SCIRT

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SCIRT.

Identified market needs for recycled fibres

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Summary

On the one hand, apparel is one of the primary human needs, but, on the other hand, the fast fashion business model has turned clothing into a disposable product. As a matter of fact, the rising demand results in production of millions of tons of textiles. However, nearly the same amount occurs as textile waste every year and is either landfilled, incinerated or exported, only low amounts are being recycled. One promising recycling attempt towards a circular economy in the textile sector is fibre-to-fibre recycling (F2F), where discarded clothes serve as input material for the production of new fibres and, eventually, new apparel. However, this closed-loop recycling path faces technical challenges and economic boundary conditions that hinder a broader market uptake. In this report, a mapping of the technical requirements around fibre-to-fibre recycling, the market situation and the economic boundary conditions are presented. The involvement of the stakeholders mentioned in Task 1.3 was important for setting up this work. Therefore, a survey and a discussion round were conducted with the stakeholders to gather their expertise in these areas. The idea of fibre-to-fibre recycling seems promising for the future. Requirements for the manufacturing of recycled fibres by these technologies are primarily a proper collection and sorting stage. Nowadays, too little collection sites exist in the EU and the sorting technologies are not well developed. Apparel consists of different woven or knitted materials that are hard to separate. Generally, fibre-to-fibre recycling technologies need more public attention due to its low notoriety, and intensive research and development is necessary. The market situation for recycled fibres is promising and will in the future tend to lead to an increased demand in recycled fibres. Today, textile industry and manufacturers face a problematic price situation: recycled fibres can be higher-priced than fibres from primary materials. In order to tackle this price situation, technologies need to be developed and legislative instruments shall be put in place to encourage textile recycling. Mandatory certificates ensure a sustainable product and fast fashion should be held back and discouraged. Textile waste landfilling and export regulations shall be put in place by EU legislation to ensure that recycled materials are actually used and a market pull for textile waste is created.

Approval

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SCIRT.

SYSTEM CIRCULARITY & INNOVATIVE RECYCLING OF TEXTILES

Innovation Action

H2020-SC5-2020-2

Identified market needs for recycled fibres

Deliverable D1.3

Version N°1

Authors:

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Keywords

fibre-to-fibre Recycling (F2F), challenges, recycled fibres, market situation, economic boundary conditions, legislative policies

Abbreviations

Acronym	Description
COVID	Corona Virus Disease
EU	European Union
F2F	fibre-to-fibre recycling
GOTS	Global Organic Textile Standard
GRS	Global Recycling Standard
PA	Polyamide
PET	Polyethylene terephthalate
Primary material	Produced material from virgin resources
Stakeholder	Project stakeholder participating in Task 1.3
t	Production Volume – 1000 kg
Textile waste	Discarded clothes and apparel, excl. shoes
ZDHC	Zero discharge of hazardous chemicals

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1 Summary

On the one hand, apparel is one of the primary human needs, but, on the other hand, the fast fashion business model has turned clothing into a disposable product. As a matter of fact, the rising demand results in production of millions of tons of textiles. However, nearly the same amount occurs as textile waste every year and is either landfilled, incinerated or exported, only low amounts are being recycled. One promising recycling attempt towards a circular economy in the textile sector is fibre-to-fibre recycling (F2F), where discarded clothes serve as input material for the production of new fibres and, eventually, new apparel. However, this closed-loop recycling path faces technical challenges and economic boundary conditions that hinder a broader market uptake.

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The idea of fibre-to-fibre recycling seems promising for the future. Requirements for the manufacturing of recycled fibres by these technologies are primarily a proper collection and sorting stage. Nowadays, too little collection sites exist in the EU and the sorting technologies are not well developed. Apparel consists of different woven or knitted materials that are hard to separate. Generally, fibre-to-fibre recycling technologies need more public attention due to its low notoriety, and intensive research and development is necessary. The market situation for recycled fibres is promising and will in the future tend to lead to an increased demand in recycled fibres. Today, textile industry and manufacturers face a problematic price situation: recycled fibres can be higher-priced than fibres from primary materials. In order to tackle this price situation, technologies need to be developed and legislative instruments shall be put in place to encourage textile recycling. Mandatory certificates ensure a sustainable product and fast fashion should be held back and discouraged. Textile waste landfilling and export regulations shall be put in place by EU legislation to ensure that recycled materials are actually used and a market pull for textile waste is created.

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2 Introduction

According to the layout of Task 1.3: Recycled fibres – define baseline, potential and needs, TU Wien conducted a survey with project stakeholders. The aim of the survey was to map the current market demand, the technical specifications (recycled) fibres need to provide and how to facilitate the market uptake. The survey consisted of three main areas with 3 to 4 questions and can be found in the Annex. The survey outcome has been discussed in an in-person meeting with the stakeholders, that was held at CETI - Tourcoing (FR) on 26th October 2021. The survey answers and the discussion outcome of the areas are summarized in this report and discussed in the following chapters.

The idea of applying fibre-to-fibre recycling in the apparel industry is one of the SCIRT project's main objectives. Currently, more information needs to be gathered regarding the baseline, potential and needs of fibre-to-fibre recycling in the textile sector. Conventional approaches such as finding applications for output materials already exist. In this work, a demand-driven perspective for using recycled fibres in textiles is applied and specific challenges, barriers and future trends are evaluated.

The contributing stakeholders, who were involved in the survey, are sellers of sportswear, jeans and casual clothing. Main components within their marketed textiles are cotton, polyethylene terephthalate, polyamides, elastane, viscose and wool .

