TECHNOLOGY • RESEARCH HIGHLIGHTS • VISIONS • SCIENCE

313

Model of circular business ecosystem for textiles

Paula Fontell | Pirjo Heikkilä

VTT TECHNOLOGY 313

Model of circular business ecosystem for textiles

Paula Fontell

Ethica Ltd

Pirjo Heikkilä

VTT Technical Research Centre of Finland Ltd

ISBN 978-951-38-8587-8 (Soft back ed.)
ISBN 978-951-38-8586-1 (URL: http://www.vttresearch.com/impact/publications)

VTT Technology 313

ISSN-L 2242-1211
ISSN 2242-1211 (Print)
ISSN 2242-122X (Online)
http://urn.fi/URN:ISBN:978-951-38-8586-1

JULKAISIJA – UTGIVARE – PUBLISHER

Teknologian tutkimuskeskus VTT Oy
PL 1000 (Tekniikantie 4 A, Espoo)
02044 VTT
Puh. 020 722 111, faksi 020 722 7001

Teknologiska forskningscentralen VTT Ab
PB 1000 (Teknikvägen 4 A, Esbo)
FI-02044 VTT
Tfn +358 20 722 111, telefax +358 20 722 7001

VTT Technical Research Centre of Finland Ltd
P.O. Box 1000 (Tekniikantie 4 A, Espoo)
FI-02044 VTT, Finland
Tel. +358 20 722 111, fax +358 20 722 7001

Juvenes Print, Tampere 2017

Preface

The Relooping Fashion Initiative aimed at piloting and modelling the circular business ecosystem for textiles. This report covers this business ecosystem modelling work and introduces the project team's crystallized vision of a higher-level system that enables the textiles industry to operate according to the basic principles of a circular economy. The aim is not to provide a detailed view of all possible material flows, actors, or interfaces between the different processes, such as reverse logistics, data, energy, water, process substances or side streams. Rather, the focus is on explaining the principles of a circular economy in the context of textiles, and drawing a picture of the key material flows and types of actors along the value cycles from end-user back to end-user. The overall goal is to maintain the value of materials as high as possible, with minimum environmental impact.

The different circular business models for textiles are introduced along the value cycles. The report covers 1) repair and maintenance, 2) re-use as product, 3) re-use as material, and 4) recycling-related activities, and business models for post-consumer/user textiles along the entire value chain. All these processes need to work seamlessly together for the circular business ecosystem to function effectively. Some parts of the value chain, such as textiles producing & design and retail, are already well established, while others, such as effective textile collection and sorting for non-reusable poor-quality textiles, are currently still missing at an industrial scale.

To solve the global textile waste problem, and to be able to replace some of the virgin materials such as cotton with recycled textile materials, new recycling technologies are at the centre of attention. This report also gives an overview of the key emerging technologies for textile recycling. Furthermore, this report discusses the topic of shared value creation in the circular economy context, since one of the goals for the Relooping Fashion Initiative was to create a circular business ecosystem, which creates shared value for all parties along the value chain.

Contents

1. Introduction

The following chapter gives a general overview of the current linear textiles value chain for understanding the starting point and the big picture of the prevailing global model Chapter (1.1). Then, the basic principles of a circular economy are explained as a wider context and objective for the transition from linear to circular business ecosystem for textiles (Chapters 1.2 and 1.3).

1.1 Current Linear Textile Production

The simplified linear model of textile production starts from the production of fibres, which are used in formation of yarns, and further knitted or woven fabrics, which are sewed into final products, which end up as waste after consumption (see **Figure 1**). Chemicals, water and energy is used and emissions released to the environment throughout every step during the entire life cycle of the product.

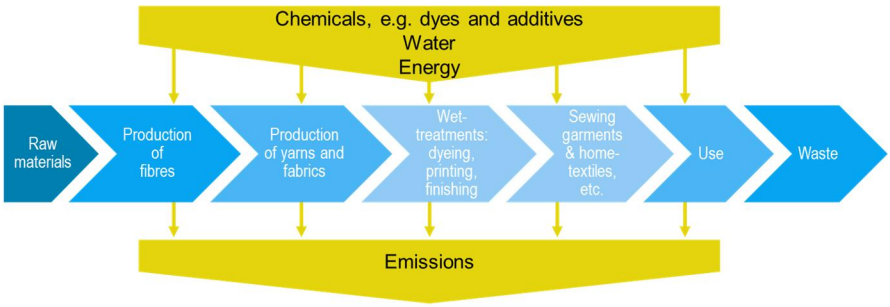

Figure 1. Simplified linear model for textile production, re-drawn from (Choudhury, 2014).

The textile business is a complex system from design and production to global distribution of clothing and textiles (see **Figure 2**). Clothing and textiles are considered as a necessity and commodity products, but also their aesthetics and design play an important role. The production chain depends on the raw material source (natural and synthetic) and also includes various additional steps such as

dyeing, printing, and finishing steps, thus involving chemical and other related industries. Distribution involves retail business, which is segmented including, for example, brand owner stores, department stores, boutiques, and markets, as well as on-line versions of these.

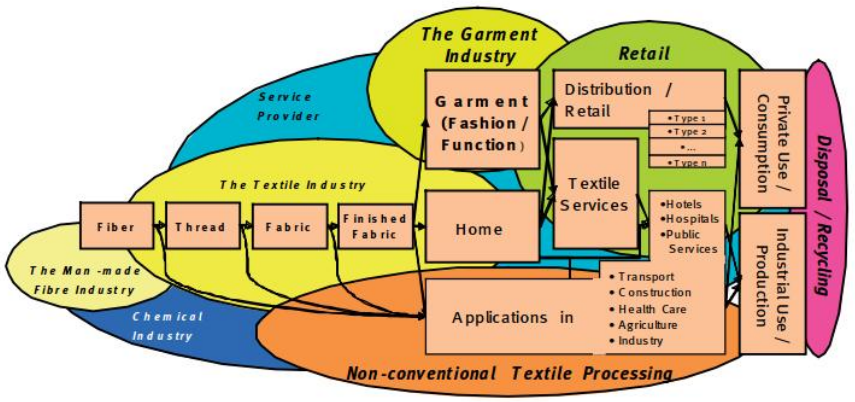

Figure 2. Textile production value chain and included businesses as presented by the Tex-Map project (Euratex, 2006).

In recent decades, especially the production steps have overcome changes and become fast moving. Textile production steps are spread all over the world and leading companies are sourcing world-wide. It is common that fibres produced on one continent are transported thousands and thousands of kilometres around and across the globe before the end-product is purchased by consumer. Natural fibre production is concentrated in specific areas, but many other parts of the production chain have partly been located based on labour costs, since textile and clothing production is a very labour-intensive industry. The textile sector in Europe and other Western countries has overcome a structural change in the past few decades, and the basic production, such as spinning, weaving and sewing, has moved to developing countries with lower wages.

It is easy to see how the economic value is distributed in the global value chain along the entire life cycle of the textiles from raw-material production to the end of life. To elaborate on the distribution of value in the industry, two industry types can be identified; 1) textiles industry comprising the production stages from fibre production to finishing the textiles, and 2) clothing and fashion industry, including the fashion and textiles design, production, distribution and retail. The textiles industry offers basic-level jobs for unskilled labour at the earlier phases of the value chain, whereas the clothing and fashion industry representing the buyer is focused on high-value-added segments where design, research and development are important competitive factors (Gardetti & Torres, 2011).

Globalization has formed two types of international economic networks – those that are producer-driven and buyer-driven – with the apparel industry typically

being one that is buyer-driven (Gereffi, 2003). Some fibre, yarn and fabric producers still act independently, but large international brands are taking care of design and retail by themselves, and may have taken control over all other steps too.

The textile industry is an important provider of basic-level jobs in many developing countries. However, the increase of global trade has not increased opportunities for social or economic catch-up among the least developed nations. Value chains are characterized by power asymmetries, with leading companies in the dominating position and dominated companies mainly in developing countries, which compete worldwide to take over certain tasks in the production process of goods. The competitive pressure to produce at low cost in low-value adding segments increases the pressure for low wages and poor working conditions (Azarhoushang, 2015).

The main social responsibility issues in the global textiles industry are related to labour conditions, such as pay levels that are under the living wage and thus insufficient to meet basic needs, excessive working hours and overtime, lack of sufficient health and safety procedures, as well as forced labour and child labour. The shift to shorter lead times, more styles and more volatile orders has a direct impact on working hours. Forced, excessive and inadequately compensated overtime is an endemic problem in the global apparel industry (Anner, 2015). It is widely known that the textiles production and the related transportation involve different kinds of occupational health issues. It is also a challenge, that many workers in the textile industry are obliged to leave their families and children to relocate for work to such an economic and living environment that is not sufficient for the workers to meet their basic needs and support their families. The lack of organization power and collective bargaining of the workers and the failure of governments to impose sufficient regulations and control mechanisms contribute to the difficulty in responding to these issues.

The environmental impacts of various textile production steps are high as reviewed by Slater (2003). The production of synthetic raw materials, such as polyester (PES), utilizes non-renewable natural resources, while the production of cotton requires a high amount of chemicals and irrigation water. Many of the textile processes are wet processes, not only using fresh water but also producing waste waters rich in salt and chemicals, which leads to high energy need for drying. In addition to high water consumption, excessive cotton production also requires large areas of land that would be arable for food production.

From an ecological perspective, the textile industry is considered as one of the most polluting industries in the world due to use of harmful chemicals, high consumption of water and energy, generation of large quantities of solid and gaseous wastes, huge fuel consumption for transportation and use of non-biodegradable packaging materials (Choudhury, 2014).

Another major environmental challenge of the current linear textile production and consumption model relates to the end of the product life-cycle.

Textile waste is a huge problem around the globe. The majority of textile waste still ends up being incineration or landfilled. More than 15 million tons of used textile waste was generated in the United States in 2013, and of this amount only 15.2 % was recycled (EPA, 2015). In the EU, an estimated 9.35 million tonnes of textiles are currently incinerated or landfilled every year. (Oakdene Hollins, 2016).

Large amounts of used post-consumer clothing are exported from developed countries to developing countries, for example, from Europe to Africa. Imports of second-hand clothing have been growing over the past decades. The import of worn clothing has grown 233% in Uganda and 1100% in Tanzania in the past twenty years (Halling, 2016).

That creates a challenge for local textile production, which is not able to compete with the imported used textiles. That also shifts the textile waste problem from the developed countries to developing countries, adding to their environmental and waste challenges. In March 2016, the governments of the East African Community, which includes Kenya, Tanzania, Uganda, Rwanda, and Burundi, proposed a ban on imports of second-hand clothes to their regional trade bloc. The ban would outlaw donations of clothing from wealthier countries by 2019. While there are many traders earning a living through the sale of these donations, the governments proposing this ban argue that they will be able to create better jobs within the textile industry, more than offsetting any economic loss faced by the traders (Halling, 2016).

The technical textiles sector differs somewhat from the traditional textile and clothing industry. In addition to different processing chains especially for nonwovens manufacturing, also the quality and performance in many cases outweigh the price in many applications. On the other hand, the technical textiles sector also includes various disposable product categories, but their production is less labour-intensive and the production has been profitable in developed countries and thus, the sector has benefited also from shorter logistic chains since also the use of technical textiles is higher in developed countries compared to the developing world.

Regardless of the structural chance of the traditional textile sector, the textile and clothing industry is still one of Europe's major industrial sectors with an annual turnover of 169 billion euro and a workforce of 1.7 million in 2015 (Euratex, 2015). According to Euratex (2015), after a long period of diminishing, the European textile and clothing industry is now showing indications of recovery. A small growth from 2014 to 2015 has been seen in terms of turnover (+2.2 %), employment (+0.4 %), number of companies (175 000, +1.9%), and exports (44.5 billion Euro, +3.6%).

The competitive advantage of the Finnish and European textile industry lies in high scientific knowledge and know-how, fashion and creativity, as well as innovations. Increased environmental awareness is also a major topic among the textile industry in the Western world (Euratex, 2004). There is a need for the develop-

ment of new environmentally friendlier production processes to comply with the tight environmental regulations. Green technologies may include, for example, use of bio-based and recycled raw materials and utilization of enzymes.

New environmentally friendly technologies such as water free textile dyeing and finishing technologies, integrated and intensified processes and replacement of chemical processing by biotechnology are being developed for more sustainable production of textiles (Euratex, 2006). Recycling of textile fibres is further development to increase sustainability and reduce the environmental load of textile production.

Figure 3. Pure Waste Factory for mechanical recycling of textile industry waste materials.

1.2 Circular Economy

According to the most common definitions, the circular economy is an economic model which aims to restore the value of resources, materials, and products as high as possible for the maximum amount of time, and then return the materials back to use in continuous cycles instead of generating waste, where the value is lost.

Circular economy is unfortunately often understood as a non-waste model only, although it encompasses also other important aspects. These aspects make the circular economy model much more sustainable than simply recycling the waste streams of our current linear economy. The wider context of circular economy can be better understood by examining the underlying schools of thoughts the circular economy is based on.

The circular economy concept has deep-rooted origins and cannot be traced back to one single date or author. However, its practical applications to modern economic systems and industrial processes have become more widely known since the late 1970s. Circular economy as a concept we know today is based on, for example, industrial ecology, cradle to cradle philosophy, biomimicry, and natural capitalism (Ellen MacArthur Foundation, 2016).

Industrial ecology is the study of material and energy flows through industrial systems. Focusing on connections between operators within the industrial ecosystem, this approach aims at creating closed-loop processes in which waste serves as an input. Industrial ecology adopts a systemic point of view, designing production processes in accordance with local ecological constraints whilst looking at their global impact from the outset, and attempting to shape them so they perform as close to living systems as possible. With an emphasis on natural capital restoration, industrial ecology also focuses on social wellbeing (Ellen MacArthur Foundation, 2016).

Michael Braungart and Bill McDonough developed the **Cradle to Cradle™ concept** and certification process. This design philosophy considers all material involved in industrial and commercial processes to be nutrients, of which there are two main categories: technical and biological. The Cradle to Cradle framework focuses on design for effectiveness in terms of products with positive impacts and reducing the negative impacts of commerce through efficiency. According to the concept, product components can be designed for continuous recovery and reutilization as biological and technical nutrients. The following three key principles are at the heart of the cradle to cradle concept: 1) eliminate the concept of waste; 2) power with renewable energy; and 3) respect human and natural systems (Ellen MacArthur Foundation, 2016).

