Applying circular economy to the fashion industry in Scandinavia through textile-to-textile recycling

Ida Marie Sandvik | APG5849/APG5850
MASTER OF INTERNATIONAL DEVELOPMENT PRACTICE
School of Social Science, Monash University, 23 October 2017.

SUMMARY VERSION

MONASH University

Contents

List of figures

List of tables

Acknowledgements

I would like to express my gratitude to my supervisor Wendy Stubbs, who has provided me with advice, feedback and critique. I would also like to thank Susan van de Meene for her help on practical matters related to this research.

I am very grateful for the scholarship from Monash Abroad International Study Program, which has financially supported the travel expenses related to this research.

A special thanks to Charlotte van den Brekel for designing the front page of this thesis.

Lastly, I want to thank all participants in this research for taking their time to provide insights and contributions.

CHAPTER 1: Introduction

The fashion industry is a significant contributor to environmental degradation and climate change (Allwood *et al.*, 2006; Fletcher, 2010; Greenpeace, 2011). This, in combination with a growing population, has put pressure on natural resources, which are expected to become more scarce (EEA, 2015; MEA, 2005; Sachs, 2015). Resource scarcity will inevitably affect the fashion industry, as the production of clothes requires materials such as cotton (Müller-Christ & Gandenberger, 2006). The fashion industry is also facing a growing issue of accumulation of textile waste, as fast production and consumption of clothing has led to a perception from consumers that clothes are disposable (Allwood *et al.*, 2006; Andersen, 2017). One way of addressing these issues is the 'circular economy'.

The circular economy dates back to 1976, when Walter Stahel suggested an idea of 'economy in loops' in a report to the European Commission (European Commission, 1976). Theoretical contributions have also come from industrial ecology (Frosch & Gallopoulos, 1989), biomimicry (Benyus, 1997), cradle to cradle (McDonough & Braungart, 2002) and performance economy (Stahel, 2010). Ellen MacArthur Foundation, who popularised the term circular economy, defines it as 'restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all time' (Ellen MacArthur Foundation, n.d.).

There is an increasing focus from governments and the fashion industry to apply circularity to the textile industry in Europe and Scandinavia. The European Commission has introduced a Circular Economy Package with the aim of a transition to better usage of resources for European businesses (European Commission, 2017). Furthermore, the Nordic Council for Ministers has proposed *A Nordic textile strategy,* with the aim of improving the reuse and recycling of textiles (Palm *et al.*, 2015). Several Scandinavian companies and organisations are investing and participating in programs focused on textile recycling such as the Ellen MacArthur Foundation *Circular Fibres Initiative* and Mistra Future Fashion. These initiatives

indicate a growing awareness amongst governments and the fashion industry in Scandinavian of the potential and need for textile recycling, which makes it an appropriate research site for this study.

Different methods can be used for companies to apply circular economy, such as reuse, resell, remanufacture and recycle (Kumar & Malegeant, 2006). Research shows that reuse has greater environmental benefit than recycling (Watson *et al.*, 2015). Yet, reuse on its own is not sufficient to reduce textile waste and does not address the issue of resource scarcity for large fashion companies. Textile-to-textile recycling is a way to address both issues of resource scarcity and textile waste in landfill.

Despite the increasing need for textile recycling and increasing interest from the fashion industry to adopt a circular economy, there is little academic research on how the fashion industry can implement textile-to-textile recycling. A review of contemporary literature demonstrated that there is currently a technological and systemic barrier in the creation of a stream of materials based on textile-to-textile recycling (Berndtsson *et al.*, 2017; Elander & Ljungkvist, 2016; GFA & BCG, 2017; Mistra Future Fashion, n.d.-a; Palme, 2017; Weetman, 2016). Therefore, this research aims to contribute to academic literature by exploring how technology and systemic change in the industry can support opportunities for textile-to-textile recycling, thereby aligning with circular economy principles. The questions guiding this research is:

How can the Scandinavian fashion industry create a system of textile-to-textile recycling?

To address the main research question, the study investigates four sub-questions (SQ)

- SQ1: What are the current practices for applying a circular approach to the fashion industry globally and in Scandinavia?

- SQ2: What are the drivers, inhibitors and enablers of creating a system of textile-to-textile recycling?
- SQ3: How can technology and innovation help catalyse change in relation to sorting and recycling of textiles?
- SQ4: What systemic changes are needed to enable textile-to-textile recycling?

A conceptual framework is developed based on current literature to guide the analysis. This study utilises an exploratory approach through a qualitative research design. Interviews are used to identify drivers, inhibitors, enablers, potential technology, and systemic change needed to create a system of textile-to-textile recycling.

1.1 Structure of condensed thesis

This thesis is structured into five chapters. Chapter 2 presents the main findings from current literature concerned with the global fashion industry and current practices of applying circular economy. Additionally, the chapter identifies drivers, inhibitors and enablers to apply a circular approach. Chapter 3 presents a summary of the methods used to address the research questions. Chapter 4 provides a summary of the main findings from the primary research, utilising the conceptual framework developed from the literature review. Chapter 5 summarises the research findings, and provides suggestions for future research.

CHAPTER 2: Main findings from literature review

2.1 High level of consumption resulting in generation of waste

The advancement of production in combination with increasing consumerism has created a mass market for cheap apparel where products are perceived and treated as disposable (Ghemawat *et al.*, 2003). Companies compete on speed of fashion cycles and production of cheap consumer goods, embodying the notion of 'fast fashion' (Barnes & Lea-Greenwood, 2006). Fast fashion is connected to low quality products that are mass-produced and standardised, for easy consumption (Fletcher, 2013; Joy *et al.*, 2012). The terms high street fashion brands and mainstream fashion brands is used interchangeably in this research to describe companies in the mid-market, including value and discount segments that produce cheap short-life apparel to the mass market based on fast industry systems (Earley & Goldsworthy, 2015; Ghemawat *et al.*, 2003; Joy *et al.*, 2012; McKinsey&Co., 2016). Figure 2.1 shows segments within the fashion industry and positioning of high-street fashion brands.