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3 Fibre Sourcing

The participating stakeholders have different expertise in using fibres in their products, whether in recycled or primary form. The involvement in the value chain with regard to procurement of raw material and processing of raw material into fibres is different for each stakeholder. The involvement of the stakeholders is influenced by the size of the company and the products they are selling. Fashion brands with high production volumes and a certain revenue seem to be well-involved in the production process of fibres and yarns, with or without recycled content. Small and midsized fashion brands, whose philosophy aims at sustainability in their products, want to use more recycled content but do not often have enough knowledge of the fibre and yarn production process. These enterprises tend to buy finished fabrics. Fashion brands agree, that products on high-priced level (luxury products), commonly contain more recycled fibres in the material. Mid-segment-priced apparel comprises recycled fibres depending on their company's philosophy. When competition is considerably strong and a fixed market position is the case, recycled fibres do not easily find their way into low priced apparel.

Cotton and PET mark the highest amount of global fibre production, making up for 77% of all fibre materials produced (Textile Exchange, 2021). Under the following headlines, the focus is thus mainly on these two fibre materials. Fibre sourcing with the aim of producing clothing can be done from two origins: by primary production from new resources (see chapter 3.1) or secondary production from discarded textiles (see chapter 0). In order to conduct fibre-to-fibre recycling, appropriate technical fibre specifications are from great importance for yarn and fabric producers.

3.1 Fibre consumption

Stakeholder that participated in the survey are sellers of sportswear, jeans and casual clothing. The widely used fibre materials in their products are cotton, PET, PA and wool. In Figure 1, the shares of worldwide production of those materials are displayed. Since cotton and PET have a fibre market share of more than three quarter, these two materials are discussed.

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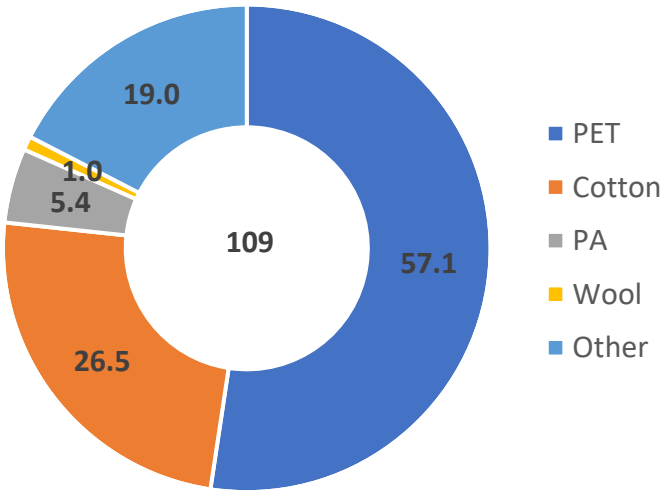

Figure 1 Global Fibre Production 2020 in Mt; adapted from (Textile Exchange, 2021)

Cotton

When cotton is used for textile production, participating stakeholder import it mainly from Asian countries, e.g. China and India. The only EU country mentioned was Greece and the supplied cotton comes with Global Recycled Standard (GRS) Certification (see more in 5.1). The global cotton fibre production in 2020 was around 26.5 Mt, whereas 0.26 Mt recycled cotton have been produced. Figure 2 shows the lead countries in preferred cotton production. India, Pakistan and China are the largest global producers of cotton after Brazil. Greece holds 2% of the world cotton production (Textile Exchange, 2021).

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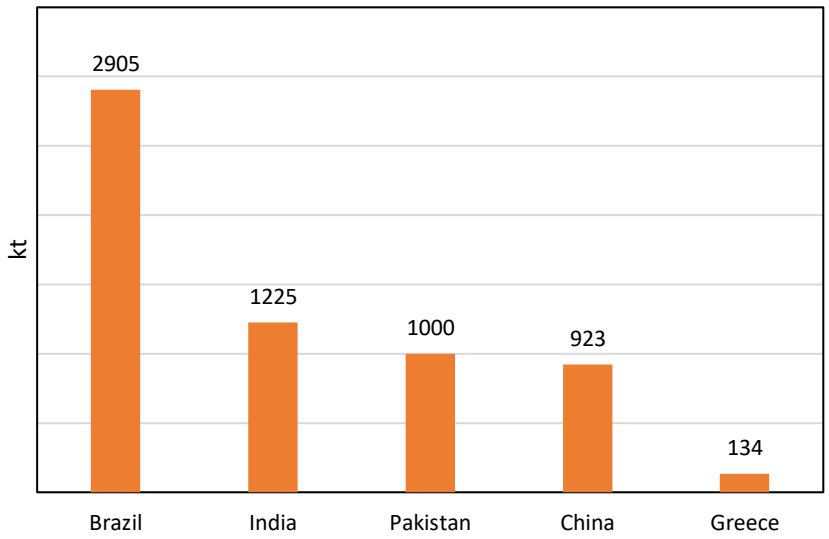

Figure 2 Preferred Cotton production in kt in 2019/2020; adapted from (Textile Exchange, 2021)

One stakeholder applies a sustainable circular strategy on cotton material sourcing. In collaboration with a local social company, "pre-loved" (i.e., the textile underwent one use phase with end user and is still in good condition) cotton textile waste is collected and sorted out by hand. Discarded cotton textiles in excellent state are separated for selling in a local thrift shop. Good-quality cotton will be used as input for new clothing production. Fractions, which are not useable for further processing, will be "downcycled". According to the stakeholder's terminology, downcycling in this context means, that items from this fraction are shredded into smaller pieces and function as filling material for car seats or building materials.

PET and PA

Polyester fibres - mainly PET, other polyester types are neglectable in fibre production - are globally the most used fibres with a production volume of 57.1 Mt in 2020, whereat 15% are marked as recycled PET (rPET). Recycled PET fibres are mainly produced from collected PET plastic bottles, the share is about 99% (Textile Exchange, 2021).

PA fibres had a market share of 5% in 2020, with a production volume of 5.4 Mt, whereat 0.11 Mt or 1.9% of this volume are marked as recycled PA (rPA). rPA can be processed from discarded fishing nets, carpets or textile waste (Textile Exchange, 2021).