Biomimicry relies on three key principles (Ellen MacArthur Foundation, 2016):

1. Nature as a model: Study nature's models and emulate these forms, process, systems, and strategies to solve human problems.
2. Nature as a measure: Use an ecological standard to judge the sustainability of our innovations.
3. Nature as a mentor: View and value nature not based on what we can extract from the natural world, but what we can learn from it.

Natural capitalism refers to the world's stocks of natural assets including soil, air, water, and all living things. The following four principles underpin natural capitalism (Ellen MacArthur Foundation, 2016):

1. Radically increase the productivity of natural resources
2. Shift to biologically inspired production models and materials
3. Providing value as a continuous flow of services rather than the traditional sale-of-goods model
4. Need to restore and regenerate natural resources increases.

According to the European Commission (EC), the transition to a more circular economy is an essential contribution to the EU's efforts to develop a sustainable, low-carbon, resource-efficient and competitive economy (European Commission, 2015). The circular economy will boost the EU's competitiveness by protecting businesses against scarcity of resources and volatile prices, helping to create new business opportunities and innovative, more efficient ways of producing and consuming. It will create local jobs at all skill levels and opportunities for social integration and cohesion. At the same time, it will save energy and help avoid the irreversible damages caused by using up resources at a rate that exceeds the Earth's capacity to renew them in terms of climate and biodiversity, air, soil, and water pollution. Circular economy also lowers current carbon dioxide emissions levels (EC, 2015).

Circular economy, enabled by the technology revolution, allows Europe to grow resource productivity by up to three percent annually. This would translate into a GDP increase of as much as seven percentage points relative to the current development scenario, with additional positive impacts on employment (Ellen MacArthur Foundation, 2015). Economic actors, such as businesses and consumers, are key in driving this process.

1.3 Textiles and Circular Economy

Circular economy cuts through all sectors of economy, and the advantages mentioned earlier apply to the textile and clothing industry as well. Discarded post-consumer textiles and other textile wastes are one of the next biggest problems for the fashion and textiles sector. For example, in Finland approximately 72 million kilograms of textile waste are formed annually, from which only 20% is collected separately. From this amount, good-quality clothes and home textiles go to reuse (12 million kilograms, 16.5% from the total textile waste), while a small portion is recycled mechanically (1.1 million kilograms, 1.5% of the total) and some (1.4 million kilograms, 2% of the total) still goes to energy production (SYKE, 2015).

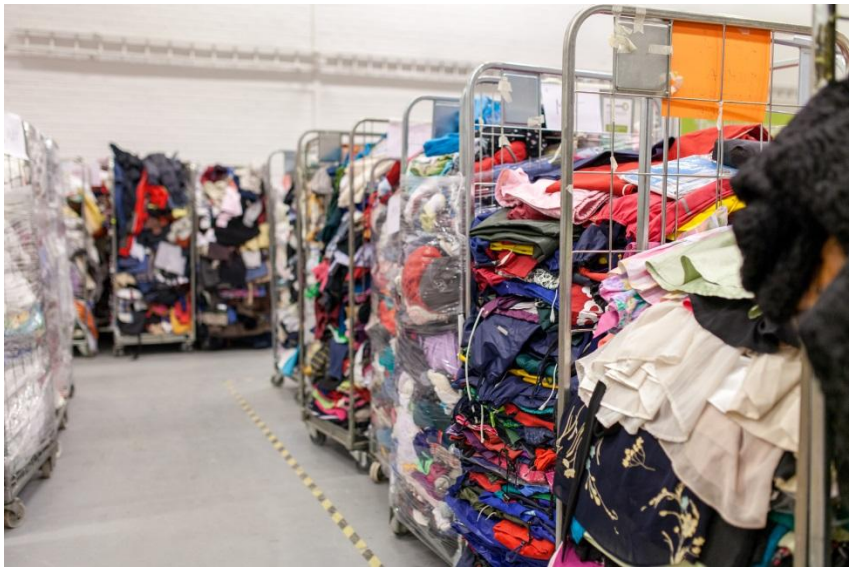

Figure 4. Discarded textiles in The Helsinki Metropolitan Area Reuse Centre.

Strategies to transform the linear textile industry into a circular industry sector can be based on three approaches: circular material flows, i.e. creating value from waste, 2) servitization that emphasizes functionality over ownership, and 3) sufficiency based on effective resource use (Sitra, 2015). The Relooping Fashion Initiative focused on circular material flows by demonstrating closed loop recycling for discarded textiles (see **Figure 5**).

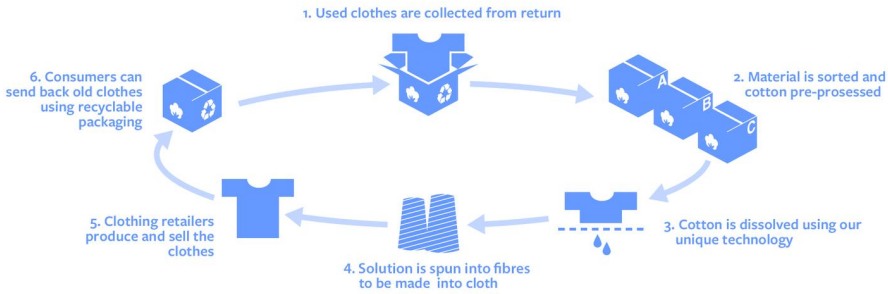

Figure 5. Post-consumer textile recycling pilot demonstrated in The Relooping Fashion Initiative.

Clothes and textiles are one of the largest consumer goods categories in the world, and the transition from a linear to circular economy of textile requires consumer commitment. Therefore, also consumer habits, attitudes, and consumer

communication were examined in our project as methods for committing consumers to circular economy.

Figure 6. Image: Helsinki Metropolitan Area Reuse Centre.

The Relooping Fashion Initiative

The Relooping Fashion Initiative aimed at piloting and creating a model for a closed loop textiles ecosystem based on the principles of circular economy. Targets of the project were to produce business opportunities and shared value for all parties within value chain. Main themes of the project included service, production, design, and business.

The research consortium included actors from all stages of the value chain providing a wide knowledge base on modelling and enabling a practical implementation of post-consumer textile recycling. In the pilot, The Helsinki Metropolitan Area Reuse Centre collected post-consumer textiles from their normal textiles donation feed and sorted out cotton materials not suitable for reuse. The materials were then grinded by SUEZ (currently Remeo), and delivered to VTT for processing into new cellulosic fibres. Seppälä's role was to design and produce a clothing line using the novel fibres in cooperation with Pure Waste Textiles. Reusable packaging by RePack enabled delivery of new clothes and return of used clothing from the consumer back to the cycle, thus closing the loop. Other project partners included Ethica, Touchpoint and Lindström.

www.reloopingfashion.org

2. Modelling of a Circular Business Ecosystem

The following Chapter 2.1 briefly clarifies the concept and origins of the term **business ecosystem**, and adds on that the central role of circular business models. Chapter 2.2 explains the key principles used in ecosystem modelling; the value cycles, and the waste management hierarchy. Chapter 2.3 gives an overview of the scope and goals of the research, and the methodologies used for the work.

2.1 What is a Circular Business Ecosystem?

The transition to a circular economy is a systems-level change and requires a new kind of value creation mind-set. Designing out waste and maintaining the value of products and materials as high as possible for a maximum period requires close collaboration among the whole value network. This means that no company can go to circular economy alone – which is especially true when large volumes of material must be processed. That is why business ecosystems are at the heart of the transition to a circular economy.

What does the commonly used term 'business ecosystem' then mean, if it is of such importance in the transition towards a circular economy? The concept was originally introduced by James F. Moore in the 1990's with the following definition (Moore, 1993): "*An economic community supported by a foundation of interacting organizations and individuals—the organisms of the business world. The economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders. Over time, they coevolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies. Those companies holding leadership roles may change over time, but the function of the ecosystem leader is valued by the community because it enables members to move toward shared visions to align their investments, and to find mutually supportive roles.*"

Every business ecosystem develops in four distinct stages: birth, expansion, leadership, and self-renewal. During the birth stage of a business ecosystem, businesses focus on defining what customers want, that is, the value of a proposed new product or service and the best form for delivering it. According to

Moore, success at the birth stage, at least in the short term, often goes to those who best define and implement this customer value proposition. Moreover, according to Moore, during the birth of a business ecosystem, collaboration is very important. From the leading company's standpoint, business partners help fill out the full package of value for customers (Moore, 1993).

Designing business ecosystems involves a complex and multi-staged process, a good knowledge of components or those elements that could be incorporated, and specific delimitations of relationships between these. In such an approach, it is necessary to elaborate a theory and transpose it into practice (Galateanu, 2013).

Circular business ecosystems are business ecosystems, which together create products, solutions and services based on the principles of a circular economy, and apply circular business models in their way of operating and doing business.

There are several different ways to present and define the circular business models. Business models are ways of operating and doing business in a way that contributes to the transition towards a circular economy. One of the best-known lists of circular business models is presented by Accenture (2014). It defines five key circular business models:

1. **Circular supplies:** Provide renewable energy, bio-based- or fully recyclable input material to replace single life cycle inputs.
2. **Resource recovery:** Recover useful resources/energy out of disposed products or by-products.
3. **Product life extension:** Extend working life cycle of products and components by repairing, upgrading and reselling.
4. **Sharing platforms:** Enable increased utilization rate of products by making possible a shared use/access/ownership.
5. **Product as a service:** Offer product access and retain ownership to internalize benefits of circular resource productivity.

Circular business model innovations are by nature networked: they require collaboration, communication, and coordination within complex networks of interdependent but independent actors/stakeholders. The challenge of re-designing business ecosystems is to find a win-win-win setting that is a balance between the self-interests of involved actors and that thereby influences and facilitates their actions to cooperatively shape the circular business model (Antikainen, 2016).

Ethica Ltd

Ethica Ltd is a Finnish circular economy consulting firm, specialized in circular business development, ecosystem creation, and urban planning. Ethica works with both private businesses and the public sector to find new, sustainable growth opportunities within the circular economy. The clients include cities, technology industry, textile industry and raw materials sector among others. Ethica operates across the globe, and has a wide network of collaboration partners.

Ethica has developed methodologies and tools which help to elaborate and describe the differences between linear and circular business models and ecosystems, and has extensive hands-on expertise in facilitating their creation. In most cases the key material and data flows, business models, and customer experience is developed simultaneously with the supportive circular business ecosystem. Ethica believes that a clearly defined ambitious target and well-articulated customer value proposition are crucial for successful circular business models.

In the Relooping Fashion project, Ethica's role was to lead two work packages, one related to circular business ecosystem modelling, and the other related to Consumer research & communications. Along with this public research, Ethica has also further developed it's methodologies related to circular business ecosystem modelling and creation.

www.ethica.fi/en

2.2 Key Principles of Ecosystem Modelling

Instead of using a complex business ecosystem modelling (theoretical or practical) approach or individual business modelling tools, a more systemic-level approach was taken in the Relooping Fashion Initiative to model the future circular business ecosystem for textiles across the whole value chain. The circular economy pilot offered a very concrete platform to test and understand all the stages needed for creating a closed loop of textiles from consumers back to consumers – from product take-back to offering a new clothing line made of the recycled fibres.

However, while the actual pilot concentrated on creating the closed loop around chemical recycling, the business ecosystem model recognizes also other actors working with re-use and recycling of textiles. This wider systemic perspective is necessary for restoring the value of used textiles in accordance with the key principles of a circular economy.

Figure 7. Four (technical) value cycles of a circular economy, simplified from (Ellen MacArthur Foundation, 2017a).

In the known circular economy system diagram by the Ellen MacArthur Foundation (2017a), recycling is the last value cycle after other measures (inner value cycles) to restore and regenerate value with minimum environmental impact are taken. Therefore, to follow the principles of a circular economy, all four value cycles of the diagram were taken as a back bone for modelling the circular business ecosystem for textiles. A simplified version of the cycles (based on the technical cycles for finite materials) is illustrated in Figure 7.

While the value cycles were used as a basis for visualizing and understanding the whole closed loop business ecosystem, it is evident that a successful implementation of the circular business model in all these stages plays a crucial role in a transition towards the textiles circular economy. Closing any of these loops requires their own circular value chains. The most relevant circular business models in the different parts of the business ecosystem are explained in more detail in Chapter 3.

According to the waste management hierarchy (**Figure 8**), waste prevention is prioritized. This puts the circular product and service design, for example designs for durability, in a very important role, and on the other hand emphasizes the role of consumers in preventing the formation of excess textile waste. In the fast-fashion culture of today, that represents a major shift in consumer behaviour. These topics will be discussed in more detail within the following chapters.

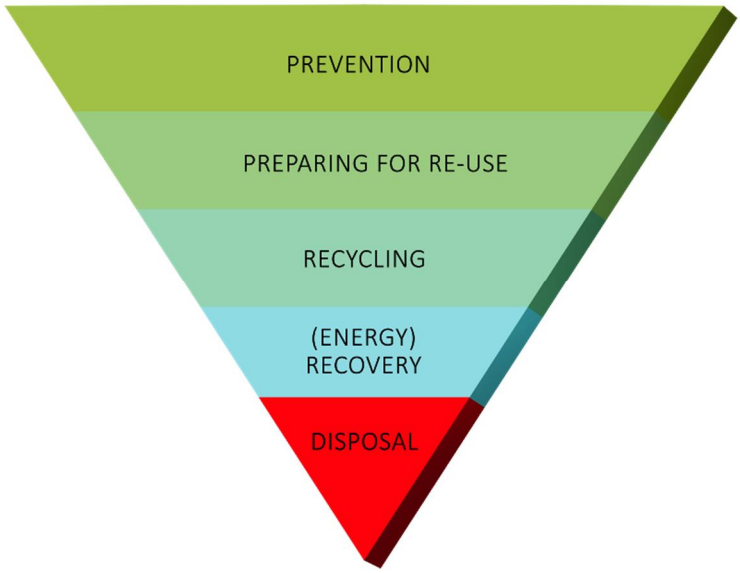

Figure 8. Waste management hierarchy.