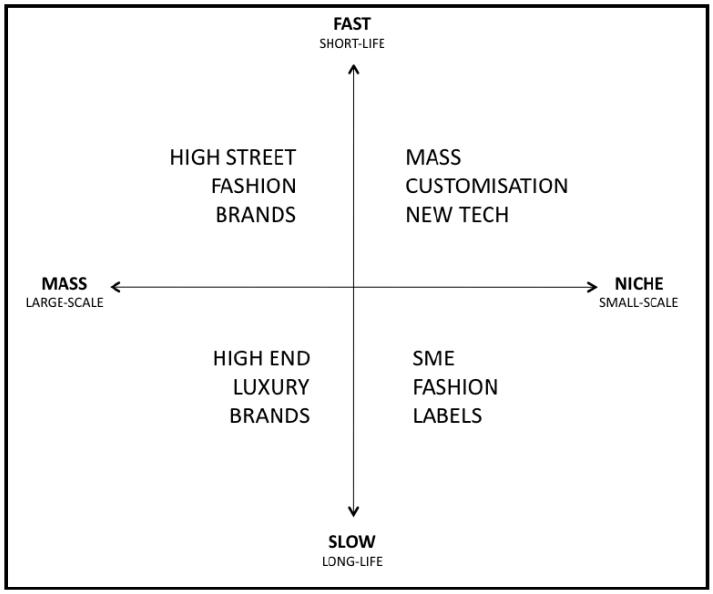

Figure 2.1. Segments of the fashion industry. Source: (Earley & Goldsworthy, 2015; Goldsworthy, 2014)

The increased speed of production and fashion cycles adopts the concept of planned obsolescence (Ewen 1976). Companies in the fashion industry embrace consumers' hunt for novelty and practice planned obsolescence by continuously encouraging consumers to feel dissatisfied with their products by presenting new trends - with the high-street brands raising the stakes (Cassidy & Han, 2013; Joy *et al.*, 2012; Niinimäki & Hassi, 2011; Sheldon & Arens, 1923; Ewen 1999). These practices are enhanced by advertising and indirect external manipulation that stem from cultural beliefs and ideals on how to look or behave (Haug & Busch, 2015; Kahneman 2012; Brooks 2015). Furthermore, a consumer culture based on individualisation and identification through objects accelerate the mass-market for cheap consumer goods (Brooks 2015; Veblen 1965; Haug & Busch 2015). For some parts of the population, consumer goods have become so cheap that prices are not considered (Brooks, 2015). This is illustrated by the increasing perception among consumers that cheap clothes are disposable, described by some scholars as "throwaway"-fashion (Andersen, 2017; Birtwistle & Moore, 2007; Cobbing & Vicaire, 2017). Vance Packard describes in *The Waste Makers* (1961), that when corporations supply an increasing amount of products, it in turn makes people buy more than they need. This contributes to creation of waste. Ewen (1999) argues that disposability is the spine of the capitalistic system, and that mass-production has created wasteful consumers. With the rise of disposable consumer goods comes an increasing global issue of waste.

2.2 Pressure on resource-dependent companies

Meanwhile materials are accumulating in landfills, global resources are becoming more scares. MEA (2005) finds that more than half of the ecosystem services have declined, ecosystem services are life supporting systems (Chapin *et al.*, 2009). A report from the European Environment Agency (2015) found that the global climate changes create a higher competition for fewer resources. The same report questions continuous growth considering the environmental changes and trends identified. Paulitsch *et al.* (2004) expect that areas

currently used for cotton, will be allocated for food crops to support the growing population (cited in Müller-Christ and Gandenberger (2006)). Ragnarsdottír and Sverdrup (2015) argue that 2017-2022 is the peak-point for wealth and after this 'we will no longer be able to take natural-resource-fuelled global GDP growth for granted' (n.p.). These factors, are expected to impact companies that are dependent on resources (Müller-Christ & Gandenberger, 2006). Literature indicates that resource-dependent companies need to decouple from natural resources or create alternatives to the linear production model to ensure long-term economic growth (Stål & Hervé, 2017; Jackson, 2017; Pal, 2017; Weetman, 2016).

2.3 Circular economy current application to the fashion industry

Since 2010, the Ellen Macarthur Foundation has been influential through challenging the linear 'take, make, dispose' mentality of the business world (Ellen MacArthur Foundation, n.d.). The Ellen MacArthur Foundation defines a circular economy as;

> 'restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times' (Ellen MacArthur Foundation, n.d.)

Through the work of the Ellen MacArthur Foundation, the concept of circular economy has been increasingly influential in many industries, including the textile and fashion industry. The circular economy in relation to the fashion industry is defined by Smith and Cunningham in Mathews (2015):

> 'A circular textiles industry is based on a system where textiles products, fabrics and fibres are infinitely and effectively cycled through connected loops within and across industries in a transparent and economical way, where producers apply business practises that enable circular use of textile resources and promote social justice, and

consumers have a healthy relationship with textiles, based on sustainable consumer practices' (Mathews, 2015, p. 54).

Applying a circular approach to the clothing and textile industry incorporate the whole value chain in a systemic rethinking of production (Goldsworthy, 2017; Ræbild & Bang, 2017). Fashion companies can integrate circularity in their business models to address the "end-of-life" of garments (Stål & Hervé, 2017). The end-of-life phase is essential for utilising waste. In a circular approach, waste is considered as a resource, and it is inevitable that resource-dependent industries will need to focus on utilising these materials due to increasingly scarce resources on a global level and also to address increasing waste (Weetman, 2016). Ashby *et al.* (2013) state that a product's "end-of-life"-stage 'is increasingly seen as a competitive necessity and has strong strategic relevance to addressing the environmental dimension in supply chains' (p. 67) (Crandall, 2006). Using textile waste as a resource can be achieved through different methods. Kumar and Malegeant (2006) identify five different ways of product recovery: repair, reuse, refurbish, remanufacture and recycle. Stahel (2016, p. 435) states that companies can implement circular economy to their business models within two different approaches, either extending the product life or recycle and regenerate the components of the products.