When PET or PA in primary or recycled form are supplied, stakeholders import these polymers from Asian countries like China, India, Vietnam, Taiwan. Spain was the only European country mentioned.

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3.2 Textile Collection and Sorting

An indispensable process and prerequisite for feasible textile recycling is the separate collection and sorting of textile waste. It is important to connect collection and sorting processes, since the output of these stages influences the further processing or may have negative impact on processing quality if not properly set up. Since today's textiles consist mostly of multi-material blends, a high accuracy in distinction of textiles during and/or after collection is necessary (Köhler et al., 2021). Usually, main fractions of discarded textiles are stained, soiled or torn apart.

Generally speaking, textile collection and sorting systems operate as a combination of reuse, recycling and waste treatment. By following the EU waste hierarchy, primarily reuse shall be achieved and recycling and waste treatment follows next. Textile collection and sorting systems, marking the initial step for recycling processes, have been already installed by public authorities, charities or brands in some European countries with the goal of reprocessing discarded textiles (Manshoven et al., 2019). Figure 3 shows EU member states, in which collected and sorted textile waste volumes have been monitored. Compared to the consumption of clothing, the collection rates are still low. Referring to figures for Germany, a rise in apparel collection and sorting can be seen.

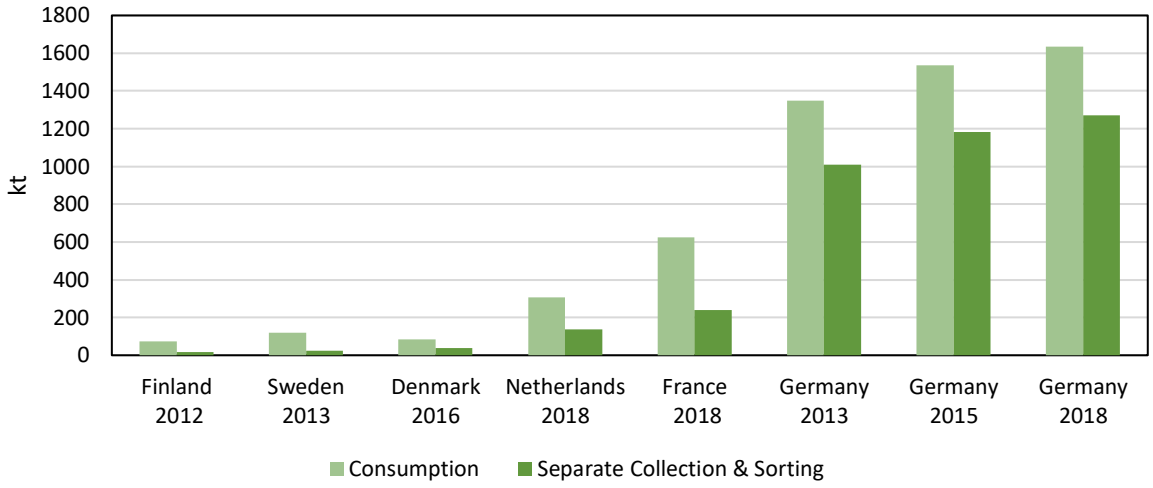

Figure 3 Textile Consumption and Separate Collection & Sorting in EU member states in kt; Figures adapted from (Watson et al., 2020) and (bvse, 2020)

Today's textile collection and sorting faces a number of problems:

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Textile composition

Apparel denominates a wide known sub-group of textiles, whose main feature is to dress people in a functional and fashionable way. Fabrics used in apparel production consist of a single material - or mono-material - or two, three or multiple material fabrics. In that, material mixes account for a considerable share. Commonly used materials for apparel are cotton, polyethylene terephthalate, polyamides, elastane, viscose and wool These materials are produced as fibres that are spun into a yarn and woven or knitted into a fabric. The sorting process after the collection is indispensable to avoid material mixes in the output of the process stage. Figure 4 shows a woman's pair of trousers, where the label states a composition of wool, PET and elastane. Using a light microscope (Keyence VHX6000), a distinction between the natural wool fibre and the synthetic PET fibre can be made. The wool fibre with its typical roof-tile shaped surface can be easily recognized. The PET fibre with its smooth surface and transparent appearance is right next to the wool fibre. In recycling processes, both the small distances between the fibres within the fabric and a typical fibre diameter of around 15 – 100 µm make it difficult to accurately separate into the two materials during mechanical recycling. Furthermore, plastics and metals are found on apparel in the form of buttons or zippers.

Figure 4 Microscope image of a wool/PET/EL trouser

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Lack of collection and sorting systems

Considering Figure 3, in some European countries the collection and sorting of textile waste has already been conducted. A comparison between textile consumption, and collection and sorting shows a huge gap. In the future, more textiles shall be collected, so that the contained material can function as input for recycling processes. This will be changed the latest in January 2025, because the EU Commission updated the EU waste policies. From 2025 onwards, the obligation for separate collection of textile waste within municipal waste collection according to EU Waste Framework Directive (EC, 2018) will be enforced on EU member states.

Further research in collection and sorting technologies

Firstly, collected textile waste needs to be sorted into reusable and recyclable waste fractions, as well as fractions that cannot be processed further. Secondly, the sorting stage aims at separating the different materials present in apparel dependent upon composition. Today, this is done via manual sorting, technology-enabled manual sorting with a differing degree of automation. Manual sorting is expensive due to labour costs and workers need good identification skills regarding the composition for the discarded textiles (Köhler et al., 2021). One future method for fully automated sorting is an optical technology for on-line capture of the textile composition. Although automated processes are more preferred than the manual sorting, they are still on pilot scale and in development. For the rising volumes that can be expected for the future, an industrial scale must be achieved (Re_fashion, 2020). One challenge in the SCIRT project is to create a fundament for an industrial scale up of collection and sorting processes.