The circular business ecosystem for textiles aims to keep most post-consumed textile materials in the re-use cycles or recycle them (depending on their quality) instead of textile waste being incinerated or ending up in the landfill. The key objective should be to use recycled textile materials for purposes that regenerate maximum value.

At the moment in Europe, post-consumer textiles that are no longer suitable for re-use are mainly sent to energy recovery. The key motivation of the Relooping Fashion Initiative and related research activities is to recycle or up-cycle this major textile material flow to new higher-value products instead of using it for energy generation or disposing it in landfills (where landfill bans do not yet exist). Therefore, energy recovery and disposal options are excluded from the ecosystem modelling (**Figure 9**), however recognizing that minor waste flows would likely still be generated from many phases of the value chain. Furthermore, it is also in the interest of waste management organizations to remove textiles from the energy fraction, because they cause problems in the incineration process.

2.3 Goal, Scope, and Methods of the Work

The goal of the business ecosystem modelling was to crystallize the future vision of the circular economy in the textiles industry, and define different actors, material flows and key processes in the wider cross-sectoral value network. Looking at the

business ecosystem from many different perspectives based on the circular economy principles (the value cycles, circular business models and circular design strategies) increases the understanding of all different means needed in the transition towards a circular economy. Crystallizing this common high-level vision, in addition to a clearly articulated customer value proposition, is one of the key success factors in the first (birth) stage of new business ecosystems.

The scope of the business ecosystem modelling work was wider than the actual circular economy pilot, which focused on the chemical recycling cycle. Widening the scope was necessary in order to ensure that the material flows follow circular economy principles and waste management hierarchy. The other cycles already exist, while recycling cycle is not yet functioning to its full capacity. This is, for example, due to technological challenges in processing fibre blends as well as handling of large amounts of reduced-quality materials and fibres. The circular economy pilot of the project gathered experience of the recycling value chain that is given the most attention also in this report. In this research, less emphasis was given to the textiles and clothing industry from fibre production onwards, although some key findings are highlighted for that part of the value chain as well.

The business ecosystem modelling work was based on experiences and the vision of the national business ecosystem in Finland, but also other international initiatives were studied. The achieved results are somewhat applicable globally. The research did not represent a full global view on the circular economy of the textiles industry, and did not aim to cover all on-going initiatives world-wide. However, many case examples and an overview of some of the most important developments are given.

This research work is based on literature studies, project workshops and individual interviews of the project partners as well as selected other local stakeholders working with the textile business and recycling.

Our vision of the circular business ecosystem of textiles is based on the four value cycles familiar from the circular economy system diagram by the Ellen Mac Arthur Foundation (shown in **Figure 7**). The simplified model describes the main material flows from one actor to another along the value chains. As business ecosystems are very complex, our modelling work focused on illustrating a high-level vision of the future ecosystem; the needed actors, their roles and their interdepencies in terms of the main product/material (used textiles) flows.

The model focuses on traditional textile products such as clothes, as well as home and interior textiles, while technical textiles and industrial textile wastes were excluded. Logistics, particularly reverse logistics, is a key enabler, as it has a central role in moving the material flows and recovering the products and materials efficiently back to use. Nevertheless, it was excluded from the visual model. The reverse logistics is, to some extent, discussed in the section related to collecting and sorting of post-consumer textiles.

3. Circular Business Ecosystem of Textiles

This chapter describes, in detail, the vision and model of a future circular business ecosystem for textiles. The model is illustrated in **Figure 9**.

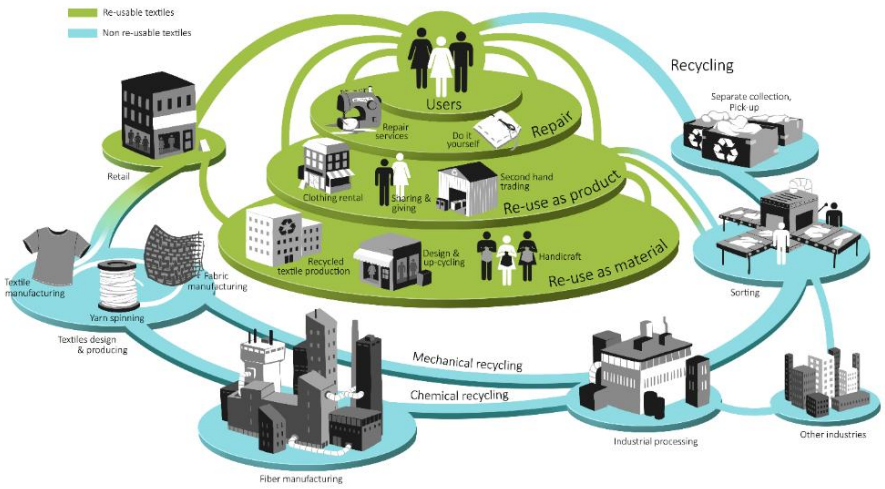

Figure 9. Model of a circular business ecosystem for textiles.

The user has a central role in creating closed loops. In this simplified ecosystem model, users include both consumers, as well as the professional/organizational textile users. For these user groups, the material flows are quite similar, but the ecosystems differ to some extent, especially in terms of ownership and roles of the specific actors.

The four hierarchical loops of the textiles circular business ecosystem all start from users, whether consumers or professional users. Users, with their values, attitudes, and most importantly their behaviours, are the key enablers of all those processes. First, with the right user behaviour and maintenance and repair, clothes and textiles can be used for the maximum length of time. When the user for any reason wants to discard clothes or other textiles products that are suitable

for re-use, the textiles should be redistributed to other possible users and re-used as products. The next preferred option for these clothes and textiles is to use them as textile materials. Only when the quality of the fabric is such that it is no longer suitable for re-use as a product or material, should it be recycled.

From all the value cycles, the textiles should always be returned to users in a format that best restores or regenerates value. Some other industries are already using the recycled textile materials as their raw material, and that will be the case in the future as well. However, it would be important to be able to direct most of the re-used and recycled textiles back to textile applications rather than to a lower-value application.

The next chapters explain the different parts of the circular business ecosystem in more detail and give an overview of the guiding principles and the key functions, actors, and related business models for closing the loops.

3.1 Use, Repair and Re-Use of Textiles

This chapter explains the role of maintenance and repair, re-use as product, and re-use as material-related functions and actors in the circular business ecosystem of textiles. Those actors, companies, and service providers work with textiles and textile materials such as fabrics, which are still suitable for use and re-use (**Figure 10**). This simplified ecosystem model does not include all possible actors, but represents the key ones (excluding logistics). This part of the circular business ecosystem of textiles already exists to a large extent, but its role could be larger in the future.

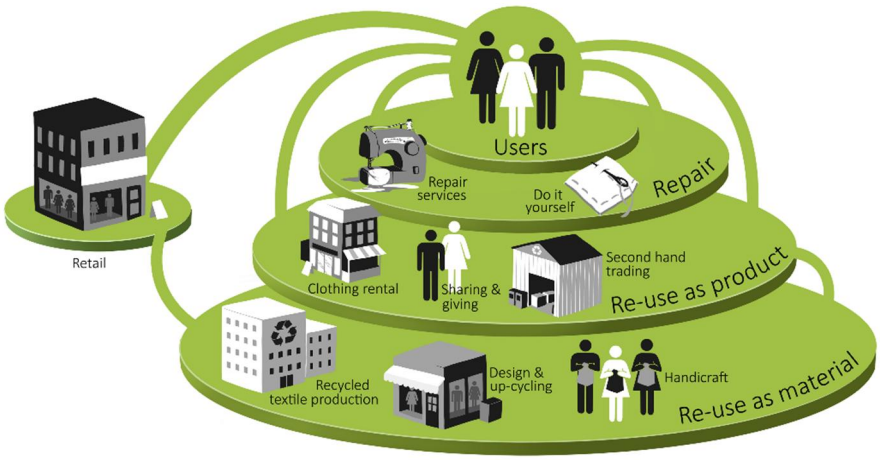

Figure 10. Loops for re-usable textiles.

The circular economy is too often confused with recycling. Also, industrial symbiosis is often related to exploitation and usage of waste or side streams as raw

materials to other processes. Those are both important aspects of a circular economy, but not the whole story. At the heart of the circular economy is the idea of maintaining the value of products and materials as high as possible for the maximum of time with the minimum environmental impact.

Therefore, the first goal is to be able to use textiles in their original format for as long as possible. The key enabler for that is circular product design. Below are the circular design strategies as introduced in the book 'The Products That Last' (Delft University of Technology, 2017):

1. **Design for product attachment and trust**
   Creating products that will be loved, liked, or trusted longer.
2. **Design for product durability**
   Developing products that can take wear and tear without breaking down.
3. **Design for standardization & compatibility**
   Creating products with parts or interfaces that fit other products as well.
4. **Design for ease of maintenance and repair**
   Enabling products to be maintained in tip-top condition.
5. **Design for upgradability & adaptability**
   Allowing for future expansion and modification.
6. **Design for dis- and reassembly**
   Ensuring products and parts can be separated and reassembled easily.

All these strategies are important for the textiles industry to move towards a circular economy. People use their favourite clothes to which they are emotionally attached much longer than other clothes. The owner keeps their favourite clothes until they break down, become aesthetically unappealing or unfit. The good quality and durability of fabric and fibres enable a longer usage and re-use of textiles, either as a product or material. A garment can be transferred from one user to another as such or as an up-cycled product, or if the fabric is still in good enough condition it can be re-purposed. Design for standardization and compatibility could mean, for example, clothing lines designed to match in different combinations for variety. Design for ease of maintenance and repair could include care and repair instructions for the user, spare parts with the original product, or information about available maintenance services. Design for upgradability and adaptability allows versatile use, for example, using the same pieces of clothing for leisure, work and festive occasions, and up-cycling when the quality of the product is high. Design for dis- and reassembly, such as easily removable zippers or buttons, makes the re-use of fabrics as material easier.

Users are at the centre of the circular textile business eco-system and the motor of the circular economy from many perspectives. They need to return goods that are no longer needed to be used for other purposes. More importantly, consumers and other end-users should create an increasing demand for re-used and recycled products, and products that are of high quality and maintain their value

longer. Consumers' and end users' roles in the circular economy of textiles is also discussed in Chapter 3.3, 'Textile collecting and sorting', and in Chapter 4, 'Creating shared value in the circular economy'.

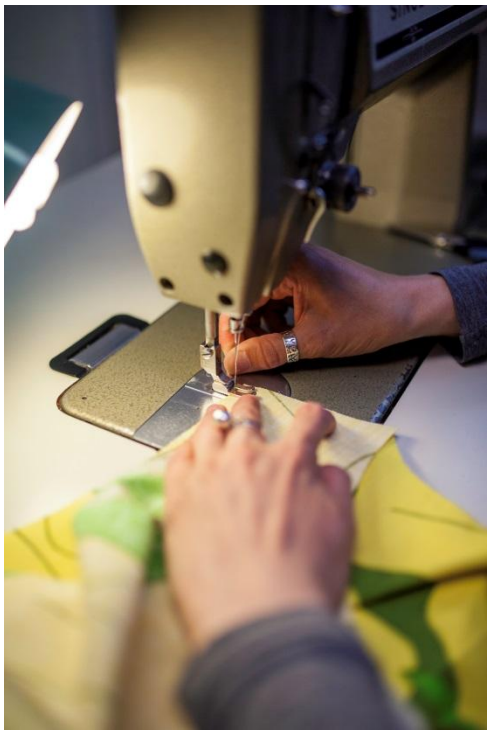

Figure 11. Image: The Helsinki Metropolitan Area Reuse Centre.

The repair and maintenance cycle in this ecosystem model includes also the repair done by the users themselves. That is no longer very common since one consequence of the current fast-fashion culture is that many people no longer see it as being worth the trouble to repair their clothes, rather they just buy new ones. An increasing number of people no longer have the skills or equipment, such as sewing machines, to do even small repair tasks like sewing buttons or repairing opened seams. Helping people to (re)learn these everyday skills could offer new business opportunities to some, in addition to the repair services already currently available. The circular business models, which aim at extending product lifetime, are especially important in this cycle, and the companies that offer these services should benefit from the transition to a circular economy as well. When clothes are designed for attachment and trust, and the fabric is durable and withstands time and wear, people are likely to be more willing to also repair clothes, rather than discard them to be recycled.

Re-use as product is the preferred option for clothes that are still in good condition, but are no longer worn by the user for any reason. There are already many different kinds of actors and service providers in this field. Second-hand trading includes, for example, the regional re-use centres, traditional flea markets, and the different on-line trading and market platforms and groups. There are also a growing number of new commercial second-hand operators with different kinds of business models. Sharing and giving include also various types of charity organizations, who distribute donated clothes to those in need. Some of the challenges in second-hand trading and charity relate to the fact that consumers/users do not always know what happens to the clothing they have donated, and whether it ends up in charity or sales. According to our consumer research (TEKI, 2016; Vehmas, 2017), transparency of the operations was one of the key requirements from the consumers for the re-use and recycling of textiles. New emerging actors of the circular business ecosystem are clothing rental and leasing companies. Clothing rental has so far focused on festive clothes as well as professional and work clothing, but new types of rental and leasing companies can be expected to grow also into everyday clothing and leisure wear. These services-based business models are expected to have significant growth potential in the future.

Figure 12. Material reuse at Touchpoint.

Re-use as material types of activities and actors include most of the currently operating textiles companies and designers that focus on clothing made of re-used materials. Discarded textiles which are, for example, damaged so that they can no longer be easily repaired for re-use in their original shape and form, but still have good-quality fabric, could be used for this purpose. The clothes or fabrics for this

purpose are seldom sourced directly from the end-users, but more often from the companies who operate with larger amounts of such textiles – like the second-hand retailers.

The Helsinki Metropolitan Area Reuse Centre

The Helsinki Metropolitan Area Reuse Centre is a non-profit organization whose mission is to improve the state of the environment by reducing the amount of waste and by increasing environmental awareness. The Centre accepts donations of re-usable clothes, textiles, and other products, which are then either sold at their stores or donated to other collaboration partners or users. As a social enterprise it also offers work for disabled people, long-term unemployed, students of Finnish language, on-the-job trainees and people performing community service.