Findings from Earley and Goldsworthy (2015) can elaborate Stahel's (2016) distinction of the two different approaches to circular economy by adding an element of speed. They argue that it is important to distinguish between short-life fashion and long-life fashion. Reuse, resell, upcycling and remanufacturing methods apply to products based on durability, quality production and long usages. Garments that are produced with low quality through fast production systems often do not have enough value to be repaired or resold, therefore these products should be taken back to recycle (Early & Goldsworthy 2015) (See Table 2.1).

Earley and Goldsworthy's findings align with current practices in the industry, where companies such as Nudie Jeans, Patagonia, Vigga and Filippa K all have integrated life

extending practices to their business models through either reuse, repair, resell or renting. These companies all produce clothes of high quality and durability, which enable them to maintain the value of the clothes (Hvass, 2015; Vigga n.d; Pal 2016; Allwood *et al.,* 2006*;* Watson *et al.,* 2015; Fletcher, 2013). Despite efforts to extend the life of garments, GFA and BCG (2017) find that 82% of clothes are sent to incineration or landfill at the end of use. This supports the argument that life-extending practices by itself is not sufficient to address the amount of textiles that are unwanted. Enhancing recycling practices is a way of redirection textile waste away from landfills and utilising it as a resource.

Table 2.1. Examples of approaches to circularity. Source: Author

Approach	**Method**	**Description**
Extend product life	Repair	Clothes can be repaired e.g. Nudie Jeans offer a service where customers can get their jeans repaired (Nudie Jeans, n.d.)
	Reuse/Resell	Includes resale of the product either by customer to customer (e.g Trendsales) or by other distributors (e.g. Charity and second hand shops).
	Remanufacturing (upcycling)	Elements or parts of a products are created into new products.
	Renting	Products are owned by a company for several customers to utilise the same product
Recycle	Recycling/recovery	Disassembling, regenerate.

Recycling is a method that can regenerate value of the fibres in discarded clothes (Ellen MacArthur Foundation n.d., McDonough & Braungart, 2002). Payne (2015) defines recycling as: 'the breakdown of products into its raw materials in order for new raw materials to be reclaimed and used in new products'. Recycling is done by disassembling or shredding

materials, and then regenerating them into new materials, that can be used in industrial production of new textiles (McCorquodale *et al.*, 2006).

In the case of textiles it is possible to recycle the materials such as cotton, wool and polyester (Wang, 2006a: 2). The use of PET-bottles has also become an acknowledged method of using recycled materials, with the clothing brand Patagonia leading development (Köhrer & Schaffrin, 2016). There are two ways of recycling textiles; mechanically and chemically (Leonas, 2017). Mechanical recycling covers processes of cutting, shredding and mechanically disassembling materials (Radhakrishnan, 2017). For example, SOEX Group[1] currently work with H&M on testing mechanical recycling (Palm *et al.*, 2015). Chemical recycling is a process where synthetic materials are broken down for repolymerisation (Leonas, 2017). Eco Circle™ developed by a Japanese company, Teijin, is one example of a chemical recycling system for polyester products, yet the recycling process is limited to only a few polyester products (Palm *et al.*, 2015). While disassembling of textiles have been explored in academic literature, the actual practices of textile-to-textile recycling is limited by the lack of adequate technology.

Several scholars and practitioners identified that a crucial barrier in creating a circular textile system is the lack of technology (Elander & Ljungkvist, 2016; Mathews, 2015; Mistra Future Fashion, n.d.-a; Palme, 2017; H&M 2017; GFA & BCG 2017). Despite the lack of commercial recycling technology, companies and organisations are working on projects to solve the technological barrier. For example, H&M collaborate with The Hong Kong Research Institute of Textiles and Apparel (HKRITA) on technology development. They announced in September 2017 that they have found promising results for a method to chemically recycle blended textiles (H&M Group, 2017). Another project is Worn Again, who works with H&M and Puma to develop a chemical textile-to-textile recycling technology

[1] SOEX Group, is a German based company, specialised in used textiles (Soex Group, n.d.).

(Worn Again, n.d.). Furthermore, Mistra Future Fashion researches textile-to-textile recycling in partnership with several clothing companies and stakeholders in the industry (Mistra Future Fashion, n.d.-b). Lastly, European Union and partners are currently working on a project called Fibersort, to develop a technology that is meant to easily sort and recycle textile waste into quality textiles (Interreg, 2016). Commercialisation of this technology could disrupt current practices, and move the textile production towards a higher level of circularity (Circle Economy, 2017; GFA & BCG 2017).

2.4 A system of textile recycling

Realff (2006) stated that implementing a recycling stream is more than a technical matter; it takes system planning that involves collection of used materials, logistics and transportation. Closing the loop is not possible for a single organisation and 'we need to move towards more radical and systematic innovation thinking while challenging the whole industry and its current practices of doing business' (Mathews, 2015; Niinimäki, 2015, p. 4). Systemic change requires changes to the linear production model that underpins mainstream business models (Ellen MacArthur Foundation, n.d.). It includes changing practices throughout the whole value chain such as design and management of end-of-life (Mistra Future Fashion, n.d.-b; Pedersen & Andersen, 2015). Furthermore, it requires collaboration between clothing companies and stakeholders such as government, researchers, collectors and recycling companies (Roth & DiBella, 2015; Müller-Christ & Gandenberger 2006). GFA and BCG (2017) identified two disruptive solutions that could catalyse the process of textile recycling:

- Establish industry-wide end-of-use garment collection
- Design for recyclability

