yet, because they are usually made of a single material, recycling them is relatively easy. Nonwoven material is also found in many reusable shopping bags. We should aim to use these bags as long as possible to reduce their environmental burden.

Above: *Nonwoven fabrics can be broadly defined as a web of structures bonded together by entangling fibres mechanically, thermally, or chemically. This process bears some resemblance to paper making! Photo by Waag and was retrieved from Flickr in June of 2021.*

TEXTILE FINISHING

Once textiles reach the consumer, they have usually been treated with dyes, prints, or coatings. These treatments are part of the textile finishing industry. In the case of woven materials (and sometimes knitted materials), the yarn or thread is often coated with a polymer (for cotton) or oil (for polyester) to lubricate the thread as it runs through the loom. However, if these surface coatings are present, the fabric cannot be bleached, dyed, or printed on.

To remove this coating, we use a process called **de-sizing**, or washing (for polyester). For printing or dyeing, particularly with lighter tones, the textile must be bleached before dyeing or printing.

DYEING

Sometimes the yarn or thread has already been dyed before weaving, but the majority of textiles are dyed as a cloth. There are, however, a few factors to consider when dyeing various textiles. Cotton is made of cellulose, which is made up of molecules containing reactive hydroxy groups. As a result, the industry has developed a broad range of reactive dyes for cotton. In addition, vat dyes, like indigo for blue jeans, are used because of their superior light fastness.

There is also a class of dyes known as **substantive dyes** or direct dyes, which adheres to textiles by non-ionic forces, known as "substantivity". The higher the substantivity, the greater the attraction of the dye for the fibre. Substantive dyes work best on textiles with high cellulose content, such as cotton, and are well-known for their light fastness.

Polyester, which is a thermoplastic polymer, is dyed with **disperse dyes**. Disperse dyes are used in dyeing hydrophobic fibres (e.g. cellulose acetate, nylon, polyester, acrylic and other synthetic fibres). Wool and nylon can be dyed with **acidic dyestuff**. The final method is known as **pigment dyeing**, which is not really "dyeing" in its truest form because the pigments stick to the fabric with the help of binders.

These dyes are not only used for dyeing textiles, but also for printing on textiles. The most important dyeing methods are:

- The pad batch process (see this video for more information)
- Jet dyeing (see this video for more information)
- Jigger dyeing (see this video for more information).

PRINTING

Printing is another important textile finishing technique. While printing makes use of the dyes mentioned above, the process is completely different. **Screen printing** and **digital or inkjet printing** are the most frequently used printing techniques. Flat screen printing and rotary screen printing are still widely applied, but rotary screen printing (invented by Stork, the Dutch machine builder) is being gradually replaced by digital printing.

Digital printing, which is becoming the dominant technique in the industry, requires less energy and fewer chemicals for printing, which makes it more environmentally friendly. Watch this video for more information about how this technique works.

Transfer printing is another important technique, particularly for polyester printing. The pattern or design is printed on transfer paper, which is then brought into contact with the polyester cloth on a heated calendar. The heat causes the dye to evaporate, and this vapour transfers the printed image onto the polyester cloth.

Finishing textiles also involves applying various coatings: water or oil repelling finishes, flame retardants, anti-crease finishes, antifungal finishes, or insect repellents. With the advent of nanotechnology, there are now finishes that prolong the lifetime of textiles by reducing wear and tear, which benefits the environment. The goal of these coatings is to make the textile suitable for a specific application (e.g. military gear, tarpaulins, roller blinds, etc.).

HOW DOES THIS CONNECT TO REFLOW?

The textile finishing process fixes textiles with a variety of dyes and coatings. Obviously, all of these coatings impede recycling and a few have a dubious environmental profile, like some water or dirt repellent finishes and flame retardants.

For mechanical recycling, discarded textiles must be selected by colour as well as material. For chemical recycling, these dyes must first be removed before the process can begin. Coated textiles are usually not suitable for recycling and must be incinerated.

Nevertheless, a lot of research is going towards making finished textiles suitable for recycling, and a lot of progress has already been made. For instance, breaking down the molecule from which the textile is made often releases the dye from this polymer, which makes it suitable for recycling. At the same time, the dyestuff released during this process can sometimes be collected and used again.

Replacing rotary screen printing with digital inkjet printing, as we discussed earlier, reduces the environmental impact of printing. Additionally, processes like CO2 dyeing reduce the water consumption in the dyeing of textiles. Thus, both sustainable finishing processes and improved recycling technology contribute to the reduction of the environmental footprint of textiles.

Above: *The industry has developed a broad range of reactive dyes for cotton. In addition, vat dyes, like indigo for blue jeans, are used because of their superior light fastness.*

QUICK FACTS

- Screen printing and digital or inkjet printing are the most frequently used printing techniques.
- Digital printing is becoming the dominant technique in the industry.
- Digital printing requires less energy and fewer chemicals for printing, which makes it more environmentally friendly.

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CHAPTER 12
INTRO TO SUSTAINABLE DESIGN

What & How

INTRODUCTION

Recycling textiles requires proper input material. The more complex the input material is, the more complex the recycling will be (and the lower the quality of the output will be). Because most decisions about the use of the materials, the structure, the colour, and the haberdashery are made in the design phase, huge environmental benefits can be obtained when using the principles of design for recycling.

More often than not, when people use the term "recycling", they are referring to mechanical recycling. As we previously discussed, there are a variety of ways to recycle textiles, each with different restrictions regarding input material. This means that "design for recycling" is not a very useful phrase, but it's often used by designers when they believe they have designed a sustainable product.

However, some modern designers also make use of recycled materials in their designs. Recycled materials are almost always more sustainable than virgin materials. Thus, from an environmental standpoint, it is clear that **recycling in design** is preferable to design for recycling.

DESIGNING TEXTILE PRODUCTS

A textile product designer has a lot of freedom, and consequently a lot of decisions to make, throughout the design process. Firstly, there is the freedom of aesthetic, which sets certain designers apart from others. Secondly, there is technological freedom, which allows the designer to choose from a broad range of methodologies, materials, fabric structures, colours, prints, finishes, closures, and more when creating a textile product. Many designers do not realise the extent to which their design choices impact the environmental footprint of the product they create.