Place of collection

All stakeholders agree that the collection and sorting stage for material recycling is very important. Textile collection can be organized by the retailer or can be done at the retailer's store, near private homes in kerbside collection or at central collection places, both provided by either municipalities or private organizations. Stakeholder point out that the place of collection has a huge impact on the quality and quantity of the discarded textiles. According to stakeholders' experience, textile waste shows higher quality when collected at stores or near homes, whereas quality is supposedly lower for central collection. Textiles discarded into big containers such as found in central places, are said to be frequently dirty and stained. However, quality of textile waste from central collection can vary depending on the system, location and EU member state. With retailers and stores, discarded textiles are mostly in good condition. Surveys show, that people bring clothes to stores or retailers that they do not like anymore, are too big, too small or washed out (Watson et al., 2020).

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3.3 Technical specifications

Fibre and Yarn Production

Yarns need to achieve certain technical specifications in order not to cause complications in the production and use phase. The main production processes for textiles are fibre and yarn spinning, followed by weaving or knitting. Woven fabrics consist of two yarns in rectangular formation called warp and weft. Knitted apparel is produced by a stitch-forming process.

Whenever a yarn producer intends to perform recycling of used textiles, the known problem of well-sorted material supply comes up, as mentioned by stakeholders. Today, apparel hardly consists of a mono-material, instead it consists most often of fibres of two or more different fibre materials that create a blend. The amount of textiles containing multi-material blends are increasing on the market (Jönsson et al., 2021). The most-used blend by far is the dual-fibre fabric PET/cotton. The quantity of multi-fibre textiles is very high, but in contrast, the quantity of feasible sorting technologies is very low. Since dismantling and sorting is very cost-intensive, sorting plants are mostly found in countries outside of the European Union or Eastern European countries (Girn et al., 2019). It is reported by the stakeholders that today, closed-loop fibre recycling is not economically viable.

Important criteria for yarn users are shown in Table 1.

Table 1 technical specifications for yarn users

criteria	**technical specification**
titre	mass per unit length, also known as yarn count
tenacity	persistence of the fibre against a force, Force/Titre
crimp contraction	percentage of the length before and after developing crimp
boiling water shrinkage	percentage of the fibre before and after treatment in boiling water
yarn regularity	uniformity of the yarn
intermingle	Interlacing of multifilament yarn
IPI-values	Imperfection Index of Yarns

Note: explanations are taken from (BISFA, 2017) or from stakeholder experts' interviews

Especially the end-user shall not have any limitations during the use phase. From the surveys, it can be concluded that the stakeholders' main goal is to deliver a textile product of high quality and wearing comfort.

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Yarns within textile products

Depending on the purpose of the textile product, haptic specifications of finished goods such as shown in Table 2 are of high interest.

Table 2 Important specifications for the end user

haptic specifications
elasticity
permeability
chlorine resistance
drying ability
opacity
soft touch
thickness

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3.4 Fibre-to-fibre recycling (F2F)

Less than 1% of the discarded textiles that are separated are reprocessed into new fibres via fibre-to-fibre recycling (Ellen MacArthur Foundation, 2017). As pointed out in 3.1, a huge amount of textile items is in circulation within economies and starting by January 2025, EU member states have to collect discarded textiles. When a direct reuse of the textiles themselves is not possible, it is obvious that recycling is most efficient when it stays on textile or fibre level and reprocesses the raw material of textiles back into the state of fibres. The reprocessing of fibres into new fibres in so-called fibre-to-fibre (F2F) recycling processes is an upcoming approach on tackling the problem of discarded textiles whenever export and incineration, let alone landfilling, are not the desired option. This method is shown in Figure 5 and explained under further chapters.

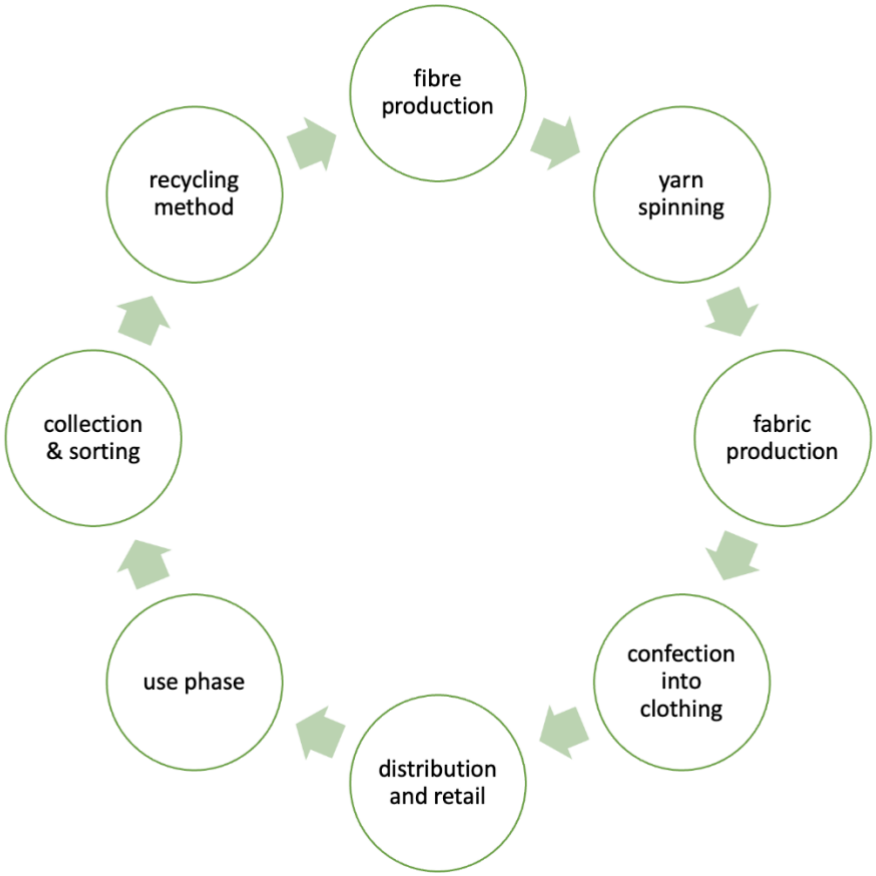

Figure 5 Scheme of fibre-to-fibre recycling (F2F)

However, this recycling method faces characteristic challenges, as described in the following paragraphs.