2.4.1 Establishing industry-wide end-of-use garment collection

Collection of clothes is an essential part of creating a circular material flow in the fashion industry, as materials from customers need to be brought back to companies to be reused or recycled (Leonas 2017; Carlsson *et al.*, 2015). Currently, used garment collection schemes have been implemented in companies such as H&M, Bestseller, KappAhl, Lindex, Gina Tricot, Indiska, Filippa K and Boomerang amongst others (Stål & Hervé, 2017). H&M, Bestseller and KappAhl collaborate with I:CO, who manage the collected garments (Hvass 2015; Stål & Corvellec 2017). Clothes can also be collected through pick-up systems, as implemented by Zara in Spain (ZARA, n.d.). Choi *et al.* (2013) found that a retailer-led collection is most effective in collecting used products. Choi *et al.* (2015, p. 193) found that implementing a garment collections scheme enhanced brand awareness and image amongst consumers. Ha-Brookshire and Hodges (2009) found that take-back initiatives demand high consumer-involvement and that easy and convenient clothing disposal is important for consumers to enable them to return their used clothes and textiles.

2.4.2 Design for recyclability

Creating opportunities for recycling textiles starts in the design-phase, therefore designers have a responsibility for the disassembling process in the creation of products (Graedel *et al.*, 1995; Leonas, 2017; Radhakrishnan, 2017; Dissanayake & Sinha, 2015; McDonough & Braungart, 2002). Gulich (2006) explored the link between the designing process of a product and the ease of recycling it after use and stated that it should be the designers' and producers' responsibility to make sure they develop products that can be recycled. Further, he recommended using a single-material system to enable an easy recycling of textiles (Gulich, 2006, p. 28). Whilst this may be applicable for companies primarily selling jeans or cotton t-shirts, the broader industry has more complex and multi-material composites, and includes products with several layers (e.g jackets). Fletcher (2013) highlighted the challenges; 'One technical factor limiting the success of textile recovery operations today is the numerous

types of materials used and extensive use of fibre blends' (p. 124). Earley and Goldsworthy (2015) emphasis that speed of life-cycles should be incorporated in the circularity of the product, and that different strategies apply to long-life garments compared to short-life garments.

2.5 Research context based on literature

This chapter investigated current knowledge, and practices of the field of circular economy in relation to the fashion industry. Figure 2.4 illustrates the context of the research and the limitations based on the findings from the literature. External drivers such as climate change, growing population and resource scarcity forces the resource-dependent fashion industry to focus on material recovery. The lifetime of long-life quality garments can be extended through reusing, reselling, repairing or up-cycling. These practices can, to a lower extent, be applied to low-quality short-life garments. Life-extending practices have create less environmental impact but can be supplemented by recycling practices to fully utilise the potential of the resources. Initiatives are set in place for textile recycling, but a technological barrier limits the industry, as there is no sorting and recycling technology to support commercial textile-to-textile recycling. Furthermore, systemic changes are needed to make financially viable for companies to adopt textile-to-textile recycling in their supply chains and business models.

This research focuses on recycling of garments and textile waste that does not have reuse-value, as indicated with blue in Figure 2.4. Furthermore, this research seeks to investigate technological and systemic opportunities, based on a framework of drivers, inhibitors and enablers. The findings from the literature review are summarised in table 2.2, which provides a conceptual framework for analysing the empirical data.

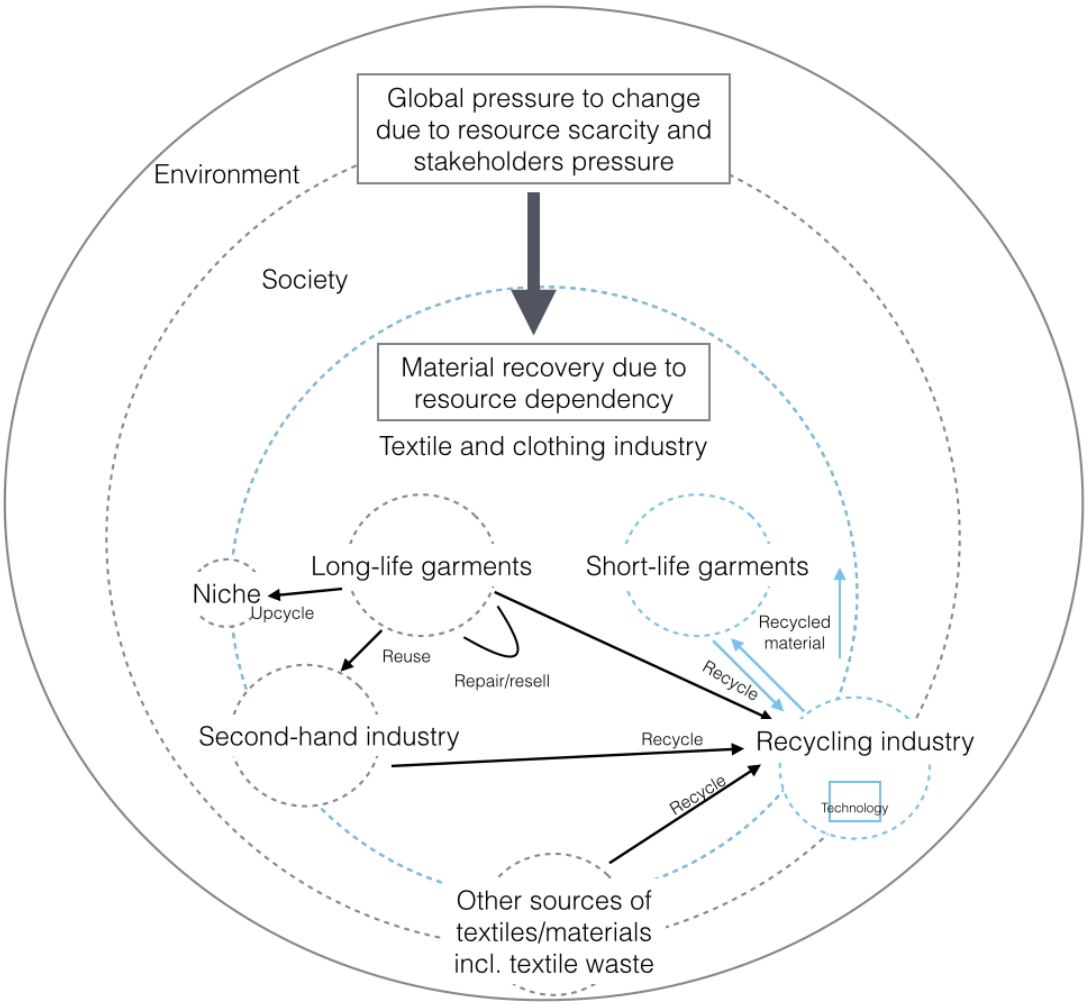

Figure 2.4 The research context, based on presented literature. (Blue lines are the area of focus) Source: Author.