Some designers, however, are very aware of their impact on the planet. Stella McCartney, for instance, calculated the environmental impact of her designs (not only textiles, but also the metals and wood she uses in her designs). Material choice is the most important factor with respect to the overall footprint, followed by the textile finishing processes and the production of the final products (all of which are determined by the design process). More detailed information can be found here.

DESIGN FOR RECYCLING

Design for recycling (or D4R) is a popular term amongst designers and textile producers because it, theoretically,indicates sustainable product design. However, this term is occasionally applied to existing products (those that do not use blends, for example) for marketing reasons. In these cases, the environmental benefits are dubious. Most cotton T-shirts, for instance, could be considered D4R because they are not manufactured with blends. Yet, conventional cotton requires copious amounts of water, fertiliser, and pesticide use. We can gather some best practices for Design for Recycling from the Swedish Mistra Future Fashion project.

DESIGN FOR RECYCLING
D4R GUIDELINES

GENERAL
- Avoid finishing with water repellent coatings and anti-bacterial treatments.
- Create mono-material designs (unless this shortens life length of product).
- Contact the fibre producer to ask which dyes and additives may be present to avoid problems in recycling.

POLYESTER
- Use 100% polyester (PET) in fabric, membranes, coatings, and trims.
- Engage with one of the few polyester fibre-to-fibre recyclers that exist on an industrial scale (e.g. Teijin/Jiaren).

COTTON
- Use 100% cotton and/or regenerated cellulose in fabric and accessories.
- Encourage the expansion of pilot plants that are available for post-consumer textiles (e.g. Re:newcell and SaXcell).

NYLON 6
- Use 100% Nylon 6 in fabric (other names are polyamide 6 or PA 6).
- Accessories should, if possible, also be made of nylon 6.
- Nylon 6.6 is NOT the same fibre. In terms of recycling, it counts as a contaminant.
- Engage with one of the few nylon 6 fibre-to-fibre recyclers that exist on an industrial scale (e.g. Aquafil).

NYLON 6.6
- Today, post-consumer nylon 6.6 (i.e. polyamide 6.6 or PA 6.6) waste cannot be recycled into textile fibres. Consider replacing this fibre until this situation changes.

Design for Recycling concepts impact not only the choice of fibre materials used, but also the choice of buttons, zippers, labels, and haberdashery.

The product can only be considered D4R if all its fabrics and accessories are made from the same material (e.g. polyester) or are easy to remove (e.g. by using Wear2 stitching yarn). See this article for more information.

RECYCLING IN DESIGN
CIRCULARITY & SUSTAINABILITY

A better way to promote circularity and sustainability is to start with recycled fibres instead of virgin fibres. Because recycled fibres generally have a much lower footprint than virgin fibres, products made from recycled materials will also have a lower footprint.

Mechanically recycled cotton has a footprint at least 50% lower than virgin cotton. Additionally, some finishing processes (like dyeing) may not be necessary (because recycled fibres have already been dyed). If the recycled fibre's pre-existing colour can be used, then bleaching and dyeing processes can be skipped. This means saving water, energy, and chemicals.

Using (mechanically) recycled fibres isn't simply a matter of replacing virgin fibres with recycled ones—it has consequences. The colour of the fibres might be one compromise for the designer because the range of colours in recycled materials is limited.

Designers sometimes overcome this limitation by adding virgin fibres with a certain colour (preferably spun-dyed polyester or viscose fibres). The structure of the yarn may also be a bit more irregular than yarn from virgin fibres. With the right techniques (e.g. certain knitted stitch patterns), however, these irregularities can either serve as an accent or be rendered virtually invisible.

HOW DOES THIS CONNECT TO REFLOW?

Using recycled fibres in design is not only good for lowering the footprint of your product, but it also generates a "pull effect" for recycled fibres. In this way, you help the textile recycling industry and the circular textile economy to grow. So use recycled fibres in your product design whenever possible!

DESIGNING
FOR SUSTAINABILITY

Design for Recycling and **Recycling in Design** are both interesting concepts for helping to lower the footprint of the textile supply chain. **Design for Sustainability**, however, is the overarching concept. With Design for Sustainability, you not only take the materials that are used into consideration, but also the processing, the use, and the end-of life scenario.

In another report from the Mistra Future Fashion project, a number of issues important to Design for Sustainability are mentioned. These issues are summarised in the table below:

Action	Climate	Water	Chemicals
1. Increase life span (resulting in increased number of uses)	impact/ number of uses	impact/ number of uses	impact/ number of uses
2. Better production technology	LESS ENERGY	LESS WATER USE	WASTE WATER TREATMENT
3. Better energy sources	LESS FOSSIL FUEL	-	less toxicity
4. Better chemicals selection and reduction of chemicals' use	LESS CLIMATE IMPACT	LESS POLLUTED WATER	LESS TOXICITY
5. Better materials	-	LESS WATER USE	less toxicity
6. Minimizing microfiber shedding	-	less polluted water	less toxicity
7. Optimize transport and packaging	less fossil fuel	-	less toxicity

From this list, the most important concepts are:"increase life span" and "better energy sources" (read renewable energy sources with no CO2-emissions).

Design for Sustainability can be thought of as the method by which the current supply chain can be transformed into a circular supply chain.

To change the supply chain from linear to circular, cooperation with companies and knowledge of company processes is necessary. A designer must be educated about every aspect of the supply chain in order to design sustainably.

Above: *Design for Recycling concepts impact the choice of fibre materials used, buttons, zippers, labels, and dyes. TextileLab Amsterdam experiements with bacterial dyes, which are less harmful to the environment. Photo by Waag and was retrieved from Flickr in June 2021.*

HOW DOES REFLOW FIT IN?