The Centre has for years been an active player in increasing the consumer awareness for more sustainable use of textiles. Some examples of this work include producing training materials (including virtual courses) for children and youngsters and adults to recognize good-quality fabrics, and learn to maintain the quality with good care. Also, repair and handicraft workshops have been arranged. Good quality is a starting point for successful re-use. The Centre's simple advice for consumers is to: "Buy for a reason – count on quality – wear re-used"

The Helsinki Metropolitan Area Reuse Centre can have an important role in textiles sorting in the future: to ensure sufficient competences and to minimize environmental impacts. Minimizing environmental impacts means using our natural resources effectively, so that the majority of textiles could be re-used as products, before being recycled. For the future textile business ecosystem, it is vitally important that the whole process and value chain is efficient, and that consumers will love the re-used and recycled textiles so much, that they are willing to buy them and take good care of them.

In the Relooping Fashion initiative, the Helsinki Metropolitan Area Reuse Centre's role was to collect, sort and process discarded textile materials for the pilot. According to its mission, the Centre emphasized the importance of sustainability of the solutions and the meaning of waste management hierarchy. The Centre also tested and developed the sorting of textile materials; what kind of competences and processes are required for the sorting to function effectively and fulfil waste management hierarchy requirements.

https://www.kierratyskeskus.fi/in_english

Three slightly different types of activities can be identified: 1) handicraft, 2) design and upcycling, and 3) recycled textile production. Handicraft includes repurposing fabrics for other use, common purposes being, for example, carpets, bags, and interior textiles, but we expect to see a lot of innovation and new ideas here. Handicraft consists of mainly individual entrepreneurs. Design and upcycling includes the current providers of recycled clothing we see today – typically smaller eco-textile companies focused on highly sustainable and innovative designs, where recycled fabric is the key raw material type. Recycled clothes are not sold as such, but they are upcycled to have a new look and feel, or only parts of the

clothes (fabrics) are re-used. This is a sector with a great growth potential as well. In fact, we expect to see new large-scale recycled textile production to emerge, when the supply of raw material becomes more sufficient, steady, and profitable. Labour intensiveness will probably remain as a challenge for the value chains based on re-used textiles, unless the political steering mechanisms start changing the bigger picture, for example, by shifting the taxation from labour towards taxation of raw materials and environmental externalities.

Retailers have an important role to play in the re-use of textiles. In the future, we foresee the retailers and brands taking a much larger role in offering used and recycled clothing lines to the consumers as an alternative to clothes based on virgin materials. Those could be virtually new clothes based on new recycled fibres, or upcycled second-hand lines based on re-use. Being close to the end-users in the value chain, retailers also have an important role and opportunity to increase awareness of the end-users and help them make sustainable choices.

3.2 Special Characteristics of B2B Business

In the business to business (B2B) landscape, the main material flows remain the same, but the roles of the ecosystem's actors can be quite different. This is mainly due to different ownership of the clothes and textiles.

Touchpoint

Touchpoint designs and produces a new kind of bold and ecological work wear and corporate gifts. Their main idea is to re-use materials which are otherwise obsolete, due to our current linear throwaway culture or lack of imagination.

Touchpoint helps their customers by offering creative and visionary solutions; almost anything can be turned into something new and functional, which is smarter and more stylish than old designs. Usage of recycled materials is at the heart of their unique, ecological business model for producing clothing lines and PR-products for businesses and other organizations.

The key strategic objective for Touchpoint is to develop a circular economy based service concepts, which support sustainable development and enable a holistic customer service experience. Usage of re-used and recycled materials coupled with good service design creates a unique value proposition for their customers: a value proposition, which is based on a meaningful story, emotion, and purpose. Touchpoint's goal is to use 100% ecological materials by 2020.

Touchpoint participated in the Relooping Fashion initiative to find new connections, collaboration partners, and circular business opportunities, as well as to exchange information about the new technologies and solutions related to recycled fabrics.

http://www.touchpoint.fi/en/

Lindström Group

Lindström is one of Europe's leading textile service companies with over 165 years of experience in the textile industry. Lindström offers textile rental services, and its rental work wear is used by over a million people every day. Rental textiles provide a completely waste-free solution for the user, as the responsibility for the ecological footprint of their use and responsible disposal is shouldered by Lindström. Lindström's rental textile service was created and is being developed in accordance with the principles of the circular economy – textiles are manufactured only for need; fabric loss is minimized and the products are designed to be easy to repair and durable in terms of use and maintenance. The garments are also recycled from one user to another until they are ultimately unusable. For example, trousers are used first in the service sector, then in the assembly industry and finally in heavy industry, where the wear and tear can be clearly visible.

Another example is the Swedish company, Stormie Poodle, which manufactures children's clothing from recycled textiles provided by Lindström Group's subsidiary, Comforta. It supplies Stormie Poodle with disposed terry cloth and bedding, which Stormie Poodle then uses to make children's clothes, terry cloth products and linen. Bedding and terry cloth products used in hotels at the beginning of their life cycle have been washed countless times, making them soft against a child's skin. The suitable pattern cutting method means that high-quality children's clothing can be manufactured even from disposed textiles.

Textiles that end up as waste are processed into new products, recycled mechanically into raw materials, or burned to generate energy. When a textile is unusable as a garment or sheet, for example, its life span is extended by transforming it into a new product, recycling it mechanically or using it for energy production.

Finding suitable uses for textiles that are in poor condition and unfit for use is another considerable challenge for Lindström. Textile waste is a globally expanding problem, to which Lindström is now actively seeking a solution. Lindström participated in the Relooping Fashion initiative to support the development of new technology innovations which enable recycling of worn-out textile waste, which is no-longer suitable for re-use.

http://www.lindstromgroup.com/

The material flows, value chains and roles remain quite similar if the professional textiles buyers/owners, such as restaurants, hotels, hospitals, etc., buy the work wear for their staff (and other professional textiles) from the B2B textile provider. Of course, the sales channels, marketing, communications, and customer front are different. The professional customer's values and environmental objectives play a big part in decision making and driving the demand for circular designs.

The B2B users will also have a central role in the take-back of used professional clothes, which makes the recovery of used textile materials more efficient. In the circular economy, the professional users must be offered efficient services for handling their used textiles in a professional manner, in accordance with the waste management hierarchy and the principles of the circular economy. This represents

a lucrative opportunity for the providers of such services – which could be the textile producers themselves (exploring the different product-service systems based business models), or individual services providers taking care of the collection and sorting.

The value chains and roles are particularly different in the case of rented professional wear and textiles. The professional work wear rental company, which retains the ownership of the textiles, can manage all the tighter value cycles or loops to ensure as efficient use of the resources as possible. The professional rental wear provider can offer professional care for the clothes, such as laundry service, to extend the product lifetime, repair damaged clothing, and direct used clothes to re-use for other user groups where they are still fit-for-purpose, and finally use the fabrics or hand them over to other users to be used as materials.

The professional textile rental companies will eventually become large providers of textiles no longer suitable for re-use. They are then also big customers for textile collection, sorting, processing, and recycling service providers. The quantities for textiles collection from B2B users are bigger, the quality is more homogeneous, and the product life cycle is more transparent, which makes it an easier source for recovered textiles materials for recycling compared to the consumer market.

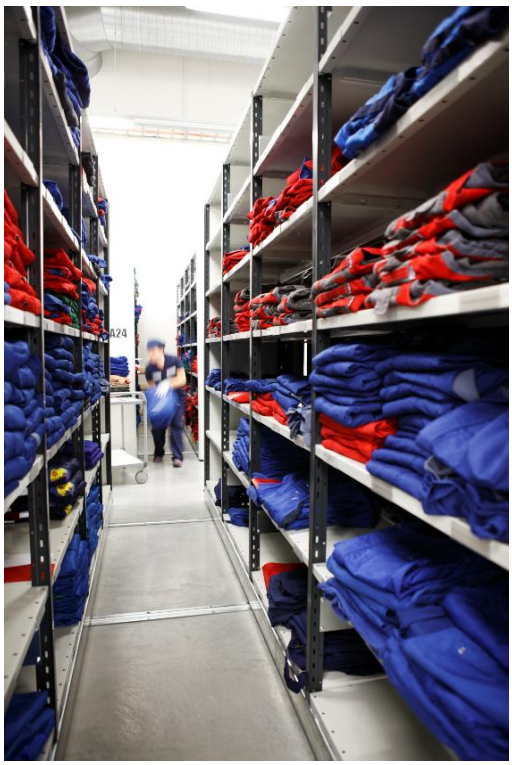

Figure 13 Work clothing in a Lindström warehouse.

3.3 Textile Collecting and Sorting

According to circular economy principles, in the future circular business ecosystem model, users should be able to better determine whether their discarded clothes could still be re-used as products, or should be recycled. Those are the two main textile material flows coming from end-users. Furthermore also the non-reusable textiles should be effectively collected directly from the consumers and other sources. According to circular economy principles, it is important to keep the good-quality, re-usable clothes in the re-use loops. Current infrastructure cannot handle total flows, and therefore this is a big issue to solve concerning the collecting and sorting of discarded textiles (**Figure 14**).

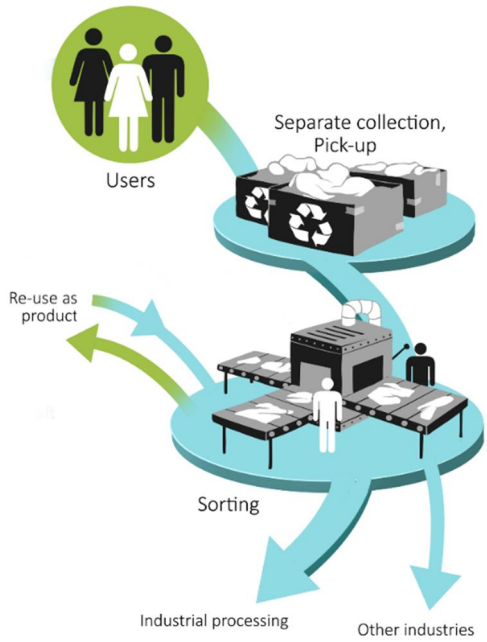

Figure 14. Collection & sorting.

Discarded textile materials are coming from consumers as well as from the professional and organizational users. Collection of post-consumer textiles is challenging since there are no municipal collection systems for textiles, and consumers do not have any obligations or governmental incentives to take care of their discarded materials. Fortunately, many consumers are already willing to deliver their used textiles for reutilization, but the focus of the existing collection routes in Finland has been to collect re-usable clothes and textiles. Currently in Finland,

post-consumer textiles are mainly going to mixed waste (57 Mkg per year, 80% of the mixed waste stream), while only one fifth is collected separately (SYKE, 2015).

Different kinds of charities, recycling centres and nowadays also waste handling companies, in cooperation with companies are collecting re-usable textile materials continuously or periodically. The collection methods as well as challenges related to sorting were examined in more detail in the Textile 2.0 project (Knuutila, 2017). One of the key findings was that currently consumers are not able to adequately distinguish between re-usable and non-reusable textiles. Even if that would work better in the future, thanks to increased consumer awareness and better collection methods, it is important to establish yet another phase of identification and sorting to ensure quality when aiming for industrial utilization of recycled materials.

Textile 2.0

Textile 2.0 was a textile recycling pilot project in the operational area of the regional waste management company, Lounais-Suomen Jätehuolto, in 2016. The pilot was led by Lounais-Suomen Jätehuolto and Turku University of Applied Sciences in collaboration with the City of Turku, SITRA, the Finnish Solid Waste Association and Ekokem.

The goals of this project were to assess ways to collect end-of-life textiles and measure their quantity and quality; to find economic and resource-efficient methods for better utilization of textile waste in line with the waste hierarchy principle; to create uniform modes of operation and instructions; as well as to create an operational platform of growth for new businesses who utilize recycled textiles.

During the project, interview surveys and studies about the amounts and quality of end-of-life textiles in southwest Finland will be performed. Events on textile recycling and networking activities were also important in achieving the goals of project and in creating momentum and value chains among the different focus groups: entrepreneurs, citizens, and public institutions. For instance, Waste Textile Days and Telaketju-workshops are events created via the project to distribute the textile material back to use, to create new products, to network and to inform different focus groups about textile recycling. The most important result of Textile 2.0 was the Telaketju project (www.telaketju.fi).

poistotekstiili.turkuamk.fi/in-english/

Business opportunities for exploitation of discarded textiles as raw materials for new products depend strongly on cost-efficient collecting and sorting processes. On the other hand, from the user perspective, the collection methods should be as easy as possible. Separate collection points nearby or pick-up from home, would be the preferred option for consumers according to our consumer research (TEKI, 2016; Vehmas, 2017). Also, the current textile take-back schemes offered by retailers and brands were seen as good options. Take back schemes may include, for example, drop off points at malls or stores or returning by mail. Recently, many actors have also been collecting textile wastes, meaning that they will also accept clothes and textiles not suitable for re-use, see examples from **Table 1**. While

some of the collected materials are already re-processed into new products in Finland or in the nearby areas, larger-scale industrial-scale utilization of collected material is still lacking. The new Telaketju project tries to solve the current chicken -and-egg problem of utilization of discarded textiles by developing collection and sorting simultaneously with development of new processes and products.

Telaketju - A collection, sorting and utilization network for end-of-life textiles

Telaketju is composed of multiple projects and organizations. The main actions started in 2017 are 1) a project for regional recycling experiments of municipal textile waste management and 2) research and development projects of research organizations and companies.

The first project focuses on the best nationwide solutions for end-of-life textile collection, sorting and processing, and spreading these solutions, thus, increasing the recycling rate of municipal waste. This part is co-funded by the Ministry of Environment. R&D projects are funded by Tekes – the Finnish Funding Agency for Innovation. The projects aim at finding new business opportunities for the Finnish industry in the area of the circular economy of textiles. The companies involved seek business mainly in textile material recycling and/or the service-based circular economy business. A renewed business provides companies with increased readiness for transformation from a linear to a circular economy; companies seek growth and competitiveness as well as target strongly at export markets. Telaketju enables networking of all organizations involved in textiles recycling in Finland, forming a new kind of ecosystem.

www.telaketju.fi

Table 1. Recent activities in collection of reusable and non-reusable materials from consumers in Finland.