Table 2.2. Conceptual framework developed from current literature.

Categories	**Subcategories**
Drivers	External pressure
	Securing future resources
	Value of textile waste
	Marketing as a circular company
	Potential extended producer responsibly

Inhibitors	No technology to support textile-to-textile recycling on a commercial scale	Lack of automatic sorting
	Separation of materials	Separation of blends /Technical and biological nutrients /Chemical and mechanical recycling
		Additives
		Lack of information about textiles (fibres, chemicals)
		Ensure there is no chemical pollution
	Costs	Restoring quality of the fibres
		Price on virgin materials vs. recycled materials
		Sorting and recycling at present stage
	Recycling of textiles must fit within sustainability framework	Environmental
		Social
	Design for recyclability – lack of connection between design and recycling	
	Size and complexity of supply chain	
	Lack of systemic support	
Enablers	Technology	Potential recycling technology
		Potential sorting technology
	Design and new materials	Design for recyclability/disassembling
		Biodegradable materials
		Recyclable materials
		Mono-materials garments
	Collaboration	

	Garment collection	
Needed technology	Recycling technology	
	Sorting technology	
	Innovation/digitalisation	
Needed systemic change	Replace linear production models/build circular business case	
	Collaboration	Collaboration to collect and manage waste stream with a collector like I:CO or with charity or innovators or researchers/academia
	Slow and fast production systems	

CHAPTER 3: Summary of methodology

This research study utilised a qualitative research design and semi-structured interviews to address the research questions. Secondary data was used to provide an understanding of current knowledge about circular economy in relation to the global, and local Scandinavian, fashion industry (Laws *et al.*, 2013). From the literature review, a conceptual framework (Table 2.2) was developed to guide the research and analysis.

Primary data were collected through interviews with relevant stakeholders in the Scandinavian fashion industry. Stakeholders were identified through a stakeholder analysis. The aim of including a broad range of stakeholders with different backgrounds and roles was to gain different perspectives on the development of textile-to-textile recycling. This decision was based on findings from the literature that argues that a circular economy requires an industry-wide change. The stakeholders included in this research cover designers, researchers, sustainability manager, experts in the technical aspects of textile recycling, business consultants, experts in circular economy theory and a project manager of a textile-to-textile programme. The official titles are not included to ensure anonymity, but a short and general role description is provided to give an indication of the field of knowledge or skills that are relevant in relation to this project.

Table 3.1. List of participants

Stakeholder type	**Code**	**Description**
Clothing company	C1	Sustainability manager
Organisation	O1	Circular and sustainable design
Organisation	O2	Circular textiles
Organisation	O3	Circular textiles
Organisation	O4	Circular economy and sustainability
Organisation	O5	Sustainable business models in fashion industry

Organisation	O6	Sustainability in clothing and textiles sector
Organisation	O7	Textiles recycling
Researcher	R1	Sustainable Fashion
Researcher	R2	Circular economy and fashion
Researcher	R3	Sustainable business models in the fashion industry

3.1 Ethical considerations

Prior to this research, a research proposal was approved by Monash University Human Research Ethics Committee, which follows ethical guidelines of National Statement and the Australian Code for the Responsible Conduct of Research. This research is identified by the code 9181/2017.

Confidentiality and anonymity was considered in terms of collection and storage of data, following official guidelines. Any sensitive information that could identify the participants was censured from the interview transcripts. Businesses and organisations are mentioned by name only in cases where information has been gained from public secondary resources. All direct quotes from participants were personally directed for approval before this thesis was finalised.

3.2 Data analysis

The transcribed interviews were coded, guided by the conceptual framework (see Table 2.2). Coding is a method that 'permits data to be divided, grouped, reorganised and linked in order to consolidate meaning and develop explanation' (Saldaña, 2016, p. 9). The coding was divided into three sections: theme, category and code (Saldaña, 2016). The themes were drivers, inhibitors and enablers, needed technology and needed systemic change.

3.3 Limitations of research methods

One limitation in this research is that the sample was biased towards one opinion-group – a group of designers, sustainability managers, and researchers etc. that all work for and believe in a circular transition for the industry. Other professionals with other worldviews or visions on business development and strategies may provide different perspectives on the challenges and barriers that may exist for a circular transition. Another limitation of the research is that some of the biggest mainstream fashion companies did not find time to participate, and therefore this research cannot represent their voice sufficiently. The sample included only one clothing company. Although other clothing companies did not participate in the research, they did confirm when they were initially contacted, that they are working on strategies to create a more circular approach and that this research study is very needed and current. Furthermore, this research is limited by the sample-size. As it is only based on eleven participants this research does not provide generalisation, but rather indications of developments of textile-to-textile recycling. In line with this, this research is limited in depth by the fact that applying circular economy to the fashion is an underexplored area, both in the industry and in academia.

CHAPTER 4: Summary of findings

The following sections summaries the analysis of primary data derived from interviews, structured after the conceptual framework (table 2.2). Drivers are discussed in section 4.1. Inhibitors are discussed in section 4.2 and enablers are discussed in section 4.3. Findings from these sections are elaborated from a technological and systemic perspective in section 4.4 and 4.5. See appendix 1 for overview of findings.