Because almost no one has access to all of this knowledge and expertise, teamwork is vital. This is where Reflow comes in. Reflow has specialists in every area of the circular textile supply chain. So, if you need help, you know where to look:

- Reflow Project on the Waag website
- Reflow Project on Amsterdam.nl website

CHAPTER 13
INTRO TO TEXTILE PRODUCTION

What & How

INTRODUCTION

The clothing we buy in Amsterdam is most often produced in Asian countries (like China, Bangladesh, Vietnam, and The Philippines), in Eastern Europe, or in Northern African countries. Technical textiles (like workwear) are often produced in Turkey, Macedonia, and Tunisia. Most of these products are produced on a massive scale in the places we colloquially call "sweatshops".

In a circular textile economy, these conditions must change so that the needs of people, the planet, and profit are met. Only then can the production of circular textiles be considered sustainable.

THE PRODUCTION OF TEXTILE PRODUCTS

The production of textile products is skilled work and requires a lot of expertise. There are many steps involved in transforming a design into an end product. Some of these steps include:

- **Pattern making:** it is essential to transfer the design into a pattern. In a pattern, each panel of the end-product is separated. A textile product may have dozens of panels.
- **Digitising of the pattern and grading**: most textile products must be made in several sizes. The original patterns must be graded to obtain several sizes. This grading is most often done digitally, but the grading itself is based on complex algorithms.
- **Plotting the pattern:** this is done in order to make the layout of the pattern on the selected fabric. The layout of the pattern is optimised to use the fabric in the most efficient manner. But the freedom of the layout might be limited if the fabric has a certain structure (which is most often the case) or if the fabric has a printed design.
- **Cutting the panels:** this can be done manually by using scissors (for single ply fabric), cutting saws (for multiply fabrics, up to 200 layers of fabric can be cut simultaneously), or lasers (for up to 10 layers of fabric).
- **Ordering:** picking the panels needed for one piece and laying them in the right order. The order is determined by the logistics of the sewing process. Also sewing thread, zippers, buttons, labels, and other accessories must be selected.
- **Sewing:** the sewing process, in which the final product is produced. For a complex product, this is done in multiple stages on specialised sewing machines.
- **Inspection:** after the sewing process is complete, the end-product is inspected. The last pieces of sewing thread are removed and, when the product has passed the quality inspection, it is ready for packaging.
- **Packaging and transport:** most products are packed in plastic bags, placed in cardboard boxes, and packed on pallets. The products are then shipped to their destination in large containers.

THE SEWING PROCESS

The goal of the sewing process is to join several panels of textile materials to form a 3D product out of 2D material. Sewing is mostly done using sewing machines, which stitch the panels together using thread. Alternatively, one can join the pieces together using hot glue.

Textile products are usually sewn manually by skilled workers. Automation of the sewing process is very difficult due to the nature of the textile materials. In the process of textile product assembly, a number of workstations are often arranged. At each workstation, a specific step in the assembly process is executed before the garment is passed onto the next workstation. Different workstations may be equipped with several specialised sewing machines, which are better able to perform certain tasks. In this system, workers are only responsible for a single, specific task, which they must constantly repeat over the course of their workweek.

Automation has begun to take off in textile production, including the sewing process. This may threaten the future of garment industry workers as this video shows. Robots can do repetitive tasks quite well, and fast, for 24hrs a day. Automation may have a huge impact on the way textile products are made. Once these products are being made by robots, it will only be a matter of time before this industry will be relocated to the region where the products are used. While automation would threaten the jobs of workers in the current garment industry, the relocation of this process would fit well within the context of a circular textile economy.

MASS CUSTOMISATION

Another interesting development in the manufacturing industry is the phenomenon of mass customisation. Mass customisation offers a way to produce textile products, especially tailored clothing and workwear, to the sizes and specifications of individual end-users. Automation and digitisation are the key drivers of this development. New technologies mean that each textile product can be unique in terms of size, colour, and accessories. This method benefits the retailer because the product can be sold before it is produced, which means there is no stock, no unsold inventory, and no sales.

Mass customised products are usually available through the internet, but blended models are also available. Examples of internet sellers offering mass customisation include: Bivolino, iTailor, and Shirtinator.

For blended models, you can check out companies like Suit Supply and Dutch Spirit. These companies come to your home to take your personal measurements and ask your preferences before producing the garment. Dutch Spirit combines mass customisation with sustainability, circularity, and new business models.

Mass customisation will most likely remain a service for those who can afford it, but this model certainly fits within a circular textile economy.

PEOPLE AND PLANET

The production of textile products is mostly manual work and is usually performed in low wage countries. While this model may benefit consumers in the Western World, it is causing havoc in the countries of origin. A number of initiatives have been started to change these practices and to provide workers in the textile and clothing industry with a decent salary, health services, and education. Additionally, NGOs, like Fair Wear and Solidaridad, are inspecting workplaces and working conditions in the producing countries.

In the Netherlands, the textile and clothing sector has made an agreement, known as the Dutch Agreement on Sustainable Garments and Textile, to improve conditions in textile producing countries. In this agreement, companies commit themselves to:

- Fighting discrimination, child labour, and forced labour.
- Supporting a living wage, health and safety standards for workers, and the right of independent trade unions to negotiate.
- Doing everything in their power to reduce the negative impact of their activities on the environment; preventing animal abuse; reducing the amount of water, energy and chemicals that they use; and producing less chemical waste and waste water.

Transparency is a critical factor when it comes to identifying risks and improving the situation in countries where merchandise is produced.

Of course, the best way to improve the situation in these countries is to buy your textile products at responsible shops who pay their workers a fair living wage and sell their products at a fair price. Buy nicer items from these shops (at a slightly higher price), and save money by buying other items secondhand.

The Reflow project supports the use and reuse of sustainable textile products and provides information to assist you in making informed choices.