Actor(s)	Collection methods	Use of collected materials (if known)
Seppälä	Collection of clothes in stores in Helsinki area Dec 2015–Jan 2016. Plan to continue the collection.	Part of the Relooping project: materials sent to sorting in The Helsinki Metropolitan Area Reuse Centre: re-usable items for re-use, non-usable cotton delivered also for Relooping pilot.
The Helsinki Metropolitan Area Reuse Centre	Continuous collection of used clothes, textiles, of which large amounts are currently not suitable for re-use.	Re-usable items are sold or donated, and non-re-usable are discarded. Non-reusable textiles were also used for the chemical recycling pilot in the Relooping Fashion Initiative.
Finlayson	Collection of home textiles in stores / discount for purchase started as campaigns in 2016. Also, collection via RePack packages.	Bed sheets used for making rag-rugs and jeans for making towels to be sold by Finlayson.
H&M	Collection of used clothes and home textiles, also damaged one's in stores at the moment.	Reuse and recycling by partner organizations.

Textile 2.0	Collection pilot in southwestern Finland with various collection methods.	Reuse and recycling by partner organizations.
Recci[1]	Collection of usable and non-usable clothes and textiles in stores continuously.	Usable sold in Recci stores, non-usable going to sorting by partner companies, e.g. for mechanical recycling.
Kappahl[2]	Collection of used clothes and textiles, also damaged one's in stores at the moment.	Reuse and recycling by partner organizations.

Figure 15. Take back schemes: drop off point at a mall by Lassila&Tikanoja[3] and at Seppälä fashion store, and a mail-based system with reusable packaging by RePack.

[1] http://recci.fi/
[2] http://www.kappahl.com/fi-FI/campaign/wear-love-give-back
[3] http://www.lassila-tikanoja.fi/lassi/ilmiot/Sivut/vaatteet-kiertoon-yhden-pysahdyksen-taktiikalla.aspx

Figure 16. Raw material sources for reutilization in textile applications based on homogeneity and wear of materials.

Discarded textiles can be divided into different categories, for example, based on the wear and tear, i.e. mechanical quality, and on homogeneity of material. Division of different materials based on macroscopic wear and homogeneity and their sources are shown in **Figure 16**. Both factors affect the possibilities for reutilization of clothes or their materials in production of new textile products. Wear and tear can be seen on a macroscopic level as damages to clothes, or on a microscopic level as reduced strength and length in fibre level.

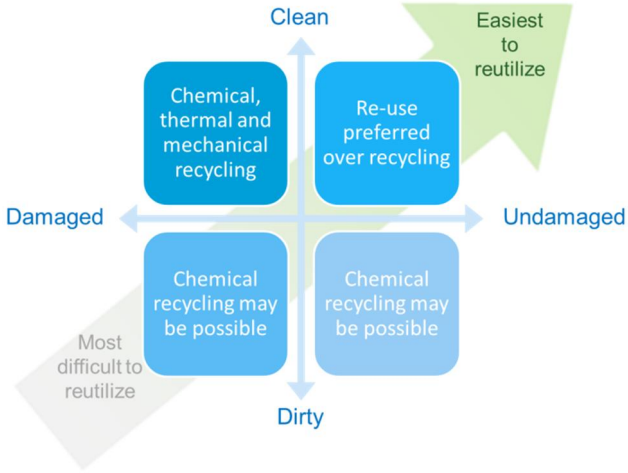

Figure 17. Reutilization methods for discarded textiles based on cleanliness and damage of clothes and textiles.

Another factor affecting reutilization possibilities is cleanliness of textiles. Possibilities for re-use and different recycling methods based on microscopic wear and cleanliness of materials is shown in **Figure 17**. Reutilization schemes for each category based on the divisions in **Figure 16** are discussed in the following.

Good as new, homogeneous. These materials include, for example, unsold clothes from retail or cutting wastes and surplus materials from textile factories. Fibre composition is known and material quality is still good, since the material has not undergone wearing and washing cycles, materials are usually clean and larger batches of homogeneous materials are usually available. This is the easiest type for recycling and is suitable for many kinds of utilization, and re-use as clothes should be the preferred choice based on the waste hierarchy (**Figure 8**) as well as life cycle assessment (LCA) (Norden, 2016). However, if there are reasons to prevent that, for example, brand patterns, logos and/or safety reasons, there textiles are suitable for mechanical, thermal, and chemical recycling as well (see Chapter 0). Industries are usually interested in finding uses for their cutting wastes and surplus materials. Small designer boutiques and small industries can utilize surplus materials and clothes for tuning and remaking, and various kinds of workshops, day-care centres and schools can utilize these materials in handicrafts. This can be helped, for example, by on-line material banks and platforms, as well as area recycling centres enabling easier networking of businesses providing and actors utilizing such materials.

Good as new, inhomogeneous. These materials include similar flows than the group above with the exception that materials are inhomogeneous. Also, the reutilization scheme is similar with the exception of recycling methods. Mechanical recycling is possible and in some cases possibly also chemical recycling for some materials. Thermal processes for production of new textile fibres are not feasible for fibre blends, but it might be possible to use them, for example, for composites.

Worn, homogeneous. These materials includes, for example, rental textiles and work clothes. Material is worn microscopically and possibly also damaged macroscopically due to wear and wash cycles. However, due to the known homogeneous composition, reuse as well as recycling via mechanical, chemical and thermal routes is possible. Due to wear, mechanical recycling to yarns is not possible without addition of virgin fibres, but nonwovens can be used and wear can even be an advantage for cotton chemical recycling, since worn cotton has properties closer to wood pulp compared to virgin cotton. Dirt and contaminants may prevent recycling options.

Worn, inhomogeneous. Most post-consumer textiles as well as some post-industrial and institutional textiles belong to this category. Quality of these materials vary from very good, i.e. suitable for reuse, to very poor, i.e. only suitable for energy use. Reutilization is challenging due to various reasons including unknown fibre type, varying stages of wear, dirt, and possibly exposure to moisture or something else lowering the reusability of the material. Dirt makes recycling more difficult, but chemical routes, for example, may enable use of dirty materials, since the route contains various chemical treatment steps which also may remove certain types of impurities. This material flow is currently mostly incinerated with

mixed wastes. If it is to be utilized and recycled, a well-organized sorting system needs to be developed, and still some of the materials may not be feasible for any other kind of purposes than production of energy.

Figure 18. Sorting of post-consumer materials in the Helsinki Metropolitan Area Reuse Centre.

One outcome of The Relooping Fashion Initiative and the Textile 2.0 projects was a new action, Telaketju, which aims at better utilization of textile waste and other discarded textile by launching simultaneously actions and R&D projects in textile collection and sorting as well as processing and product development.

Sorting facilities of post-consumer textile waste can be found, e.g., in Germany operated by SOEX (SOEX, 2017). Their professional personnel carry out the sorting. If tags are unreadable or missing, identification of fibre materials is difficult or impossible also for professionals. Therefore, if pure textile fractions are wanted, training and long-term experience is needed. Currently in Finland, many organizations in the third sector are active in sorting and the work is done by employment promotion workers and trainees. This approach can be considered as insufficient when targeting reuse of clothes and textiles on an industrial scale. In addition, accuracy of manual sorting may prove limited for mechanical and especially for chemical recycling. Technologies, such as IR-spectrometers, may help identifying

fibre types, but they may not be helpful in identifying textiles that have re-selling value. A post-consumer textile flow may contain also valuable clothing, e.g., brand and retro clothes, and these cannot be recognized by technology. This recognition requires an eye for fashion and thus longer experience.

REMEO

Remeo (formerly SUEZ Suomi) is an environmental services company, offering waste management and consulting services to companies as well as waste collection to households. In addition, Remeo operates various material handling sites around Finland to provide industries with recovered materials used for recycling and energy production.

Remeo's role in the Relooping Fashion Initiative was to provide insight into material collection and handling on an industrial scale for the textile ecosystem. For VTT's technical trial, Remeo organized the processing of the cotton material provided by the Helsinki Metropolitan Area Reuse Centre.

The Relooping Fashion Initiative has a very important role in paving the way for a true circular ecosystem for textiles. By creating a large-scale application for cotton-based textile waste, it creates a pillar for the ecosystem that provides a solution for material that cannot be re-used as clothing. The volume of unusable textile waste is currently so vast, that incineration provides the only viable form of recovery now. Remeo's goal is to provide its customers with the best possible handling of the materials collected. Higher rates of recycling are being requested increasingly, and the best way to achieve this is to decrease the amount of materials heading for energy recovery.

www.remeo.fi

The sorting process needs to be not only accurate, but also economically viable. Our consumer study (TEKI, 2016; Vehmas, 2017) confirmed the earlier assumption that clothes produced from recycled materials cannot really be priced higher than those made of virgin materials. Some consumers even expect them to cost less. As long as the price of virgin materials is low, also the cost of sorted raw material must be low, or the costs of sorting needs to be covered by some means.

3.4 Producing Recycled Fibres

When textiles have been sorted, the non-reusable textile fraction should be processed on an industrial scale. In order to maintain the value of the material as high as possible, producing recycled fibres for new clothing should be the preferred option, naturally considering also the environmental impact of production methods and over-all life cycle.

There is a huge need for chemical processes for handling poor-quality and possibly also impure textiles and larger volumes. Other industries can use the recycled materials as well, and in the future, we expect to see many high-value applications for recycled fibres there too.

Most of the mechanical recycling methods and all chemical and thermal recycling methods require a known type of raw material. Therefore, industrial pre-

processing includes phases like recognition and detailed sorting of material, and in case of clothes, also removal of accessories such as buttons and zippers. There are four main material flows that can be identified from industrial processing to new fabrics, as seen in **Figure 19**: 1) mechanical recycling aiming either at nonwovens, or to yarns and further knitting and weaving; 2) chemical recycling of cotton; 3) chemical and/or thermal recycling of synthetic polymers; and 4) chemical recycling of synthetics at a monomer-level. Terminology is not fully established. Sometimes the term '*fibre recycling'* is used for mechanical recycling, the term '*polymer recycling'* for chemical recycling of cotton and thermal recycling of synthetics, and in that classification the term '*chemical recycling'* refers only to monomer-level recycling of synthetics.

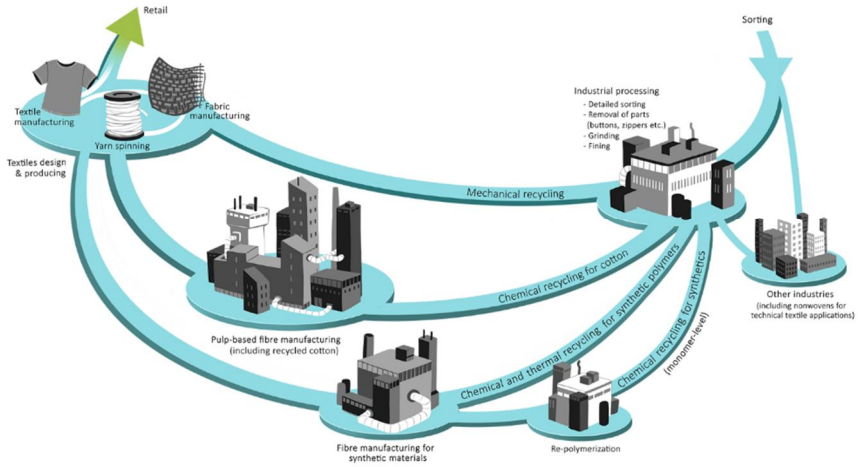

Figure 19. Producing recycled fibres.

In mechanical recycling, material is recycled as fibres. Textile is broken down into separate fibres in the pre-processing step. These fibres are re-produced into new textile structures. Since the strength of the fibres may be reduced due to textile processing and in the case of post-consumer textiles also by wear and washing cycles, typical products for mechanically recycled fibres are nonwovens made, for example, by carding and needle punching. Commercial producers of this kind of product already exist, for example, Finnish Dafecor, who has production plants in Janakkala and Jyväskylä.

Mechanical recycling of yarns for production of clothes and textiles is also possible, especially for unworn pre-consumer materials. Rotor spinning of yarns can be carried out also with weakened and shortened post-consumer based fibres, but they are typically mixed with stronger and longer virgin fibres. The Finnish company, Pure Waste Textiles, operates in India and manufactures yarns and further

knitwear and fabrics for new clothes from clothing factory cutting waste. Mechanical recycling is possible for both synthetic and natural fibres and it is used all around the world even though volumes could be larger.

Chemical recycling for natural and synthetic fibres, and thermal recycling for synthetic fibres involve breaking down of fibres into their building blocks. All textile fibres are composed of polymers, long chain-like molecules comprised of repeating smaller units. In the case of cotton and other natural vegetable fibres, this polymer is cellulose, the same natural polymer found in wood, and is composed of glucose units. Synthetic polymers are produced by combining small, typically petroleum-derived monomer molecules in a polymerization process to form polymer chains. Fibres can be produced from recycled polymers with normal fibre spinning processes, wet-spinning for cellulose and typically melt-spinning for synthetics. In spinning, fibre length and strength can be restored and fibres are, thus, suitable for all kinds of textile processing. If synthetic polymers are too damaged, they can be chemically broken down to monomers, which are repolymerized and, thus, regain polymer properties. Polymer length of cellulose obtained from cotton is longer than that obtained from wood pulp, therefore used and worn cotton materials can, in theory, be recycled countless times.

Common synthetic textile materials are thermoplastics, meaning that those can be melted for formation of new products – this process is called thermal recycling. Thermal polymer recycling for PES is available technology. For example, by DutchaWearness from who can recycle their work clothing eight times before polymers are too damaged (DucthAwearness, 2016). Globally chemical monomer level recycling is available for synthetics such as PES by Teijin and polyamide (PA) by Econyl, but these methods are not commercially used in Finland. In order to produce new textiles from these materials, repolymerization is followed by a thermal fibre spinning process.

Figure 20. Development work of cellulose carbamate fibres at VTT.