4.1 Drivers

4.1.1 External pressure

External pressures such as a growing population (Sachs, 2015) and increasing scarcity of resources due to climate change makes production for resource-dependent companies more vulnerable (EEA 2015; MEA 2005; Paulitsch, Baedecker, Burdick 2004; Müller-Christ & Gandenberger; Accenture 2004; Sachs 2015; Weetman 2016). Participant C1 flagged this as a driving force for change in the current practices of producing textiles and clothes:

> 'it is like this: do we want to have a business and society, today, tomorrow and beyond? It is not more complicated' (C1).

It is increasingly clear that there will not be enough resources to support the growing population based on current practices of producing and consuming (O5). This mean that companies are forced to change current production models if they want to sustain their business (O5):

> '[going circular] is not something that should be done of philanthropic reasons, it should be done because if you do not, your company will close' (O5).

4.1.2 Securing future resources

The increasing focus on textile-to-textile recycling is a matter of 'long-term secur[ing] the materials that we need to create the products' (C1; Müller-Christ & Gandenberger 2006). Due to resources scarcity, legislation might constrain the availability of natural resources and create a market for recycled materials (R2; R3):

> 'The demand for recycled cotton as a source of new material will be higher in the next five years or so. So basically [companies want] control over it' (R3).

4.1.3 Value of textile waste

GFA & BCG (2017) estimate the value of utilising textile waste through recycling can contribute with €4 billion to the global economy in 2030 (p. 12). Tapping into waste as a resource provides new business opportunities (R1; O6; C1).

4.1.4 Marketing as a circular company

Marketing is a driver for high-street brands to show commitment to sustainability (O3; O5), as garment collections can enhance the brand image amongst consumers (Choi *et al.,* 2015). This align with consumers in Scandinavia being increasingly aware and focused on companies' sustainability profiles and performance (Pasquinelli & Ravasio, 2013). Marketing is a way to manage consumer perceptions (O3), and to satisfy consumer demand for sustainability (Gam *et al.*, 2010; McKinsey&Co., 2016; Shen, 2014).

4.1.5 Potential extended producer responsibility (EPR)

The possibility of EPR as a legislative framework could drive the industry towards reuse and recycling practices (R3; O5):

> ‘It is also potentially the legislation, in France they have EPR law on textiles, meaning that all brands or importers that put new textiles products on the French market have to pay a fee for the collection and reuse/recycling activity or they have the responsibility themselves and organise a collection’ (R2)

In alignment with this, the Nordic Council of Ministers (Watson *et al.*, 2015) and Mistra Future Fashion (Elander *et al.*, 2017) have presented policy packages for EPR-systems, to push changes toward better utilisation of textiles.

4.1.6 Additional points

Three additional drivers identified in the interviews were ‘reach climate goal’, ‘engage with consumers’, and ‘competition’. From a company perspective it is driving factors ‘to reach our climate goals... And to engage our customers in this journey’ (C1). As literature show, it is crucial to engage with consumers to collect used textiles (Ha-Brookshire & Hodges, 2009). In addition to this, it is a matter of competition between large brands to access the textiles “resources” through consumers. Furthermore, competing to become the market leader is a driving force (R2). This aligns with clothing companies in Scandinavia confirming that they are working on implementing circularity (See section 3.3).

4.2 Inhibitors

4.2.1 Lack of technology to support textile-to-textile recycling on a commercial scale

There is currently no technology to support textile-to-textile recycling on a commercial scale, which is an inhibiting factor (GFA & BCG, 2017; H&M, 2017):

> ‘[a] truly circular textiles industry will not happen until these technologies are fully developed, industrialised, and replicated’ (Mathews 2015, p. 56).

The interviews revealed three steps under the recycling process: sorting, disassembling (mechanically or chemically) and regeneration (O3: O7). The technological barrier applies to sorting and recycling, and is an inevitable barrier that needs to be overcome to enable textile-to-textile recycling (O2; O3; O7; R3) (Elander & Ljungkvist, 2016; GFA & BCG, 2017; Mathews, 2015; Mistra Future Fashion, n.d.-b)

4.2.2 Separation of materials

Separation of fibres is another inhibitor in relation to textile-to-textile recycling (O1; O2; O4; O7; R1; R2; R3)(Leonas, 2017; Pal, 2017; Palm *et al.*, 2015; Radhakrishnan, 2017; Wang, 2006a). The four main technical challenges with textile-to-textile recycling is (O7):

1. Separation of blends
2. Separation of additives
3. Restoring quality
4. All processes need to be sustainable

Separation of blends

Garments often contain different materials, for example cotton and polyester – these materials are recycled through different methods, and thereby create a challenge of separation (Allwood *et al.*, 2006; Elander & Ljungkvist, 2016; Gulich, 2006; Pal, 2017; Palm *et al.*, 2015; Radhakrishnan, 2017; Wang, 2006a). Yet, completely avoiding blends is not a viable solution because from a design and durability perspective blends can increase the quality of the product (O7) (Allwood *et al.*, 2006).

Separation of additives

Besides the blends, additives also need to be removed from the garments. Additives are elements such as zippers and buttons. This complicates the sorting and recycling process further (R3) (Elander and Ljungkvist (2016).

In relation to additives, it is important to ensure knowledge about chemicals used in garments (O2; O5; O4) and overcoming possible contamination from the use-phase of collected garments (R3). Elander and Ljungkvist (2016), found that there is a '[l]ack of information regarding chemicals and hazardous substance in textile products' (p. 32).

Restoring quality

Degradation of fibres begins during consumer use from washing and wearing (O7), but also in the process of disassembling the fibres (O1; O4; O5; O6; O7):

> 'fibres are degraded, and that we somehow need to restore to be able to operate according to circular economy and to compete with virgin high quality materials. So we need to somehow convert this worn material into something with higher value again' (O7).