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Collection and Sorting

Today, not enough textiles are collected and sorted to accumulate sufficient amounts for producing recycled fibres in F2F processes. Furthermore, usable fractions are even less since a lot of discarded textiles are stained or soiled (Girn et al., 2019). The revised EU Waste Framework Directive commits EU member states to the collection of discarded textile waste. Even if a separate collection of textile waste is mandatory by January 2025 the latest, up to now no binding targets (such as collection rates, recycling rates and recycled contents) from EU Commission has been announced. Further information is provided under chapter 0.

Textile Condition

The discussed multi-material fibre blends found in textiles are imposing problems for F2F (Harmsen et al., 2021). Therefore, a first step of F2F always is the separation of the fibres to obtain pure secondary fibre raw materials (Piribauer & Bartl, 2019). A further challenge is that textile fabrics moreover consist of trims, zips and labels, which are mainly made from different polymers or metal. Additional chemicals are also used in apparel for giving it a different appearance or property. Examples are adding colour by pigments or using organic compounds such as flame retardants that are spun into the fibre lumen (Vecchiato et al., 2018). The impact of those apparel improvers or modifiers into F2F are not fully investigated yet and further research is necessary.

Low F2F Technology Readiness Level (TRL)

Commercially available technologies for economic and ecological fibre-to-fibre recycling are not yet available. Different recycling technologies are still in development and further laboratory validation is being conducted (Jönsson et al., 2021) and a direct objective in SCIRT project.

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Challenges in F2F on examples by SCIRT stakeholders

PET fibre recycling is applied by a stakeholder via a combined extrusion and melt spinning process. The input requirements for the polymer extrusion process are a maximum fibre length or polymer chip size of 3mm with a certain viscosity over a given shear rate range. An important process parameter is the intrinsic viscosity. If the intrinsic viscosity falls below a certain value, the melt spinning process cannot be conducted, because the low viscosity will lead to rupture of the spun fibres when drawn off afterwards in the spinning stage. When the intrinsic viscosity is too high, too much pressure is built up at the melt-spinning die and fibres cannot be spun. Further information on recycling processes can be found in literature (Palacios-Mateo et al., 2021).

An additional problem is the moisture level in the extrusion process. Water occurrence in the process results in the degradation of the PET polymer into lower chain length or even its monomers. Moreover, temperature affects the PET extrusion process. These two key parameters need to be met prior to the extrusion process.

Elastane in textiles affects the recycling process (Jönsson et al., 2021). As a result of the chemical structure, textiles containing elastane in larger amounts are not yet suitable for current recycling methods, where a limit may already be reached at a sub-1%-level. The rubbery material cannot be easily degraded thermally and tends to clog filters of recycling machines, resulting in a process stop because of the rising pressure. When textiles are cut down in small pieces and are fed into classical mechanical recycling lines, an elastane content of more than 3% is a problem and creates white dots in the fabrics after remanufacture.

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4 Market situation of recycled fibres

Fashion brands outline that the market competition in apparel sales is very strong, since many players are on the market. Fashion brands also need to serve the latest trends and always have an eye on their consumers. By switching to more expensive production materials, as recycled yarns are at the moment, it is hard to keep up with the price and sales. Price elasticity is not a feasible tool as it only ranges in the low-Euro range for typical items. Drivers of sustainability, called eco-warriors by one of the stakeholders, are having a hard life on the market. Consumers are aware of paying a certain price for a kind of apparel. When a certain limit is exceeded though, the price is too high for consumers and the fashion brand loses its position on the market due to a sales decline.

4.1 Sustainability

To be in line with the sustainable and environmental developments, some fashion brands already use recycled fibres in their textiles or produce new sustainable apparel (Rotimi et al., 2021). Today, textiles containing recycled materials do not have to be at higher price, nevertheless more sustainable products are found in the high-priced segments, as pointed out by stakeholders. Fashion brands stated that there is higher price elasticity in the middle or on top of price range. The consumers are aware that they pay a higher price while creating a less impact on the environment.

4.2 Price situation

All stakeholder have the same experience that yarns of recycled fibres can cost more than those from virgin material. The cost gap is not always constant and depending upon the present price situation of the virgin and recycled material. For instance, a stakeholder complains that rPET fibre price can be higher by an additional 30% in comparison. For PET material from primary resources, purchasing volumes, oil price context, PET bottle availability, worldwide demand and sanitary situation mark up the price. For rPET material, the cost intensive recycling technology including transport, dismantling and treatments for conditioning, underline the high price (see also in (Leal Filho et al., 2019)). Today's textile composition is the big problem for the recycling industry. As already mentioned, apparel consists mostly of different polymer and/or natural fibres within the fabric, not mentioning dyes, sewing thread and so on. All these materials and combinations are hardly feasible for treatment under one single recycling method, different process streams and/or combinations are necessary.

Recycled fibres can be higher-priced, but the environmental impact for landfill and incineration is less or avoided and enterprises can save money concerning this part of waste management. Avoiding incineration also saves CO_2 emissions and no hazardous gases are released (Palacios-Mateo et al., 2021). Yet, raw material costs for many textiles are rather low compared to the necessary production steps to yield the final textile. So at least from this point of view, using recycled fibres should not impose a big impact on the actual price label.

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When sourcing raw materials for textile production like fibres or yarns, stakeholders mention the problem of competition in buying recycled material versus primary material. For primary materials, steady supply is given, but prices undergo fluctuations. The graphs in Figure 6 show the PET chips price situation in Europe, China and the United States between May 2020 and April 2021. (ICIS, 2021) state that the PET price shown in this figure is strongly correlating with the COVID pandemic. Feedstock shortages and low inventories, tight supply and high freight costs as well as a rising demand for PET chips are some of the explanations for the price rise observed since around December 2020.