Cellulose from recycled cotton can, in principle, be utilized as a raw material of cellulosic man-made fibres, also called regenerated fibres, instead of virgin dissolving pulp obtained from wood. In practise, chemical pre-processing is needed for adjustment of cellulose properties for fibre spinning, and these technologies are in the development stage. Cellulose does not melt, and thus, fibres are produced by dissolving it. Technologies for production of man-made cellulosic fibres include commercially available viscose and lyocell technology, as well as development stage one's including cellulose carbamate (CCA), Biocelsol as well as Ioncell. The main difference between the methods is the strategy for making solution from cellulose for the fibre spinning process. Viscose and carbamate processes rely on derivatization of cellulose and Biocelsol for enzymatic treatment to make cellulose soluble in a water-sodium hydroxide (NaOH)-based system; these water-based technologies can utilize existing viscose wet-spinning facilities. Lyocell and Ioncell processes, on the other hand, make cellulose solution by changing the solvent, and those have their own requirements for spinning and recycling of solvent. A short summary of the technologies is presented in **Table 2**.

Table 2. Production routes for cellulose based man-made fibres.

Process	Approach to cellulose dissolution	Spinning method	Environmental and other notions
Viscose	Derivatization with CS_2 to form cellulose xanthate, which is soluble in aqueous NaOH.	Wet-spinning	CS_2 is an environmentally and occupationally hazardous chemical. Recovery of salts from waters is needed.
Lyocell	Use of NMMO as a solvent, no derivatization needed.	Wet or dry-jet-wet spinning	NMMO is expensive, and solvent needs to be recycled.
CCA	Use of urea to form cellulose carbamate, which is soluble in aqueous NaOH/ZnO_2 solution.	Wet-spinning	Recovery of salts from waters is needed.
Biocelsol	Use of enzymes to make cellulose soluble in aqueous NaOH/ZnO_2 solution.	Wet-spinning	Recovery of salts from waters is needed.
Ioncell	Use of ionic liquid as a solvent, no derivatization needed.	Dry-jet-wet spinning	Ionic liquid is expensive, and a solvent economic recycling system needs to be developed.

Currently, most of these technologies are studied to enable used cotton as a raw material. Even though the principle of spinning is the same, the pre-processing steps required to make cotton suitable for the processes vary and are the actual step needing research and development. VTT has been involved in development of the process for cellulose carbamate (The Relooping Fashion Initiative) and Biocelsol technologies as well as with Finnish Aalto University for

Ioncell technology within the DWoC project. In Sweden, work is carried out for lyocell and viscose processes (e.g. Mistra Future Fashion project), and furthermore Swedish Re:NewCell is turning discarded cellulosic textiles into dissolving pulp suitable for all spinning processes. Commercial actors such as Lenzing and EVRNU have indicated also development of products using recycled cotton-originated raw materials alongside virgin one's. A short summary of the recycling projects and pilots is presented in **Table 3**.

Table 3. Research and pilot projects aiming for use of textile wastes for production of cellulosic fibres.

Project / company	Method	Information
The Relooping Fashion Initiative	Cellulose carbamate	Project aiming for industrial pilot scale (www.reloopingfashion.org).
Trash-2-Cash	Cellulose carbamate, lyocell	Project aiming for separation and recycling of cotton-polyester blends in lab-scale.
SaxCell	Viscose, lyocell processes	Lab pilot (Saxion, 2017).
DWoC	Ioncell	Project work in lab scale.
Re:NewCell	Turns cotton fabric into dissolving pulp	Industrial pilot (Re:newcell, 2015).
Mistra Future Fashion	Lyocell and viscose	Project work.
Textiles back to Textiles	Re:newcell, lyocell	Project aiming for combining re:newcell and lyocell processes for making new textile materials in pilot scale (Wargön Innovation, 2015).
EVRNU	Not specified on webpage	Prototype jeans with Levi's (Levi's, 2016; Evrnu, 2016).
Lenzing	Lyocell process	Launching production in commercial scale exclusively offered to leading retailers and brands (Lenzing, 2016).

VTT

VTT Technical Research Centre of Finland Ltd. is the leading research and technology company in the Nordic countries. Our research and innovation services give its partners a competitive edge all over the world. We pave the way for the future by developing new smart technologies, profitable solutions, and innovation services. We create technology for business – for the benefit of society. Resource sufficiency and circular economy solutions are one of VTT's focus areas. VTT has various activities related to the circular economy of textiles such the national Relooping Fashion Initiative (2015–2017, www.reloopingfashion.org), which is coordinated by VTT, and EC funded Trash-2-Cash (2015–2018, www.trash2cashproject.eu).

VTT has a large role in development of a cellulose carbamate (CCA) technology-based recycling method for cotton. CCA technology enables production of cellulosic man-made fibres with a process similar to viscose, but utilizing chemistry without harmful CS_2 needed for viscose. In cellulose carbamate technology dissolved pulp, which can be obtained from wood, but just as well from used paper, cardboard or cotton textiles, is made soluble to a water-NaOH system using urea. Mechanical properties of fibres are similar to viscose, and thus fibres cam be used for a wide range of textile applications from fashion to home textiles and to technical applications.

In the end of 2016, a VTT spin-off, **The Infinited Fiber Company** (http://infinitedfiber.com/), was founded for scaling up of cotton recycling via cellulose carbamate (CCA) dissolution. The company is located within VTT's Bioruukki piloting centre and is developing a process package for licensing. The first funding round aimed for delivery of customer samples in summer 2017, and the first operational production plant is expected around 2019.

www.vttresearch.fi

3.5 Textiles from Recycled Fibres

The recycling loop continues from fibre manufacturing to the production of textiles (**Figure 21**). This part of the value chain was not studied in detail, since it already exists, and no major technological changes are expected to textiles production due to usage of recycled fibres or re-use of cloths and fabrics. The current yarn spinning technologies and textile manufacturing technologies can handle recycled textiles with some adjustments. However, looking at the roles of the different actors along the value chain, we start seeing some major changes the circular economy is about to bring to the current textile production value chain.

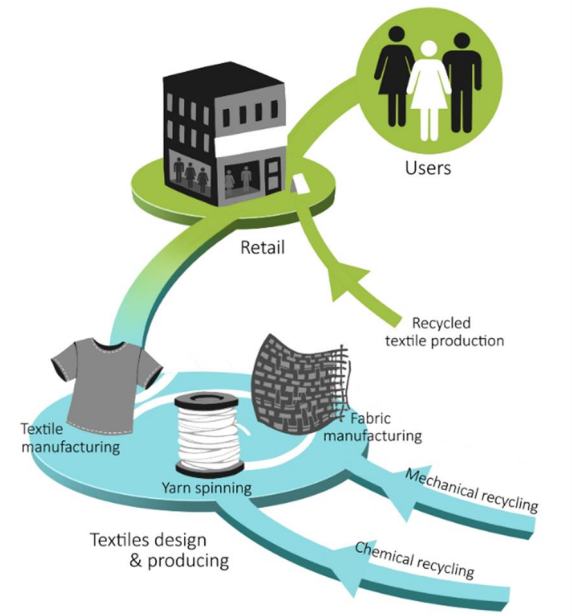

Figure 21. Textiles from recycled fibres.

Mechanical recycling processes currently produce materials mainly for nonwovens, where the quality/wear of the fibre material is not so crucial. In that case, the textile waste materials can be transported in different formats (usually torn or grinded) directly from industrial processing to the fabric manufacturers.

A small, but growing number of recycled clothing producers, such as Pure Waste Textiles, already now use mechanically recycled cotton fibres for yarn spinning and production of recycled fabrics and cloths. Rotor spinning is more suited to short fibres and it is typically applied for recycled processes, but also ring-spinning methods have been recently used for finer recycled yarn grades. That is not very common due to the earlier-mentioned challenges related to fibre quality, mainly length and strength. Pure Waste Textiles tackles this challenge by using pre-consumer textile waste, and some fashion retailers, like H&M, tackle it by mixing post-consumer recycled fibres with virgin materials.

Thermal and chemical textile recycling processes are already available for synthetic materials, such as PES and PA, but they are not widely used yet. Recycled PES fibres used widely in textile products are currently mainly coming from recycled polyethylene terephthalate (PET) bottles. Chemical recycling for post-consumer cotton and mixed fibres are still in the development stage.

Pure Waste Textiles

Pure Waste Textiles is a Finnish clothing company that produces 100% recycled yarns, fabrics and ready-made garments in India. The company uses pre-consumer textile waste as raw material. The textile waste is collected from nearby factories and comes in the form of cutting clips and spinning waste. After sourcing the materials, the material is sorted by colour and quality, and carded carefully apart without weakening the quality of the fibres. The cotton is then spun into yarns, and finally turned into a 100% recycled high-quality textile. When buying a Pure Waste Textiles t-shirt, the customer receives a friendly reminder of the amount of water saved: a total of 2 700 litres.

Pure Waste Textiles has production facilities in the Tirupur area of India. In terms of the environment, the company wants to ensure that the production does not contaminate or deplete the area's already sparse natural resources. For example, the plant has a rainwater collection system and it uses renewable energy, such as wind and solar power. Not only environmental aspects are considered, but social and economic responsibility as well. The company wants to give back to the society and offer good working conditions for their employees. The aim with the new unit in India is to produce mass quantities of fabric, made of recycled materials.

In the Relooping Fashion Initiative, Pure Waste Textiles' role is to test the spinning of fibres into yarn, and manufacturing of the fabrics and clothing for the pilot. The company believes that textile waste recycling has huge potential. The world's population is growing, and not enough cotton and other raw materials can be produced to meet the demand. "We have no choice but to increase the use of recycled materials. Chemical recycling brings new opportunities to use also post-consumer textile waste for producing durable, high-quality recycled fabrics and clothing."

www.purewaste.org

The growing interest among the textile industry, and more specifically the biggest consumer clothing producers and brands towards recycled textiles, is the key driver for developing the new recycling technologies. Brands are interested in recycled textiles and fibres mainly because they anticipate challenges and possible price fluctuations in the virgin materials (such as cotton) supply in the longer term, or they want to offer more sustainable choices to the increasingly conscious consumers. Whatever are their motivations, this places the brands and retailers in a central role in the circular business ecosystem of textiles.

From the textiles business ecosystem and value chain perspective, circular economy will definitely change the roles of the different actors within the value chain. Brands and producers are taking a much bigger role; they are closest to the consumers, and being also closely involved in the R&D initiatives for the new recycling techniques, brands are taking a larger role in fibre producing as well. Although many phases remain in the value chain between fibre production and the consumer, setting up the circular material flows will shorten the value chains, because brands will have to work very closely with all the actors of the entire business ecosystem.

Figure 22. Spinning of mechanically recycled fibres at Pure Waste Textile's Tirupur Factory.

A good example of a new kind of collaboration is Lenzing, one of the forerunners in the circular economy of textiles with their Tencel® fibre made partly of post-industrial cotton waste fabrics with lyocell technology. "Close cooperation with the sustainability leaders in the retail business gives us the chance to find common solutions to overcome sustainability-related challenges in the fashion industry and effectively implement circular economy concepts," says Robert van de Kerkhof, CCO of Lenzing (Lenzing, 2016).

This is a very different business approach compered to how the linear global textiles industry currently operates in a large scale, with extremely long and complicated global supply chains, and lack of transparency over the product life cycles. It is very likely that transition to a circular economy will substantially shorten the value chains, and that can be further amplified by the local authorities' desires to find growth opportunities to local economies from new circular business models. Therefor an extremely interesting question is: how will the transition to a circular economy eventually affect the textiles value chains on a larger scale. The changes to textiles manufacturing will most likely be more economical, societal, and environmental than technical, depending on the drivers and motivations of the producers.

Seppälä

Seppälä is a Finnish fashion chain founded in 1930, with over 100 stores in Finland and Estonia. Seppälä is a family-owned company offering inspiring and affordable fashion for women, men, and children. Responsibility is one of Seppälä's values, and Seppälä collections include many sustainable fashion products.

Seppälä is very committed to developing the circular ecosystem of textiles. As part of the Relooping Fashion initiative, Seppälä collected over 2600 kg of worn-out textiles from customers at Seppälä stores. The customer feedback about the textile collection was very positive, as there is not yet a functioning textile collection system in place in Finland. The take-back campaign offered also an excellent opportunity to raise consumer awareness about the environmental facts related to cotton farming, and the new opportunities a circular economy can bring to the textiles industry. After the campaign carried out for the Relooping Fashion initiative, Seppälä continues to collect old worn-out textiles in their stores.

Seppälä's important role in the Relooping Fashion initiative was also to design the prototypes and a clothing line made of the new fibre, and to test the characteristics and possibilities of the new material together with Pure Waste Textiles Ltd. Seppälä is very interested in bringing ecological clothing lines based on the circular economy to the market, and believes that they should be designed to meet the requirements and expectations of their existing customer segments. To have a maximum positive impact, it is very important that the new textiles and clothes made of recycled fibres will be an affordable option to most consumers.

www.seppala.fi

Brands, as well as retailers, have an important role being at the end-user front of the circular business eco-system. Brands are currently driving the circular economy from this angle as well, for example by introducing textile take back schemes either as campaigns or a permanent service to their customers at the brand stores, and simultaneously using the take-back campaigns as an effective means to engage consumers in textile recycling and increase their awareness about the textiles waste problem. Online stores are encouraging their customers to recycle old clothes with innovative solutions, such as selling their goods in returnable packages, which can be used for returning old textiles for recycling by post. This kind of packaging service is offered, for example, by the Finnish company RePack.

RePack

RePack is a Finland-based start-up, which provides reusable packaging options for online retailers and shoppers. The RePack delivery packages can be conveniently and easily returned, and then reused. Shoppers pay a small deposit for the RePack shipping option, and get reimbursed after the bag or box finds its way back to the company via any post office around the world. Currently 70% of the packages are returned for re-use.

RePack is a sustainable alternative to disposable packaging, as it is made of very long-lasting material, and can be re-used at least 20 times. Repack participated in the Relooping Fashion initiative to offer a sustainable delivery packaging option for online sales, and to increase the overall circular impact of the entire business ecosystem.

www.originalrepack.com/

During the next few years we expect retailers to have much larger role in offering consumers also re-used and recycled textiles and clothing lines. Those can be based on re-used materials (re-designed and up-cycled brand products), or products based on new fabrics from recycled fibres. In both these cases the consumer expectation is that the products are as good as new. Until now, the retailers have not yet seriously stepped into the second-hand textile market, which is currently dominated by regional re-use centres, flea markets and a few new operators.,

Both retailers and brands are expected to also increasingly apply new circular business models, which are based on product use, rather than sales. Marks & Spencer, for example, is seeking to develop pathways to transform its current linear business and operational model to one that is circular. The company has earlier concentrated on consumables, such as plastic packaging, and now it aims to apply that thinking to all areas of their business: food, construction and operations, and clothing (Ellen MacArthur Foundation, 2017b).