Above: *The production of textile products is skilled work and requires a lot of expertise. Pictured above is a demonstration of traditional silk weaving at the museum, Haus der Seidenkultur (HdS). Photo by Waag and was retrieved from Flickr in June 2021.*

MORE INFORMATION

More information about the steps in the production of textile end products can be found here:

- Sew Port: How Clothes Are Made
- How To Make A T-Shirt by John Santos
- Tour in Our Garment Factory in Bangladesh by Soorty Enterprises (this last example is quite a long video, but shows the complexity and scale of the production)

CHAPTER 14
RETAIL CONSUMERS & END-USERS

Who & How

INTRODUCTION

Once we have transformed recycled textile products into fabrics, these fabrics are then used to make textile products for consumers. Then, these products are transferred to the retail sector, where they are sold in shops or online.

Retail is broadly defined as the process of selling consumer goods or services to customers through multiple channels of distribution to earn a profit. The term "retailer" is typically applied where a shop or a chain of shops offers products to customers.

Retail and consumer shopping habits are particularly relevant to the textile industry. For many, shopping is often thought of as a recreational activity. Recreational shopping, however, frequently involves activities that do not result in a purchase (e.g. window shopping or browsing). It is important to note that there is a wealth of literature available on the socio-political impact of shopping habits, and this article will only scratch the surface of a much larger conversation.

TEXTILE PRODUCTS AND END-USERS

When we think of customers buying textile products, we generally think of shops on the highstreet or in shopping centres. While shops are certainly the most common outlet for these products, there is a wide range of buyers for textiles. The healthcare industry, for instance, uses an immense amount of textile products (e.g. bedsheets, uniforms, surgical gowns, etc.). In the hospitality sector, textiles are used to furnish hotel rooms with towels and restaurants with upholstery and tablecloths. Additionally, governments and militaries require special uniforms, tents, and technical textiles (e.g. personal protective equipment, bullet-proof materials, etc.).

In these professional areas, the end-users are not the ones buying the textiles. Instead, this is done by professional purchasing experts: buyers. Because awareness of the textile industry's significant environmental footprint is growing, buyers for organisations are now under pressure to take this into account when purchasing textile products. Buyers for the Dutch military, for example, are now insisting that military textiles must contain a minimum amount of recycled materials and that military textile waste is recycled.

HOW DOES THIS CONNECT TO REFLOW?

First of all, the staff responsible for public procurement could be convinced that setting a minimum target on recycled content would create market pull and contribute to business cases for recycling organisations. In this way, recycled textiles could be employed in technical areas and technical areas could provide textiles to recycling organisations. Secondly, we must look beyond the fashion industry and consider a variety of sources of discarded textiles for recycling. The advantage of textile waste from the public sector is that it is usually well-defined material without too many auxiliaries. Home textiles are already part of the Reflow programme.

RETAIL
IMPACT & SUSTAINABILITY

A lot has been written about the negative impact of the clothing industry on the climate. While the textile industry has a reputation for being the "second biggest polluter", this is simply not true. Agriculture, tourism, and oil and gas production are all bigger polluters than the fashion industry (which actually comes in 10th). However, while other industries have a larger carbon footprint, we must still work to minimise the environmental impact of the textile and clothing industry.

One of the biggest issues in the clothing industry is supply chain logistics. For example, yarn is spun at a facility in location A and is then transported (sometimes over thousands of kilometres) to a weaving mill in location B. After weaving, the product is then transported to a dye or printing shop in location C (occasionally on the other side of the globe). Once the product has been dyed, it is then transported to clothing factories in location D.

The European clothing industry usually imports its clothing and textile products from countries like China, Bangladesh, Turkey, India, Pakistan, the United States, and Cambodia. Yet, because of the unpredictable dynamics of the fashion industry, these sources may change from month to month. We must therefore ask the question: do these unpredictable dynamics lead to "fast fashion", or is it the other way around?

The fashion industry has created a market where an item of clothing, due to constantly changing fashion trends, must be replaced as quickly as possible after its purchase (e.g. buy it, wear it, toss it). To remain competitive in this field, retailers must drive their prices down to the lowest possible level. Such low prices are only possible under the following conditions:

- Abandoning the relationship between value of a product and the material it is made of (i.e. dematerialisation of the textile industry).
- Keeping labour costs as low as possible. The social cost of low-cost textile products is therefore extremely high. These costs, however, are not reflected in the price of the garments, but are indirectly paid by society (see this article for more information).
- Keeping the time to market as short as possible and avoiding stock. Consequently, the time between offering products at normal retail prices and offering them at discounted sale prices is decreasing. This is so the new collection can be on display as quickly as possible.
- Adjusting the scale of production to fit transportation possibilities. In this case, the sea container is the determining measure and the transport costs are kept as low as possible if the container is filled.

HOW DOES THIS CONNECT TO REFLOW?

Currently, this supply chain can only function with advanced IT systems and logistics software. Taken together, all these aspects constitute a heavy burden on our environment. The Reflow project aims to change this. There are many ways to counter this environmental burden. Changing the way the overall supply chain functions would, obviously, be the ideal way to achieve this. However, changing this massive, powerful, and extremely competitive business structure would be exceedingly difficult and therefore beyond Reflow's capabilities. However, there are many things that can be done indirectly (many of which were described in previous chapters). Reflow's key concerns can be summarised as a focus on increased recycling and prolonged use.

FASHION

LOOKING ON THE BRIGHT SIDE

Not everything is doom and gloom. Fashion is also an important mode of expression for people—and it's fun! Like art, fashion can be thought of as an aesthetic expression at a particular time, in a particular place, and in a particular context. By wearing specific clothing styles, people can express personal, social, and/or political statements.

Style could be loosely defined as a coherent and persistent manner of dressing generally linked to a specific culture, social class, or movement. Fashion, on the other hand, can be defined as the manner of dress during a certain time period within a certain social context. With the increasing mass-production of consumer commodities at lower prices, sustainability has become an urgent issue amongst politicians, brands, and consumers. We are now seeing many designers moving away from big industry labels and designing fashionable clothing with minimal environmental impact.

From our perspective at Reflow, these designers deserve our support because they represent a group of stakeholders who design textile products with minimal environmental impact in mind. Modern fashion design should be about applying design, aesthetics, and natural beauty to clothing and accessories.