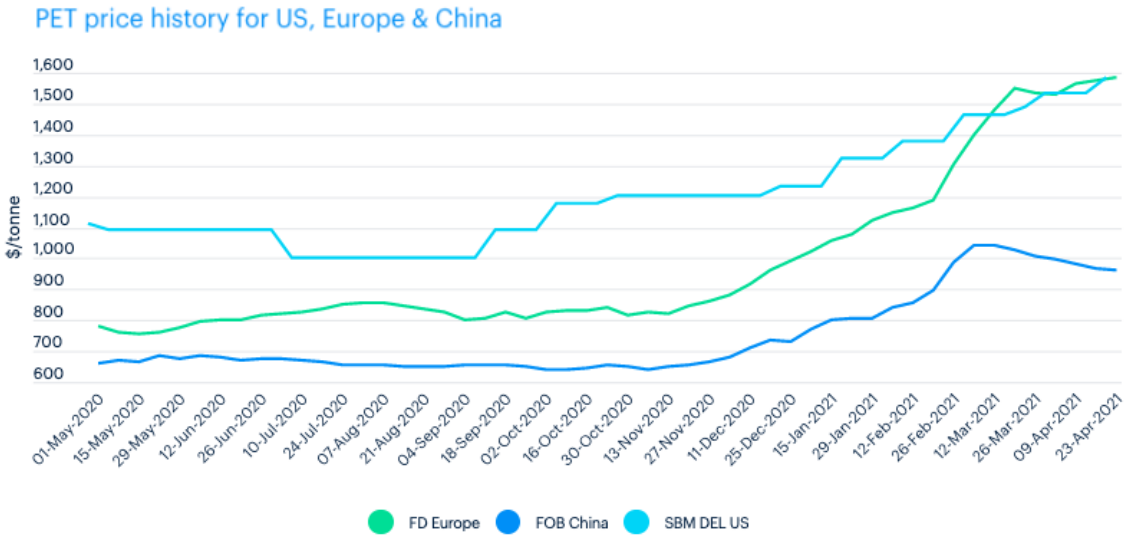

Figure 6 PET chips price between 05/2020 and 04/2021 (ICIS, 2021)

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Recycled material is rare on the market, since not enough recycling technologies are available at the moment. Recycled polymer material is bought by a stakeholder as yarn or chips, depending on the required fabric production input. Yarn and chips are bought from all over the world and processed in different places. PET bottles can be processed to flakes in country A, these flakes are further worked in country B and yarn-spinning is undergone in country C. Figure 7 shows a combination of the consulted stakeholders' expertise and information from (ICIS, 2021), which is at most points overlapping. The price of recycled PET chips, which serve today mostly as production input for rPET-fibres, is strongly depending on five different impact factors. The manufacturing industry (for instance automotive or textile) and packaging industry are creating a wide market pull for rPET-chips, to fulfil their sustainability targets. The rPET-bottle production is strongly depending on rPET chips and is also influenced by seasonal effects such as rising demand for on-the-go beverages plastic bottles in tourism destinations. The last impact factor, societal effects, marks the change of today's society towards more sustainable products and circular economy as well as the global COVID pandemic with its consequences that are mentioned above. The high demand of rPET, limited supply and no tracking possibility is an obvious basis for the possibility of fraud in this market.

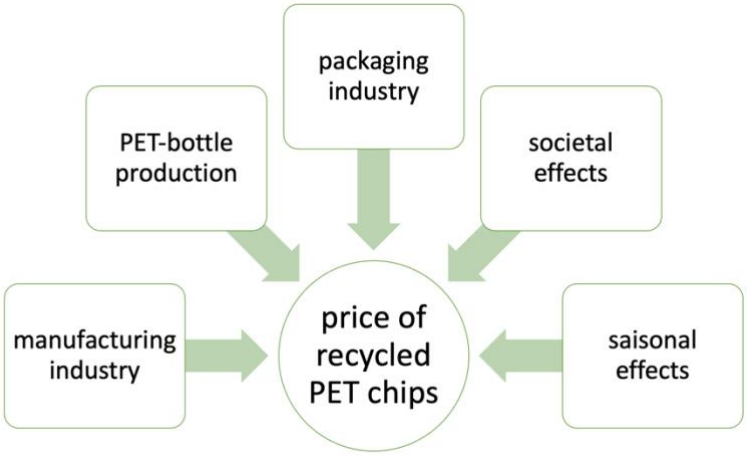

Figure 7 Impact factors on the price of rPET chips

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5 Economic Boundary Conditions

In this section, actions are described that need to be faced to facilitate the market uptake of recycled fibres or yarns.

5.1 Certification

The involved stakeholder are aiming at more intense use of certificates serving as sustainability standards. Certificates themselves aim at increasing recycled content in products and reducing the environmental impact caused by production processes. Fashion brands seek for good certificates to ensure that the consumer pays good quality. Certificates used in textile industry today and appreciated by the stakeholder are presented below.

GRS (Global Recycling Standard)

Products certified by GRS introduce certain criteria for the production phase, the working conditions and the use of chemical substances. The latest version GRS 4.0 adopted the ZDHC's Manufacturing Substance List and for the GRS 5.0 ambitious goals have been set up. Further information can be found in (Textile Exchange, 2020).

GOTS (Global Organic Textile Standard)

The GOTS programme is a non-profit organization that sets worldwide standards for the whole textile chain, especially for organic fibres. In 2020, GOTS held 10.338 certified facilities all over the world and 25.913 approved Chemical Inputs from suppliers have been accepted. Further information can be found in (Global Standard GmbH, 2020).