Brands are in the key position in the whole circular business ecosystem for textiles, particularly from one determining viewpoint, and that is the customer value proposition creation. Well-defined customer value proposition is central for the profitability of the new circular business models of all business ecosystem actors. In the emerging new business ecosystems, as discussed in Chapter 2.1, businesses together focus on defining the value of a proposed new product or service and the best form for delivering it. According to Moore (1993), those who best define and implement this customer value proposition are most successful at least in the short term. For producing the new recycled clothing lines, brands are now working closely with the entire value chain, and have a unique possibility to create new sustainable value propositions, based on new parameters. But can, or should, sustainable value be more expensive than less sustainable? This question related to the profitability of circular business models, along with the wider objective of shared value creation, was discussed in the Relooping Fashion initiative, and a thesis project on Creating Shared Value in a Circular Economy was conducted for the project. The results of the thesis are summarized in the next chapter.

4. Creating Shared Value in Circular Economy

Creating Shared Value (CSV) is a principle that creates economic value by addressing the needs and challenges of society (Porter & Kramer, 2011). The Relooping Fashion Initiative included a thesis project by Essi Becker, focused on questions concerning the potential of circular business models to optimize the economic, environmental, and social well-being in the means of CSV principles. The findings of the study indicate that the circular economy model possess a huge potential for creating shared value, but requires radical changes in the current thinking models and systems (Becker, 2017).

Three key ways to create shared value can be found from the existing literature; 1) society's needs, 2) redefining value chains, and 3) stakeholder involvement. Society's needs represent a huge potential for a variety of businesses. Those can be seen as opportunities to create new business ideas, to serve new markets and to solve longstanding issues. Porter & Kramer (2011) have also introduced the needs for change throughout the value chain. On the procurement side, with supportive actions and co-operation, such as sharing technology and information, businesses may gain a lucrative supplier network. Besides the supportive supplier networks, operating with local suppliers can create a productive and vital surrounding society for business. New profitable distribution/business models can also dramatically reduce resource use. By collaboration with the stakeholders throughout the value chain, companies can achieve greater logistical and resource efficiency, higher level of knowledge, research and development, as well as waste and transportation cost reductions. In the best scenario, clusters can drive productivity, innovations and competitiveness of local businesses and the economy (Porter & Kramer, 2011).

Looking at our vision of a circular business ecosystem for textiles, all those ways to create shared value are at the heart of the circular model. The main direct opportunities of the circular economy relate to resource efficiency, possibility to replace and reduce the usage of virgin materials, elimination of waste, new opportunities for employment, business, and innovation, as well as promotion of sustainable consumption habits and fostering socio-economic well-being.

The Relooping Fashion project members interviewed for the thesis work stated that value is not divided evenly in the textile value chain. Cotton farmers and manufacturers bare the environmental and social costs, such as lack of water, expo-

sure to toxic chemicals and inhumane working conditions, while the brand owners reap the economic profits. Fortunately, the awareness and markets have been developing in a direction, where an increasing number of consumers require fashion brands to take responsibility for the whole product value chain.

The circular economy model emphasizes the collaboration throughout the value chain, thus having potential to share the value more equally and increase transparency throughout the product life cycle (Becker, 2017).

However, according to the study, achievement of the circular economy model's full shared value creation potential also confronts several challenges. The empirical findings of the study address that traditional value proposition and business models need to radically change. In practice, this means rethinking of traditional supply chains, location, productivity, and distribution strategies (also noted by Porter & Kramer, 2011). The results of the thesis work also indicate that the current market mechanisms, capital models, and infrastructure are slowing down the change. Cost-effectiveness is currently driving the competition, which makes investments and massive changes in processes less tempting (Becker, 2017).

According to the Relooping Fashion consumer research (TEKI, 2016; Vehmas, 2017) the general expectation is that clothes produced from recycled materials should not be higher priced than those made of virgin materials, and some consumers even expect them to cost less. Price of the recycled end product is an extremely important factor, when textiles made of recycled fibres are expected to reach the mass market, not only the environmentally conscious niche consumer segments. This is a central challenge for textiles recycling, as long as the prices of virgin materials are low.

On the other hand, the low prices and often also low quality of the so-called *fast fashion* encourage the continuance of the current unsustainable *buy, wear, throw away* consumption habits, whilst in a circular economy, products should be designed to last. The low prices of fast fashion can only be explained by the power asymmetries of the value chain leading to competitive pressure to produce at the lowest possible cost, despite the negative economic, environmental and social impacts. Products that are designed according to the circular economy principles, such as the Cradle to Cradle principles (discussed in Chapter 1.2), are sustainable by design, because social sustainability, such as working conditions, is also considered.

From the materials perspective, recycled raw materials should not be more expensive than the diminishing virgin materials and resources. It is expected that in the long-term, the prices for virgin materials will rise, and even the playing field and competitive position for recycled and secondary materials. However, in the meantime, because our current economic model fails to include the cost of the externalities (environmental and social issues) in the prices of virgin raw materials, political and economic incentives should be created in favour of more sustainable materials.

When profitable on a larger industrial scale, circular business models will radically change current value chains. Brands will have an even bigger role along the whole value chain starting from textiles take-back and fibre production – this requires shorter supply chains with fewer key players. New distribution models based on re-use and sharing will also shorten the supply chains. Other key drivers for shorter supply chains include the increased requirement for transparency, as well as local authorities' desires to boost local economies with local circular business ecosystems. The *cluster thinking* introduced in the context of creating shared value also highlighted the benefits of local value networks for local societies.

In addition to policies and economic incentives, defining and communicating the value proposition for circular textiles to new customers is crucial. For reaching real impact, new textile products based on recycled materials and fibres should not remain as luxury products affordable only to a few people. Recycled products should be available and affordable to the mass market, but at the same time the emotional engagement for the products should be elevated, so that consumers are willing to take good care of them, and use them longer. The quality of the fabric must be high, so that the products last long and can be re-used before being recycled. All those superb technical qualities, along with the material health, shared value, and overall sustainability of the products, should be at the heart of the newly defined value proposition for circular textiles.

Figure 23. Image: The Helsinki Metropolitan Area Reuse Centre.

5. Summary and Conclusions

This report described a model for a closed loop textiles ecosystem which is based on the principles of a circular economy. This ecosystem lays a foundation for re-use and recycling of textiles, focusing especially on the post-consumer textile waste fraction currently not suitable for recycling.

Transition to a circular economy is a systems-level change and requires a totally new kind of value creation mind-set. Designing out waste and maintaining the value of products and materials as high as possible for a maximum period of time, requires close collaboration among the whole value network. That is why business ecosystems are at the heart of the transition to a circular economy. Circular business ecosystems are business ecosystems, which together create products, solutions and services based on circular economy principles, and apply circular business models in their way of operating and doing business.

Our vision of the circular business ecosystem of textiles is based on the four value cycles familiar from the circular economy system diagram by the Ellen Mac Arthur Foundation. The simplified model describes at a high level the main material flows from one actor to another along value chains. Although business ecosystems are very complex in detail, our modelling work focused on illustrating the high-level vision of the future ecosystem. Crystallizing this common high-level vision, in addition to a clearly articulated customer value proposition, is one of the key success factors in the birth stage of new business ecosystems.

While the value cycles of a circular economy – 1) maintain and repair, 2) re-use as product, 3) remanufacturing and re-use as material, 4) recycle – were used as a basis for visualizing and understanding the whole closed loop business ecosystem, it is evident that the circular business models applied successfully in all these stages play a crucial role in a transition towards the circular economy of textiles. Closing any of these value cycles or loops requires their own circular value chains.

The four hierarchical loops of the circular business ecosystem of textiles all start from users, whether consumers or professional users. Users, with their values, attitudes and most importantly their behaviours are the key enablers of all those processes. The first goal for textiles in a circular economy is to be able to use textile products in their original format for as long as possible. A key enabler for that is circular product design; clothes should be designed to last and maintain good fabric quality. With the right user behaviour, as well as maintenance and repair, clothes and textiles can be used for the maximum length of time. When the

user for any reason wants to stop using the clothes or other textiles products suitable for re-use as a product, they should be redistributed to other possible users . The next-preferred option for clothes and textiles that are still suitable for re-use, but no longer in their original format, is to use them as textile materials. Only when the quality of the fabric is such that it is no longer suitable for re-use, should the clothes and textiles be recycled to be used as raw materials for new products.

One of the biggest issues to solve for a circular business ecosystem for textiles, is the collection and sorting of textiles, especially those no longer suitable for re-use. Those collection methods should be as easy as possible for the users. Home pick-up is the easiest, and one of the most preferred options from the consumer perspective, albeit not financially efficient until there will be effective reverse logistics systems in place.

In the future circular model, users should be able to determine whether discarded clothes that they no longer use could still be re-used as a product, or whether they should be recycled. However, we see that currently the users are not sufficiently able to do that, which indicates a need for better instructions, awareness raising and collection methods. Even if consumers would in the future be better at sorting the textiles for recycling, it is important to establish a professional sorting standard based on quality of the product, and the type of fibre for enabling industrial-scale utilization. In addition to accuracy, sorting needs to be carried out economically. As long as virgin materials prices are low, also the cost of sorted raw material for recycling has to be low, or the costs of sorting need to be covered by some other means.

Industrial processing also requires removal of parts such as buttons and zippers, and refining of the fabrics according to the use specifications. The main material flows that can be identified from industrial processing to new fabrics include mechanical recycling of fibres either to nonwovens, or to yarns and further knitting and weaving, and chemical and thermal recycling methods of fibre raw materials for new fibres.

Mechanical, fibre-level recycling is possible for both synthetic and natural fibres and these processes are used around the world even though these volumes could be larger. In chemical and thermal recycling, fibres are broken down into their building blocks and new fibres are produced so that the length and strength of the fibres can be restored. Thermal recycling is applied commercially in small scale for synthetics, but the chemical process for cotton from cellulose is a widely studied emerging technology. Technologies available for using this cellulose as raw material for man-made cellulosic fibres include commercially available viscose and lyocell processes, as well as development-stage processes of cellulose carbamate (CCA), Biocelsol and Ioncell. There is a huge need for chemical processes for handling larger volumes of poor-quality textiles and possibly also impure materials.

Water–sodium hydroxide solvent-based technologies, viscose, CCA and Biocelsol, can utilize existing viscose wet-spinning facilities, while lyocell and Ioncell processes have their own requirements, and recycling of solvent. Currently, most of these processes are studied to enable used-cotton as a raw material.

The growing interest among the textile industry, and more specifically the biggest consumer clothing producers and brands, towards recycled textiles, is the key driver for developing new recycling technologies. This places the brands and retailers, who are close to consumers, in a central role in the circular business ecosystem of textiles. Being also closely involved in the R&D initiatives for the new recycling techniques, brands are getting a bigger role in fibre production as well. Setting up the circular material flows will shorten the value chains, because brands will have to work very closely with all the actors of the entire business ecosystem. The retailers and brands will in the future also increasingly apply new circular business models, which are based on product use, rather than sales.

Figure 24. Image: The Helsinki Metropolitan Area Reuse Centre.

Furthermore, brands and retailers are in the key position in defining the new circular customer value proposition – which is central for the profitability of the new circular business models of all business ecosystem actors. The price of the recycled end product is an extremely important factor, when textiles made of recycled

fibres are expected to reach the mass market – not only the environmentally conscious niche consumer segments. This is a central challenge for textiles recycling, as long as the prices of virgin materials remain low.

On the other hand, the low prices and often also low quality of so called “fast fashion” encourages the persistence of our current unsustainable *buy, wear, throw away* consumption habits, whilst in a circular economy, products should be designed to last. The low prices of fast fashion can only be explained by the power asymmetries of the value chain leading to competitive pressure to produce at the lowest possible cost, despite the negative economic, environmental, and social impacts. Products that are designed according to circular economy principles, such as the Cradle to Cradle standard, are sustainable by design, because social sustainability, like working conditions, is also considered.

Looking at our vision of circular business ecosystem of textiles, the circular economy has great potential for shared value creation. During the business ecosystem modelling work, that remained as a key guiding principle, although the research was not extensive enough to study the topic in detail. Furthermore, it is yet difficult to predict how the shared value-related objectives will be realized in future circular business ecosystems. Some of the key potentials and key challenges for the shared value creation are introduced in this report, concluding the report with the importance of a new value proposition for circular textiles.

The main direct opportunities of the circular economy relate to resource efficiency, the possibility to replace and reduce the usage of virgin materials, elimination of waste, new opportunities for employment, business and innovation, as well as promotion of sustainable consumption habits and fostering socio-economic well-being.

For reaching real impact, new textile products based on recycled materials and fibres should not stay as luxury products affordable only to few. Recycled products should be available and affordable to the mass market, but at the same time the emotional engagement for the products should be elevated, so that consumers are willing to take good care of them, and use them longer. The quality of the fabric has to be high, so that the products last and can be re-used before being recycled. All those superb technical qualities, along with the material health, shared value, and overall sustainability of the products, should be at the heart of the newly defined value proposition for circular textiles.

The transformation from a linear economy to a circular economy has been started in the textile sector, but as we know there are certain parts still missing. A lot of work still needs to be carried out in Finland in order to enable more efficient utilization of discarded textiles and materials. One outcome of The Relooping Fashion Initiative was the starting of a new action, Telaketju, which aims for better utilization of textile waste and other discarded textiles by launching simultaneous actions in textile collection and sorting, as well as processing and product development.

The ecosystem modelling work has crystallized many important success factors for circular business ecosystem of textiles. Those are, for instance, the importance of a shared systems level vision, inclusion of many different actors along the value

cycles, and the formation of a well-articulated new value proposition for customers. Collaboration is crucial, so that the necessary investments can be made to scale up the actions towards a circular economy. Consumers are ready, brands are interested, and several parts of the puzzle are being solved. It is our planet that can no longer wait. We hope that this report gives further courage to the increasing number of stakeholders to take the necessary next steps and speed up development towards truly circular textile products available for all.