Above: *Designers at TextileLab Amsterdam aim to bring about social change in the field of textiles, fashion and materials. They explore the potential of dyeing with bacteria as a less harmful alternative to standard industry dyes. Photo by Waag and was retrieved from Flickr in June 2021.*

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CHAPTER 15
RECOGNISING CIRCULAR TEXTILES

What & How

INTRODUCTION

Fabrics and products made from recycled textiles are what we refer to as "circular textiles". But how can you recognise circular textiles when shopping for the most sustainable products? It's not always easy to tell how sustainable or circular a specific textile product is—even for the experts. Luckily, you can sometimes find labels on textile products that can help you make the most sustainable decision.

CONTENT LABELS

All textile products sold in the EU must include a composition label, which lists the fibre composition of the textile product. Most of the time, the country of origin and the wash and care instructions are also included. These labels often list the use of recycled fibres (a requirement for circular textiles), but recycled content does not have to be mentioned (i.e. you can list "cotton" instead of "recycled cotton" on the label). Thus, while content labels might indicate whether or not a product is made from circular textiles, you have to look very carefully.

COMPANY LABELS

Sometimes brands have sustainable product lines, like the H&M Conscious Collection. The products in this line are made with at least 50% sustainable fibres. In the case of recycled cotton, 20% is considered enough to make it into the Conscious Collection. This collection is more sustainable than their standard product lines and is helping H&M improve their environmental profile. However, there is still a lot of room for criticism as H&M are encouraging customers to buy more instead of buying fewer, higher quality items. A critical review of H&M can be read here.

There are also smaller, inherently sustainable and circular brands in today's market. Two examples of sustainable, circular brands are Mud Jeans and Loop-a-life. When you buy brands like this, you are guaranteed to be buying circular products.

Mud Jeans has a leasing system in place for their jeans. In this system, they own the materials the jeans are made from, so the jeans are returned to Mud Jeans when they are discarded. Currently, up to 40% of recycled cotton is used in the composition of their jeans. They are planning to produce jeans made from 100% recycled cotton using both mechanically and chemically recycled cotton.

Amsterdam-based Loop-a-life is another brand only selling textile products containing a high percentage of recycled content. They also control large parts of their production chain. Part of the materials they use come directly from a textile sorting centre near Amsterdam where the materials are sorted based on fibres and colours. Wool is their preferred material, but productions containing recycled cotton also make up part of the collection. Production occurs mostly in Southern Europe, while sales happen in The Netherlands.

WHAT'S IN A BRAND?

RANKING BASED ON ETHICS & SUSTAINABILITY

The sustainability of many brands is ranked by an entity known as Good On You. Their system ranks brands not only on sustainability and circularity, but also on ethical aspects. You can check out their list of the most sustainable brands in Europe here.

Although the highest ranking brands usually sell their products for higher prices, it is useful to know which ones rank near the top of sustainable fashion lists like these. High-ranking brands usually charge higher prices because they produce on a much smaller scale, use more expensive materials, and pay their workers a decent salary.

GRS AND RCS

Global Recycled Standard (GRS) and Recycled Claim Standard (RCS) are labels issued by Textile Exchange to indicate recycled content in products. Textile Exchange has set a number of criteria which must be fulfilled in order to be allowed to use these labels.

Companies using these labels have to prove the origin of the recycled fibres and the amount of recycled fibres in their products. A minimum of 20% recycled content must be present in the intermediate products, and only products with more than 50% may use the GRS logo on the label. Aside from recycled content, GRS also demands proof that the production is not harmful to people and the environment. You can read all of the requirements listed in the full document here.

The Recycled Claim Standard is an international, voluntary standard that sets requirements for third-party certification of the recycled input and chain of custody. The goal of the RCS is to increase the use of Recycled materials. The objectives of the RCS are:

- Alignment of recycled definitions across multiple applications.
- Track and trace recycled input materials.
- Provide consumers (both brands and end consumers) with a tool to make informed decisions.
- Provide assurance that materials in a final product are actually recycled.

The Recycled Claim Standard is intended for use with any product that contains at least 5% recycled materials. Each stage of production is required to be certified, beginning at the recycling stage and ending at the last seller in the final business-to-business transaction .

REMOKEY

REMO (REcycle MOvement) has a track and trace system for recycled textile content in place. Companies can join REMO to show that they are using recycled content in their products and that they are transparent regarding the supply chain. REMO calculates and quantifies the environmental benefits of using recycled fibres instead of virgin fibres.

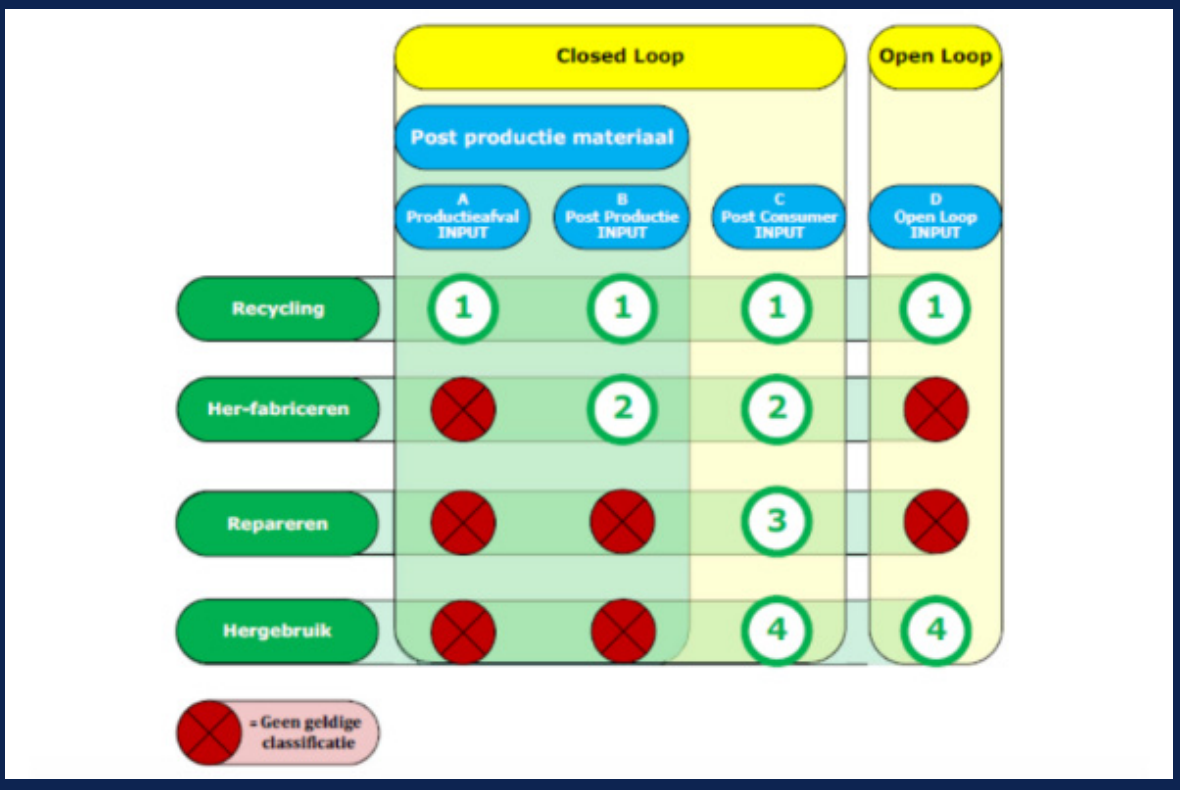
An important aspect of REMO is that they provide an internet landing page. This landing page greatly helps companies to communicate their use of recycled fibres and the environmental savings accompanying the use of these fibres.