Trials with recycled textiles results in a quality that can only be used as pillow filling, and thereby only function as down-cycling (O4) (Elander & Ljungkvist, 2016). The current output of small-scale textile recycling therefore must improve in quality and quantity:

> 'in order to achieve circular economy, it is very important that the fibres that we create, can compete with cotton so that we actually are able to replace cotton' (O7).

Restoring the quality of the fibres is closely related to economic incentives to buy recycled fibres, especially in the context of companies that are competing on price.

Recycling of textiles within a sustainable framework

Besides the technical challenges mentioned above, recycling of textiles must fit within a sustainable framework. Wang (2006b) suggests that processes of recycling must be considered from both an environmental and economic perspective when comparing alternative methods of material recovery. Firstly, this means that recycled textiles must be able to match current production prices (O7). Secondly, emissions from recycling must not exceed current levels of emission related to productions of a garment (O5). Textile recycling also contains a range of chemicals, which need to be considered for full material recovery (R2; R3; O2; O4: O6). Furthermore, the social aspects are not directly considered in the circular economy theory (R1)(Benyus, 1997; Frosch & Gallopoulos, 1989; McDonough & Braungart, 2002; Moreau *et al.*, 2017). Yet, circular economy does not mean compromising on social aspects of production (O1; O2; O4; R1; R2). Moreau *et al.* (2017) propose that principles from solidarity economy[2] can be combined with circular economy theory to establish the social dimension.

4.2.3 Costs

An inhibiting factor for textile-to-textile recycling is the related costs of current sorting practices and further, costs of developing a recycling system including technologies (O4; O2; R2; O3). Current sorting practices are 'done manually which is a challenge and it is expensive for doing fiber-to-fiber recycling' (O2). Dissanayake and Sinha (2015) and Carlsson et al. (2015) argue that it is therefore not financially viable at current stage.

Costs related to development of the necessary recycling system is research, technologies and restructuring waste streams, that is creating infrastructure for used garments (O3; O5; R3). Nayak *et al.* (2015) argue that retail leaders are 'concerned about the return on investment and net profit by investing the extra cost into the existing system' (p. 9) referring to

[2] Solidarity economy is a social movement that builds on foundations of reciprocity and requires responsibility for the other part in an exchange (Moreau *et al.*, 2017).

implementation of radio frequency identification (RFID). Costs related to usages of any new technology must be aligned with the aim of producing cheap and competing prices.

4.2.4 Lack of connection between designer and recyclers

As stated in the literature review, design for recyclability entails that the disassembling phase is considered in the design of the product (Gulich, 2006). This creates incentive for designers and recyclers to work together so products can be easily recycled (R1; R2). The current disconnect between the design-phase and recycling-phase is an inhibitor (O1; O4; O5; O6; R1; R2) (Dissanayake & Sinha, 2015; Leonas, 2017; Radhakrishnan, 2017). Furthermore, the physical and mental gap between designers and production creates a barrier for designing for recyclability, as the designer does not have responsibility for the products as a whole and thereby only is a small part of the decision process in product development (R1) (Fransson *et al.*, 2013; Leonas, 2017). Findings from Graedel *et al.* (1995) state that 80-90% of a products' environmental and economic cost is determined during design, which supports the argument that it is an inhibiting factor that designers do not have more influence of product development.

4.2.5 Size and complexity of supply chain

The size and complexity of the supply chain of large fashion retailers is an inhibitor (O3; R1):

> 'Changing the supply chain is hard, fast fashion supply chain are really big… A fast fashion company might contract a factory, who contract another factory – so there are subcontractors involved, which makes it challenging' (O3).

Fransson *et al.* (2013) argue that it can be difficult to make all contractors and subcontractors align with a standard proposed by the focal company. In alignment with this:

> ‘the supplier industry, or supply chain they are definitely not ready yet. And we are very dependent on the supply chain of fabrics and manufacturing to be able to actually make those nice circular concepts’ (O1).

Literature studying the application of sustainability initiatives throughout large supply chains highlights the difficulty of aligning all involved stakeholders (Ashby *et al.*, 2013; Caniato *et al.*, 2012). Applying a circular approach is no different, and the size and complexity is therefore an inhibiting factor.

4.2.6 Lack of systemic support

Academic literature and practitioners from the fashion industry place emphasis on the need for systemic change (Chapter 2). While the current lack of systemic support for recovery of textiles is an inhibitor (O1; O2; O3: O4; O5):

> ‘if a company is producing products that at end of their first life cycle only can be recycled, there it not much value in those today because … it is really challenging to use them as a recycling feed-stock today. So these garments are a burden on the system today, because they have limited end markets for recycling. And the end market for recycling post-consumer textiles that do exist are not very profitable’ (O3).

Elander and Ljungkvist (2016), similarly find that there is no sufficient market for recycled textiles. The lack of a recycling market creates an inhibitor to access the needed materials and ensure sufficient supply (O1; O4; C1).

In relation to this, there is a legal barrier to access resources: ‘current policies [in Denmark] do not allow companies to collect textiles in a scalable amount’ (O4). Watson *et al.* (2015) concludes that legal and volunteer EPR policies might stimulate companies’ collection of textiles. Miljøstyrelsen (2014) advocates for a more cohesive framework concerning waste

fees and VAT rules (p. 9). In alignment with this, participants highlight that regulations create a foundation for changing current practices in the industry (O6; O7; R2; R3). Yet, the recycling of textiles should be incentivised by identified drivers (section 4.1) and thereby create demand (O1; O4; O5). Systemic change is further explored in section 4.5.

4.3 Enablers

4.3.1 Technology

Despite of the current technological barrier, potential technological solutions can enable the process of textile-to-textile recycling (O5; O1; R1; R2; O7). A trust in technology is apparent: 'There is no doubt it will be possible' (O5) - 'there are more than enough engineers, technologies and industries that are ready to recycle, or will find solutions' (O1). This is backed up by several projects currently happening (Section 2.3):

> 'A lot is happening there as well; there is a big EU project on this. There are companies developing technologies and testing some. So we can expect that this will change in the years to come' (R2).