Acknowledgements

We sincerely thank all the Relooping Fashion project partners and other stakeholders for their great insight and contribution to the ecosystem modelling work. Special acknowledgements go to the following people, who have participated in the ecosystem workshops and who we have interviewed to gain a better understanding of the needs of different actors in the future circular business ecosystem for textiles in Finland:

Erica Adlercreutz, Seppälä

Essi Becker, Thesis worker

Pia Engström, The Helsinki Metropolitan Area Reuse Centre

Ali Harlin, VTT Technical Research Centre of Finland

Christian Hindersson, Suez Finland (currently Remeo)

Sami Hirvonen, Metsäsairila

Tarja Hämäläinen and Seija Forss, Lindström

Henna Knuutila, Turku University of Applied Sciences

Juha-Matti Kykkänen, Recci

Harri Lankinen, Mikkelin Toimintakeskus (Mikkeli Reuse Center)

Jaakko Leskinen, City of Forssa

Marjo Määttänen, VTT Technical Research Centre of Finland

Carita Peltonen, Touchpoint

Jukka Pesola and Anders Bengs, Pure Waste Textiles

Petri Piirainen, RePack

Marja Pitkänen, VTT Technical Research Centre of Finland

Anne Raudaskoski, Ethica

Hanna Tukiainen, Helsinki Region Environmental Services Authority

References

Accenture (2014) Circular Advantage, Innovative Business Models and Technologies to Create Value without Limits to Growth. p. 12-14.

Anner M. (2015) Worker resistance in global supply chains; Wildcat strikes, international accords and transnational campaigns, International Journal of Labour Research, Decent work in global supply chains, 7(1-2) p. 17-34.

Antikainen M., Valkokari K. (2016) A Framework for Sustainable Circular Business Model Innovation, p. 7.

Azarhoushang B., Bramucci A., Herr H., Ruoff B. (2015) Value chains, underdevelopment and union strategy, International Journal of Labour Research, Decent work in global supply chains, 7(1-2), p. 7.

Becker E. (2017) Shared Value Creation in Circular Business Model: Case Relooping Fashion Initiative p. 62-103.

Choudhury A.K.R. (2014) Environmental Impacts of the Textile Industry and Its Assessment Through Life Cycle Assessment, Chapter 1 in Roadmap to Sustainable Textiles and Clothing (ed. by Muthu S.S.), p. 1-40.

Delft University of Technology (2017) Products that last http://productsthatlast.nl/site/app/index2.html#/page/0/6, accessed 23.2.2017.

Ellen MacArthur Foundation (2015) Sun, McKinsey Center for Business and Environment Growth Within: A circular economy vision for a competitive Europe p. 12 https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_Growth-Within_July15.pdf.

Ellen MacArthur Foundation (2016) https://www.ellenmacarthurfoundation.org/circular-economy/schools-of-thought/cradle2cradle, Accessed 3.10.2016.

Ellen MacArthur Foundation (2017a) System diagram, Accessed 2.3.2017 https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram.

Ellen MacArthur Foundation (2017b) https://www.ellenmacarthurfoundation.org/ce100/directory/marks-and-spencer-m-s. Accessed 1.3.2017.

EPA (2015) Advancing Sustainable Materials Management: Assessing Trends in Material Generation, Recycling and Disposal in the United States Fact Sheet https://www.epa.gov/sites/production/files/2015-09/documents/2013_advncng_smm_fs.pdf, Accessed 25.3.2017.

Euratex (2006) Strategic research agenda of the European Technology Platform, for the future of textiles and clothing, June 2006.

Euratex (2015) Key Figures 2015 - The EU-28 Textile and Clothing Industry in the year 2015, http://euratex.eu/fileadmin/user_upload/documents/key_data/Euratex_Keyfigures_-_2015.pdf.

European Commission (2015) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Closing the loop - An EU action plan for the Circular Economy p.2 http://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_1&format=PDF

Evrnu (2016) The Evrnu Technology, http://www.evrnu.com/technology/, accessed 10.10.2016.

Galateanu E., Avasilcai S. (2013) Annals of the Oradea University: Business Ecosystems Architecture, p.81.

Gereffi G., Memedovic O. (2003) The Global Apparel Value Chain: What Prospects for Upgrading by Developing Countries p. 3.

Halling K. (2016) Not So Fast (Fashion)! African Countries to Ban Secondhand Clothing Imports, http://www.sustainablebrands.com/news_and_views/waste_not/kelsey_halling/not_so_fast_fashion_african_countries_ban_secondhand_clothin Accessed 25.3.2017.

Knuutila H. (2017) Private communication.

Lenzing (2016) TENCEL® - enabling 'circular economy' in the textile world & next-generation ecological fiber, http://www.lenzing-fibers.com/presseinformationen/presseinformationen-detail/tencelR-enabling-circular-economy-in-the-textile-world-next-generation-ecological-fiber/, accessed 10.10.2016.

Moore J.F. (1993) Predators and Prey: A New Ecology of Competition, Harvard Business Review article p. 76.

Oakdene Hollins (2016) Chemical recycling – A solution for Europe's waste textile mountain? p. 1 http://www.oakdenehollins.com/media/433_Summary/MMU-01_433_Summary.pdf Accessed 25.3.2017.

Porter M.E., Kramer M.R. (2011) Creating Shared Value. Harvard Business Review, 89.1, 2 Jan-Feb, p. 62-77.

Re:newcell (2015) Company web pages, http://renewcell.se, Accessed 10.10.2016.

Saxion (2017) SaXcell a revolutionary fibre, https://saxion.nl/site/index/saxcell/revolutionaryvirginfiber/, Accessed 24.7.2017.

Sitra (2015) Service-Based Business Models & Circular Strategies for Textiles, https://www.slideshare.net/SitraEkologia/servicebased-business-models-circular-strategies-for-textiles, Accessed 21.7.2016.

Slater K. (2003) Environmental impact of textiles: Production, processes and protection, Woodhead Publishing, 240 p.

SOEX (2017) Company web-pages http://www.soexgroup.de/group.html, Accessed 26.9.2017.

TEKI (2016) Project workshops and research work related to consumer habits.

Vehmas K., Raudaskoski A., Heikkilä P., Harlin A., Mensonen A. (2017) Communication and branding in circular fashion, submitted to Journal of Fashion Marketing and Management.

Wargön Innovation (2015) Textiles back to Textiles, http://wargoninnovation.se/projekt/textiles-back-to-textiles, Accessed 10.10.2016.

Series title and number

VTT Technology 313

Title	**Model of circular business ecosystem for textiles**
Author(s)	Paula Fontell & Pirjo Heikkilä
Abstract	The goal of the Model of a Circular Business Ecosystem for Textiles is to present a vision for the future circular textile industry and its actors, material flows, and key processes. Although the model is based on a national project, it can be applied in any country or region. The report also includes an overview of the international key developments, projects, and solutions in the context of textiles and a circular economy. The textile business is a complex system from design and production to global distribution of textiles. The life cycle of textiles starts on farms or from the production of other raw materials. The fibres are formed into yarns that can be further knitted or woven into fabrics. Fabrics are sewed into final products, sold to consumers, and discarded as waste after consumption. Chemicals, water and energy are used and emissions released to the environment at every step during the entire life cycle of the product. One of the largest global problems with the current business model is the high amount of textile waste that still ends up in landfills or is incinerated. Circular business ecosystems are business ecosystems, which together create products, solutions and services based on the principles of a circular economy, and apply circular business models in their way of operating and doing business. Materials flow through the hierarchical value cycles of maintenance, reuse, remanufacturing, and recycling, and nothing is wasted. Transformation of the traditional linear economy into a circular economy is a systems-level change and requires a totally new value creation mind-set. Close collaboration among the whole value network is needed in order to design out waste and maintain the value of products and materials as high as possible for a maximum period of time. This report presents a model of the circular textile industry. The modelling was based on waste management hierarchy and the technical cycles described in the Circular Economy System Diagram by the Ellen Mac Arthur Foundation. The model encompasses and discusses the following sections of the business ecosystem: use, repair and reuse of textiles, textile collecting and sorting, production of recycled fibres, and production of textiles from recycled fibres. Fundamental success factors for circular business ecosystems are discussed. Those are, for instance, the importance of a shared systems-level vision, inclusion of many different actors along the value cycles, and the formation of a well-articulated new value proposition for customers. The report also presents a study on creation of shared value in a circular economy.
ISBN, ISSN, URN	ISBN 978-951-38-8587-8 (Soft back ed.) ISBN 978-951-38-8586-1 (URL: http://www.vttresearch.com/impact/publications) ISSN-L 2242-1211 ISSN 2242-1211 (Print) ISSN 2242-122X (Online) http://urn.fi/URN:ISBN:978-951-38-8586-1
Date	November 2017
Language	English, Finnish abstract
Pages	58 p.
Name of the project	The Relooping Fashion Initiative
Commissioned by	
Keywords	Circular economy, textiles, closed loops, business ecosystem, business model
Publisher	VTT Technical Research Centre of Finland Ltd P.O. Box 1000, FI-02044 VTT, Finland, Tel. 020 722 111

Julkaisun sarja ja numero

VTT Technology 313

Nimeke	**Ekosysteemimalli suljetulle tekstiilikierrolle**
Tekijä(t)	Paula Fontell & Pirjo Heikkilä
Tiivistelmä	Suljetun tekstiilikierron ekosysteemimallin tavoitteena on esittää visio tulevaisuuden tekstiilien kiertotaloudesta ja sen toimijoista, materiaalivirroista ja avainprosesseista. Vaikka malli perustuu suomalaiseen projektiin, sitä voidaan soveltaa kansainvälisesti. Raportti sisältää myös yleiskatsauksen tekstiilien kiertotalouden kehitykseen ja erilaisiin ratkaisuihin maailmalla. Tekstiililiiketoiminta on monimutkainen järjestelmä, joka kattaa vaiheet suunnittelusta ja tuotannosta vaatteiden ja tekstiilien maailmanlaajuiseen jakeluun. Tekstiilien elinkaari alkaa pelloilta tai muiden raaka-aineiden valmistuksesta. Kuiduista tehdään lankaa, joka voidaan edelleen neuloa tai kutoa kankaaksi. Kankaat ommellaan lopputuotteiksi, myydään kuluttajille ja hävitetään käytön jälkeen jätteenä. Tuotteen elinkaaren jokaisessa vaiheessa käytetään kemikaaleja, vettä ja energiaa ja tuotetaan päästöjä ympäristöön. Yksi tämänhetkisen liiketoimintamallin suurimmista globaaleista ongelmista on suuri määrä tekstiilijätettä, joka poltetaan tai sijoitetaan kaatopaikalle. Kiertotalouden liiketoimintaekosysteemit ovat arvoverkostoja, jotka yhdessä luovat kiertotalouden periaatteiden mukaisia tuotteita, ratkaisuja ja palveluja ja jotka soveltavat kiertotalouden liiketoimintamalleja toiminnassaan. Materiaalit kulkevat hierarkkisissa suljetuissa kierroissa (ylläpito, uudelleenkäyttö, uudelleenvalmistus, kierrätys), eikä mitään hukata. Perinteisen lineaarisen talouden muutos kiertotaloudeksi edellyttää toimintamallien, rakenteiden ja niiden vuorovaikutusten yhtäaikaista muutosta ja vaatii aivan uudenlaista arvonmuodostusmallia. Koko arvoverkoston tiivis yhteistyö on välttämätöntä, jotta tuotteiden ja materiaalien arvo voidaan pitää mahdollisimman hyvänä mahdollisimman kauan. Tässä raportissa esitetään ekosysteemimalli suljetulle tekstiilikierrolle. Mallinnus perustuu jätehuollon etusijajärjestykseen ja Ellen Mac Arthur Foundationin systeemidiagrammin teknisiin kiertoihin. Mallissa käsitellään seuraavia liiketoimintaekosysteemin osia: tekstiilien käyttö, korjaus ja uudelleenkäyttö; tekstiilien keräys ja lajittelu; kierrätyskuitujen tuotanto ja tekstiilien valmistus kierrätyskuiduista. Raportti tuo esille joitakin tärkeitä kiertotalouden liiketoimintaekosysteemien menestystekijöitä. Niitä ovat esimerkiksi yhteisen systeemitason vision merkitys, eri arvokiertojen toimijoiden huomioiminen kokonaisuudessa sekä hyvin artikuloidun uuden arvolupauksen muotoilu asiakkaille. Raportti sisältää myös selvityksen jaetun arvon luomisesta kiertotaloudessa.
ISBN, ISSN, URN	ISBN 978-951-38-8587-8 (nid.) ISBN 978-951-38-8586-1 (URL: http://www.vtt.fi/julkaisut) ISSN-L 2242-1211 ISSN 2242-1211 (Painettu) ISSN 2242-122X (Verkkojulkaisu) http://urn.fi/URN:ISBN:978-951-38-8586-1
Julkaisuaika	November 2017
Kieli	Englanti, suomenkielinen tiivistelmä
Sivumäärä	58 s.
Projektin nimi	Tekstiilien kiertotalous
Rahoittajat	
Avainsanat	Tekstiilien kiertotalous, suljetut kierrot, liiketoimintaekosysteemi, liiketoimintamalli
Julkaisija	Teknologian tutkimuskeskus VTT Oy PL 1000, 02044 VTT, puh. 020 722 111

Model of circular business ecosystem for textiles

This report is based on the work carried out in The Relooping Fashion Initiative (www.reloopingfashion.org). Partners of the initiative are VTT Technical Research Centre of Finland Ltd, Ethica Ltd, Remeo Ltd, The Helsinki Metropolitan Area Reuse Centre Ltd, Seppälä Ltd, Pure Waste Textiles Ltd, RePack Ltd., TouchPoint Ltd and Lindström Ltd. The Relooping Fashion Initiative was funded by participating organizations and Tekes – the Finnish Funding Agency for Innovation as group of public and company projects during 2015–2017.

ISBN 978-951-38-8587-8 (Soft back ed.)
ISBN 978-951-38-8586-1 (URL: http://www.vttresearch.com/impact/publications)
ISSN-L 2242-1211
ISSN 2242-1211 (Print)
ISSN 2242-122X (Online)
http://urn.fi/URN:ISBN:978-951-38-8586-1