REMO not only has a large client base in countries well known for their circular textile industry (like Italy and Spain), but also has a number of clients in the Netherlands and Belgium. Information about a product can be easily retrieved by scanning the QR-code on the label of REMOkey products.

DUTCH NTA ON CIRCULAR TEXTILES

The Dutch standardisation organisation NEN has recently issued a Dutch Technical Agreement (NTA) on Circular Textiles. This agreement outlines when a textile product may be referred to as circular. In this agreement four categories are distinguished: post-consumer recycled materials, pre-consumer products (unsold/unwanted by customers and therefore refurbished or recycled), recycled industrial waste, and recycled materials from other production chains (like PET from packaging). This NTA will be completed with test methods to prove the circularity of the product, and will be available by the end of 2021.

The NTA Circular textiles scheme is shown in the figure below.



Above: *Buyers beware! Many labels are issued by the companies themselves as a marketing device and are not checked by third parties. Be skeptical of marketing messages while shopping. Are the brand's claims backed up by evidence? Photo by Laurie Skelton.*

OTHER LABELS

There are a number of other labels meant to make you believe the product has been produced in a way that saves the planet and helps the workers.

Many of those labels, however, are issued by the companies themselves as a marketing device, and the validity of their claims is often not checked by third parties. Therefore, the value of these labels is low, if they have any value at all.

There are also labels that look at the welfare of the workers in the textile and clothing supply chain, but the description of these labels is beyond the scope of this chapter.

If you want more information on such labels you can check out the Eco Label Index.

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CHAPTER 16
TEXTILE USE & CARE

What & How

INTRODUCTION

Eventually, the textile products we buy will begin to show signs of wear. After prolonged use, the colour fades, spills cause stains, the fabric tears, and unpleasant smells begin to linger. This is, of course, completely normal. We all accept that textiles have a limited lifetime. However, to reduce our environmental footprint, prolonging a textile product's life is of the utmost importance.

When we talk about sustainability, we usually focus on raw materials, textile chemistry, recycling, and the longest possible product life. All of these things are important, but how sustainable is the product during the use phase?

In the context of the Reflow project, it is important to understand that a significant portion of the environmental impact of textiles is related to the laundering and maintenance of textiles. There are a lot of exciting technological developments happening in the area of textile care. For instance, there are now technologies and materials that help keep clothing from smelling bad for prolonged periods, so the garments don't have to be washed as often.

For other types of textiles (e.g. bed sheets, towels, and underwear), however, there are additional hygiene concerns that make frequent washing necessary. Despite the environmental footprint, changing and washing certain textiles is essential for health and wellbeing.

LAUNDRY

Most households have a washing machine and, quite often, a tumble dryer. Regularly cleaning your clothes and household textiles is vital for maintaining sufficient hygiene standards within your home.

To do the laundry, we require water, detergent, and energy (both for heating and for the rotation of the drum). It takes time for the textile to release the dirt and pollutants into the washing water, and modern detergents help keep the dirt from redepositing on the clothing. While hotter wash cycles increase energy consumption, there is a very good reason for higher temperatures: hygiene. To kill bacteria and other germs, always wash towels and underwear at temperatures higher than 50C.

Additionally, it is important to regularly clean your washing machine, especially the rubber closure and the detergent dispenser, to maintain a hygienic environment. Proper hygiene standards become even more important when washing laundry at lower temperatures, as microbial contaminations can cause foul odours and infection. The use of powder detergents containing activated oxygen bleach provides a way to achieve high microbial reduction in low temperature washing.

Once the textile products have been washed, they must be dried. Unfortunately, tumble dryers are not as energy efficient as washing machines. Washing and tumble drying are intensive processes, which contribute considerably to the wear of the textile products. Fewer washing and drying cycles result in a longer life for textile products.

WHY SHOULD YOU WASH LESS?

By washing our textiles less, we use fewer chemicals, less water, and less energy. We also extend the life of our clothes and save time and money. We don't have data for the Netherlands or Amsterdam, but an average household in the USA washes about eight loads of laundry a week, and the entire laundry cycle takes about 3.5 hours. In France, textile care reaches nearly six hours per week.

And laundry is expensive: washing and drying costs €1.30 per load (excluding the cost of the machine), which is €520 per year. For developments in the area of domestic laundry, you can watch this video (in Dutch).

Washing, unfortunately, also has its downsides. For instance, a garment made of fleece loses up to 20 percent of its weight per year when washed once a week, which indicates that it pollutes our waters with microplastics.