OEKO-TEX

Aligning with the United Nations Sustainable Development Goals (SDGs), OEKO-TEX is focusing on a sustainable, trustworthy and safe international textile and leather industry. 18 independent textile and leather institutes and 21.000 manufacturers, brands and trading companies worldwide work officially with OEKO-TEX. Further information can be found in (OEKO-TEX Association, 2021).

Certificates ensure that the textile value chain operates under controlled conditions. Stakeholders also approve that certificates shall not exceed a certain number, so that the consumer is not overwhelmed with them. A handful of certificates must ensure complete safe and independent value for the textiles. A legislative framework is needed, forcing fashion brands to use certification for their products. Now, there is no regulation that stipulates fashion brands having to use certifications for their products. The sourcing of environmental correct production materials without making use of child labour is one of the stakeholders most mentioned issues. Eventually, all brands agree that they need commonly mandatory tools at hand that would guarantee for certain thrustworthy standards.

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5.2 Fast Fashion

Fast fashion stands for high production volumes of often low-quality products with short market launch cycles that are frequently also sold at cheap prices. As such, the dwell time on the market of fast fashion products is fairly low. The idea of this business model is to keep up with the latest design trends by bringing new cloth-collections on the market in short periods. The consumer is able to always buy the latest trend at low prices, resulting in a mass consumption of low quality products (Manshoven et al., 2019). Big Fast Fashion brands are bringing 16 or 24 collections on the market within one year (bvse, 2020).

Stakeholders agree on the problem of fast and "super-fast" fashion brands that focus on big volumes and low prices. Since these players have a great impact on the market, there is not much room for circular and sustainable fashion which currently is more expensive. Companies that focus on sustainable products have to deal with the handicap of not being competitive on the market right now. Or, as to cite the following quote of a stakeholder:

"It can't be the case that consumers and brands, that make the right choices, are financially punished for this."

If it is not possible to produce sustainable textile material at the same costs as in the "normal way" for virgin material, instruments ought to be created that facilitate the market uptake of recycled textile products. Stakeholders agree that using the European Green Deal idea to a modern, resource efficient and competitive economy encourages textile recycling. Financial, legislative and social instruments need to be put in place to create the most important thing: market pull for recycled fibres. Appropriate actions will result in a higher demand for recycled fibres, further development in recycling technologies and pressure on fashion brands to develop apparel containing recycled material. As a result, the snowball effect will also push the various fibre-to-fibre recycling approaches.

5.3 Landfill and Export of Textile Waste

Nowadays, it is common practice that collected and sorted textile waste is landfilled or incinerated, as there are too few other areas of application. Not enough circular solutions for further processing exist e.g. as with fibre-to-fibre recycling (see 3.4) and already existing ones are challenging (Köhler et al., 2021). To overcome this issue, the European Commission adopted the Circular Economy Package in 2015. EU countries are directed towards a circular economy by a ban on landfilling of separately collected waste by 2030 (EU, 2020). This and the implementation of obligatory separate waste collection according to EU Waste Framework Directive has raised necessary awareness of discarded textiles and textile waste.

Export is also an issue. Collected textiles that are not suitable for reuse in the place of first use (typically industrialized markets) or recycling are exported. Stakeholder provided information that for now, no strict regulations are applied to which textiles are being exported. In some European countries, the landfilling of textiles is forbidden, but may then be landfilled without concern abroad. Exporting textiles has been a growing market activity across Europe. In 2019, the export rate of textile waste from the EU-27 countries was about 1.3 Mt, whereas in 2003 it was 400.000 Tons (Köhler et al., 2021).

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Besides, the lack of suitable recycling technologies and alternative post-use treatment routes for textile waste other than landfilling, the issue is aggravated by another fact: the export to other countries. By following their business models, brands as well as countries have different reasons on exporting textile waste, as stated out in Table 3.

Table 3 Issues regarding textile waste export

Reasons for exporting textile waste
High labour costs in developed countries. By exporting textiles to African or Asian countries, the costs are lowered (Watson et al., 2020)
Generating revenue: selling collected clothes is a business (Bartl, 2020)
Ban on landfilling of textile waste: some EU countries have a ban on landfilling and others do not. Those ones, that have a landfilling ban in place are sending large amounts of textiles to other countries, even within the EU. Concerning European countries' waste, exported textiles tend to be landfilled in other countries (frequently ending up on non-sanitary landfills), which means the problem is not solved but made into a global problem at different places (Ellen MacArthur Foundation, 2017)

5.4 Legislative instruments

All stakeholders agree that in the world today there is a need for a system where sustainability is pushed forward and supported. Free capitalism surely has its advantages, but a negative side is the rising production and, furthermore, increasing overproduction. Lowering the production volumes cannot be the case, since employees need to be paid. For the environment, lowering the volumes is a plus, but that is a disadvantage for employed people, because they are paid by means of the generated revenue. I.e., from a business perspective only, a change will not be achieved. Legislative instruments that support sustainability and a better future within textile industry need to be put in place. Within the discussion rounds, stakeholders agreed on the following key policies:

Mandatory Certification for Textiles

One starting point for ensuring a sustainable future and driving the EU to a genuine circular economy within the sector, is a mandatory certification for produced or imported textiles. Textiles have to be labelled with certificates, so that the consumer is aware of buying a sustainable cloth. In order for that to be reliable, supervisory authorities should be monitoring the system. Appreciated and independent certification organizations are presented in 5.1.

Import ban on Low Quality Apparel

Within the stakeholders, the conclusion was drawn that an import ban on low quality apparel should be put in place. By setting minimum standards for textiles for durability or technical criteria such as number of minimum washing cycles a piece needs to undergo and stay in shape is required. A directive is needed to work against fast-fashion trends.

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Mandatory Education on sustainable lifestyles

The young generation are not aware of the impact they have when buying cheap goods such as clothing, which stands for fast fashion products in most cases. On the other side, teenagers do care about the environment, climate change and the global future of the world. Children need to be encouraged on how they can change the world by acting different in front of the grown-ups. They need to be educated in school on sustainable behaviour and lifestyles and what impact buying a new pair of jeans for the use in a certain period of time has. This topic is also discussed in (Rotimi et al., 2021).