CLEAN CAN ALSO BE GREEN

Of course, there are many scientific and technical developments arising to ease the burden of domestic maintenance, including laundry. For example, there are products that can be sprayed onto a garment to help it to stay clean and fresh. Usually these products contain silver oxide, water, or oil repellents. These products claim that they prevent the growth of odor-causing bacteria by either using low concentrations of silver salt or by reducing the amount of moisture to inhibit bacterial growth.

But the choice of materials can also help. If you invest in materials like merino wool, you can save yourself the trouble of washing a lot of clothes. If you air out the merino products overnight, odours will quickly disappear without washing. Washing is only necessary for sheep's wool if the clothing is really dirty. This is one reason why many outdoor sportsmen wear merino underwear (especially on longer tours).

LAUNDER FOR LONGEVITY

HOW TO MINIMISE THE IMPACT OF THE USE CYCLE

- If you have a choice, buy fabrics that are naturally durable and require little care.
- Try to wash your clothes as little as possible. This does not mean you have to wear dirty clothes (hygiene is important), but remember that the more frequently you wash something, the faster it will degrade.
- Fold clothes along the seams to avoid unwanted creases and to maintain the shape of the item.
- Learning basic clothing repairs (e.g. replacing a loose thread or a missing button) can make pieces last longer and save you tonnes of money.
- If you do not have time to iron, steam your clothes by hanging them in the bathroom while you take a hot shower.
- Empty out pockets before washing. Remember to remove tissues or other odds and ends which can make a mess of your laundry.
- Close zippers and other fasteners to prevent snagging. Also, loosely tie strings and sashes to prevent tangling.
- For denim, hang jeans in the bathroom before a shower (the damp steam will keep them fresh between washes) or freeze them in a plastic bag for two days to remove odours.
- Avoid the dryer when you can. Researchers found that repeatedly drying cotton garments led to cracks in the clothing, which reduced fabric strength by 25 percent or more and also caused pilling.

LAUNDER FOR LONGEVITY

SOME MORE TIPS & TRICKS

- Do not over-wash clothes. Select the setting on your washing machine that allows for the least amount of soaking and fewest spin cycles. For delicate fabrics, use a gentle cycle.
- Reduce fading: wash your clothes inside out. Spin cycles can be hard on clothes – it is much better for the inside of your clothes to face the brunt than the outside.
- Avoid washing an entire garment to remove a stain. Instead, gently dab the stained spot with detergent and place it face down on a paper towel for a while.
- Delicate fabrics should be hand-washed. Hand-washing saves water and prevents your clothes from excessive spinning inside a washing machine.
- Some detergents use harsh chemicals which can fade, shrink, and tear delicate fabrics. Use as little detergent as possible. Powdered detergents can be harsher on clothes, so opt for a liquid one instead.
- Do not overuse the dryer. The heat from the dryer is probably ruining the fabric, the elastic, and the metal parts of your clothing. The dryer can shrink and fade your clothes. If you must use the dryer, do so on a low heat setting.
- Get clothes out of the washer and hang them out to dry as soon as possible to prevent small wrinkles and to allow them to air.
- If you have a backyard or outdoor space, buy a clothesline and allow your clothes to dry naturally outside. Consider purchasing a collapsible drying rack for clothes if space is an issue.
- Be careful with the iron. Proper ironing is essential to good clothing maintenance. It gives you wrinkle-free trousers and crisp shirts with a strong shape. Ironing is the key to preventing fabric roll – when shirt and jacket collars lose their crispness with age. But irons also have a dark side. They can:
  - Soil your clothes (rust stains from a dirty iron)
  - Burn your clothes (if you pick the wrong setting)
  - Permanently stain your clothes (heat sets stains into the fabric)
- Remove stains immediately. Act immediately: once the stain forms a chemical bond with the fabric, it becomes permanent.

PROFESSIONAL
TEXTILE CARE

For hotels, restaurants, and other professional organisations using textiles, maintenance is often farmed out to the professional textile service industry. Professional Textile Care includes the Textile Cleaning Industry (TC) and the Textile Services/Industrial Laundry (TS) sector. Textile Cleaning predominantly focuses on consumers, with a variety of different businesses such as traditional laundry and dry cleaning shops; centralised plants with more automation and pick-up points; coin-operated laundries; and, more recently, laundry on demand services (through apps).

The Textile Services/Industrial Laundry sector focuses on customers in business sectors like HORECA (i.e. hotels, restaurants & catering), health care (i.e. hospitals, nursing homes, home care) and trade & industry (i.e. a wide variety of industries in need of work wear, mats, hygiene, etc.). Within the Textile Service sector, laundries usually either offer a laundry service for customers who own the textiles, or offer a textile rental service where customers rent the laundry's textiles. Textile rental is actually quite common (especially in mature markets). Due to size and scale, there could be environmental benefits to using the textile service industry.

WHAT SHOULD OR SHOULD NOT BE DRY CLEANED?

Fabrics that (usually) do not need dry cleaning include:

- Cotton.
- Synthetic fabrics like polyester, nylon, spandex, acrylic and acetate. These will not shrink, so it is safe to wash them in warm water. However, remember to use gentle or low dryer settings because they can permanently wrinkle in a hot dryer. These fabrics also produce a lot of static electricity in the dryer so remember to use a dryer sheet or hang them to dry.

Fabrics that should be dry cleaned include:

- Linen.
- Rayon.
- Silk. While silk is a natural material, it requires special care. Dry cleaning silk tends to be easier.
- Wool. This sturdy fabric should be dry cleaned whenever possible. Smaller wool products can be hand washed.

Professional cleaning will certainly save you from having to replace quality items in your wardrobe.

MENDING & MAINTENANCE
TEXTILE CARE

To prolong the lifetime of your textile product, fix small clothing damage issues immediately. If you tear a small hole in your shirt or lose a button on your coat, be sure to reach for your sewing kit. Watch this video to get an idea of what basic mending looks like.

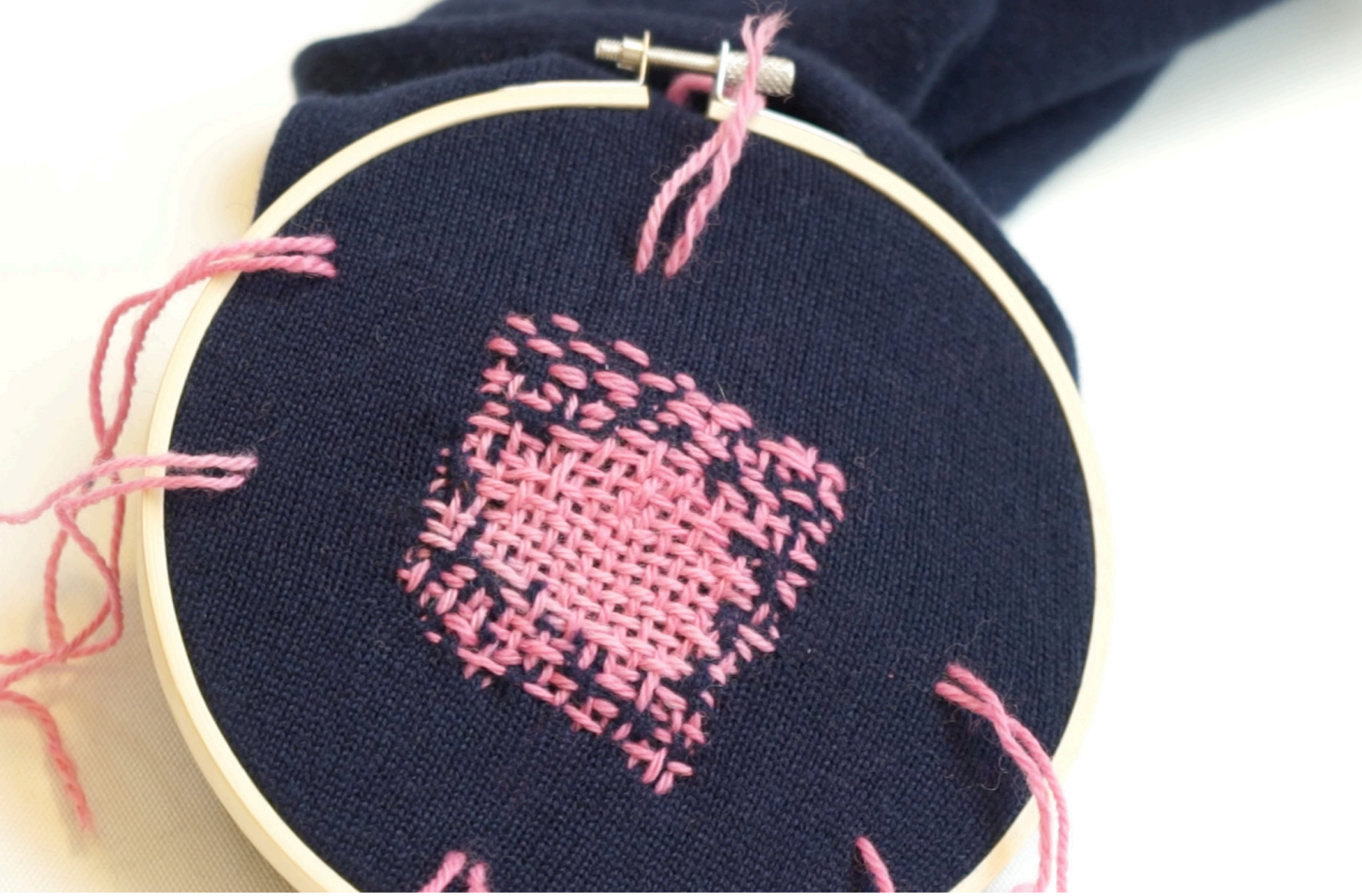
If you are not comfortable doing this kind of clothing maintenance yourself, it is worth your time to find a tailor who is willing to help repair any damage or make alterations to new clothes. A good tailor can save you from having to buy new items of clothing by keeping your old favourites in top condition for many years.

BASIC REPAIRS

- **Buttons & Zippers:** You can do this at home with a basic sewing kit. It takes almost no skill to sew or tighten them.
- **Loose lining**: If the lining on trousers or jackets becomes loose or if they are looking worn out, take them to the tailor to have them replaced. Don't wait until you have sizable holes on the inside of your jacket.
- **Tapering:** Over time, jackets can lose their shape because of poor clothing maintenance. Waist suppression brings the waist of a jacket in to create a pronounced "V" shape over your torso.
- **Altering Length:** Ensure your trouser legs are the right length. A little cloth to work with is sufficient for a tailor to alter the length to make sure the trouser isn't too short or drooping all over the floor.
- **Holes:** Small holes, especially around the seams, are relatively easy to fix. Take your clothing to a tailor before the holes get bigger.
- **Cuff & collar fray:** Clothes tend to wear out earliest and worst at the edges. Damaged fabric can be hidden by folding the cuff over and stitching it into place, creating a new edge. Note that this will shorten the sleeve or leg slightly.

HOW DOES THIS CONNECT TO REFLOW?

Prolonging the lifetime of your textile product has real environmental benefits. As we discussed above, there are numerous actions you can take to extend the in-use time of your textile product. Prolonging textile use for as long as possible is one of the goals of Reflow. If you have used the products for as long as possible, then remember to discard it in such a way that the material can be recycled.



Above: *Repairing your clothing doesn't have to be boring—it can be a form of creative expression! Do you have a hole in your favorite sweater? Give visible mending a try. Photo and mending by Beatriz Sandini.*

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THANK YOU FOR READING

Through this booklet, we hope to address the environmental impact of the textile industry by focusing on discarded consumer textiles. This publication only scratches the surface of a very complex issue, but we hope that it helped you learn how you can make a difference no matter who you are! You can lower your carbon footprint through recycling old clothes, making informed shopping decisions, or simply changing your laundry habits. Thanks for reading!

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.