However, education has its limits: people intend to buy clothes as a reward, to fit into a social group or to stand out within their friends. It is in humans' nature to compare, look better, want to separate or fit in in a group of people. In the age of between approximately 10 to 20 years, young people try to "find themselves" and experiment with different clothing styles. At this point, influence can be generated in a positive way. Education in schools and big players of the fashion industry need to start challenging the younger generation soon. Education institutions shall be addressed to place a sustainable lifestyle in their list and fashion brands should enhance this mind-set. Within this new education form, parents shall also be considered. A conscious consumption must be achieved in the near future.

Used textile export regulations

Discarded textiles contain large amounts of raw materials that could be recycled. High percentages of discarded textiles are exported to other countries. Regulations could keep the material inside the EU and push the industry to make use of it.

Enhancing Supply Chain in Europe

Since the start of the COVID crisis in the European Union, voices get louder for bringing the supply chain back to Europe. The market in the European Union can be more dynamically reacting to societal circumstances like COVID. For enhancing the European Union as a great and forward-looking economic player, it is necessary to be less dependent upon foreign countries. Today, the fibre supply is strongly dependent upon mainly Asian countries, as pointed out in 3.1.

Implementing a European production system, transport routes can be shortened and cuts in the supply chain can be prevented. A good example here is the catastrophe of the "Evergreen" ship in the Suez-Canal. The ship ran aground on sand and it took weeks to get it free, causing a mass traffic congestion in both Suez Canal directions and resulting in delivery difficulties that lasted for weeks.

More jobs could be generated and unemployment caused by several factors (e.g. COVID pandemic) could be attenuated, while the added value and profitability stays in the European Union. Concerning this, investments should be made to bring industry or parts of it (back) to Europe. This topic is also discussed in (Repp et al., 2021).

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6 Conclusion

In order to run along with the European Green Deal to a competitive and circular economy, the reprocessing of textile waste is indispensable. Today, large amounts of discarded textiles are either landfilled, incinerated or exported to other countries, mainly outside of the EU. These common applications are a threat to a sustainable, modern textile sector. The revised EU Waste Framework Directive (Directive EU 2018/851) stipulates a mandatory separate collection of textile waste for EU member states as of January 2025.

The collection and sorting process of discarded textiles is not easy. More locations for efficient textile collection need to be created by EU member states. It is important to consider different aspects of the collection places, because experience shows that the quality of discarded textile differs between public containers, household and retailer collection, as well as EU regions, cities and countryside. Apparel consists of different woven or knitted materials that are hard to separate. Further research and development in sorting technologies is an absolute must for an accurate separation of the different materials used in apparel and subsequently, easier accessibility of recycling processes.

The idea of fibre-to-fibre recycling (F2F) seems a promising technology for the future. Yet, the easy principle of using discarded textiles as production input for new textiles comes with some quite not so easy challenges. As mentioned above, more textile waste supply is necessary to feed these recycling technologies. The supply needs to keep up single variety and without soiling. If enough suitable input for fibre-to-fibre recycling is available, more focus will lie on developing this recycling technology. F2F at the moment runs at small or pilot scale.

The facilitation of the market uptake of recycled fibres and its economic boundary conditions were discussed intensively. Recycled fibres are spun into a yarn and increasingly find their way into new products that are designed by fashion brands. Some companies aim at using more recycled materials to get in line with their sustainability goals, so a slight market pull can be assumed, yet market competitiveness hampers the adoption in a greater extent. An example on the most use fibre material on global scale shows that the price is rising because of demand and supply not being equal. Recycled PET fibres are produced nowadays on industrial scale and more economic and ecologically agreeable technologies are necessary to feed the rising demand. Strict key polices from EU legislature such as import bans on low quality apparel and export regulations on textile waste can guarantee, that feasible material for certain recycling technologies stays in the European Union. An outcome of this will be an enhanced textile supply chain in Europe. Mandatory certification on new textile products will ensure more sustainable products and lead to pressure on the fast-fashion business model that stands for low quality products, cheap prices and high production volumes and largely counteracts efforts by forerunners for a more sustainably textile sector. The fast-fashion business model is contrary to the EU Green Deal and actually contemporary to a certain degree among young people's mind-set. Education on sustainable lifestyle needs to be taught more intensely in schools to encourage the young people to better resource usage and shopping behaviour, because they make up the largest target group for fast fashion and may thus play a key role in a future sustainable textile industry.

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9 Annex

Survey **27th August 2021**

Area 1: Recycled fibres

1. To which point are you involved in the value chain of recycled fibres?
2. Which products exist in your market segment, that contain a certain percentage of recycled fibres?
3. What forms of recycling of cotton, PET, PA, EL and viscose (cellulose regenerate) fibres are used in your region/business/products?
4. What are common problems of recycling the 5 above mentioned materials (including blends) in your region/business/products?

Area 2: Technical requirements (mechanical, optical, haptic)

1. Which are the technical criteria (parameters) of used fibres that are important for your products or your field of research?
2. Could you specify the latitude or range those parameters need to attain to be used in the production process?
3. Which experiences do you have in terms of purchasing recycled fibres (domestic, abroad)?

Area 3: Facilitate market uptake

1. What's the cost gap between recycled and primary fibre of the 5 mentioned materials in your region/business/product?
2. If you already use recycled fibres: what is the cost gap of recycled fibres from the sources you know (e.g. domestic, import from low wage countries)?
3. What are the economic boundaries, that hinder the market uptake of recycled fibres?
4. What are consumers ready to pay and at which level is the loss of margin, or which loss would be acceptable in your company's / brand's opinion, respectively?

Is there anything else what is important to you? Feel free to describe your topic in addition!

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