Lu and Hamouda (2014), find that there is growth in enterprises focusing on recycling for textiles. Participant O7 predict that:

> 'in 10-15 years we will probably have some kind of fibre recycling plant on a commercial scale for certain controlled streams like cotton or cotton/polyester' (O7).

In relation to recycling and sorting technology, digitalisation is an additional enabler for the recycling of textiles (Section 4.4) (O2; O3; O4; O5; O6; O7; R1; R2; R3).

4.3.2 Design and new materials

Design and the introduction of new materials is an enabling factors for textile recycling (O1; O2; O4; O5; O6; O7; R1; McDonough & Braungart, 2002; Radhakrishnan, 2017).

> 'Design is an enormous contributor to circular economy. Adopting a circular design mindset and designing according to circular economy principles is a mandatory skillset for designers' (O2).

Designing to enhance circularity is a matter of designing products that have high durability, longevity or recyclability (Baker-Brown, 2017; Earley & Goldsworthy, 2015; Goldsworthy, 2017; Moreno *et al.*, 2016). The design-phase is crucial to enable recycling (O1; O4; O5; O6; R1; R2). Design to enable recycling should focus on easy disassembling (R3)(Leonas, 2017; Radhakrishnan, 2017). Considering the challenge of blended materials and additives, mono-materials are a suggestion to make the disassembling easier (O1).

Lu and Hamounda (2014) provides an example of a company called Vaude, that creates all additives from polyester to make the recycling process less complicated. Academic literature present design-practices introducing new materials such as biodegradable materials, recyclable materials and mono-materials (Benyus 1997; Shen 2014; Hu et al. 2014; Payne 2015; Leonas 2017; Weller 2013; Hu et al. 2014; Early & Goldsworthy 2015; Gulich 2006; Radhakrishnan 2017). Following that, companies and researchers are experimenting with alternatives such as hemp and waste products for example pineapples, grapes, oranges, and cow dung (Ananas Anam, n.d.; Global Change Award, 2017b, 2017c; Orange Fiber, n.d.). Yet, the introduction of new materials can be an inhibiting factor, because it creates a challenge with recycling streams (R1; O4). When a new material is introduced, a recovery-stream needs to be considered, as well as the technical disassembling of the material. Participant O4 suggests that companies that choose to introduce new materials must take responsibility for the recycling of them.

4.3.3 Collaboration

Collaboration is an enabling factor (C1; R1; R2; R3; O1; O3; O4; O5; O6; O7)(GFA & BCG, 2017; Pal, 2017; Poldner, 2013). The different kinds of collaborations mentioned throughout the interviews are discussed in section 4.5.2-4.5.5. The general finding about collaboration is that it is a necessity to enable textile recycling and creation of a stream of recycled materials (C1; O1; O3; O4; O5; R1; R2). For example collaboration with consumers is crucial to gain access to resources for textile recycling (Carlsson *et al.*, 2015; Choi *et al.*, 2014; Choi *et al.*, 2013).

4.3.4 Garment collection

Currently, only 20% of clothes are being collected for reuse and recycling practices (GFA & BCG, 2017). Gaining access to the clothes that otherwise end up in landfill or incineration, is an enabling factor to create a recovery stream for textile-to-textile recycling:

> 'If you look at the total streams of the garments in the world, not only for [company], but for everything, it is absolutely not enough collected today and more needs to be collected' (C1).

Collecting garments is directly related to circularity:

> 'Reclaiming products at the end of their life is ultimately what circularity is all about, so that is the future of the industry' (O3).

This supports a fundamental idea of circular economy by using waste as a resource (Chertow, 2007; Frosch & Gallopoulos, 1989; McDonough & Braungart, 2002).

4.4 Technology for textile recycling

Understanding the drivers, inhibitor and enablers provides a foundation for understanding what technological and systemic changes are needed to realise textile recycling. This will be discussed in the following sections.

The interviews indicate that digital tools are essential in textile-to-textile recycling (O2; O3; O4; O6; O7; R1; R2; R3). Initiatives and ideas are illustrated in table 4.5.

Table 4.5. Participants' suggestions of digitalisation to enhance circularity and recyclability

Usage	**Suggested technology**
Production	• 3D printing (O5) • Decentralised production and digital receipt (R1)
Sorting/recycling	• Material scanning for easy and commercial sorting (O3; O6; O7) • Radio Frequency Identification (RFID) (O2)/Tagging (O7) • Digital passport (ID-code or chip) (R1; R2; O7) • H&M Global Change Awards – Content Thread (O7)
Connecting technology	• Connecting demand and supply of "textile waste" (O3; O4; R3)

4.4.1 Production and digitalisation

In line with other industries, there is a potential for automation and technology to take over current production practices of garments, for example 3D printing (O5). Knitting-technology and 3D printed textiles is mainly apparent in small-scale productions, for example Dutch designer Iris van Herpen and the Belgian fashion designer Bruno Pieters have experimented with 3D printed garments (Iris van Herpen, n.d.; Moorhouse & Moorhouse, 2017). Adidas tested in 2017 an in-store production technology, where products were fitted to the individual customer and knitted within a few hours (Adidas, 2017). 3D knitting and customisation can reduce clothing waste by producing based on real-time demand (O5), and in relation to textile

recycling it presents an opportunity to incorporate design for easy disassembling and recyclability (Section 4.3.2).

Another usage of digitalisation in production is digital receipts that can change the current ways of making clothes, through better documentation and transparency (R1). Through the digital receipts, producers can document used chemicals and fibres included in the products, and thereby enhance transparency for recyclers. This is a way of addressing current issues around a lack of knowledge of contents in clothes and textiles, as presented in section 4.2.2. A recent article by Mckinsey & Co. (Alicke *et al.*, 2017) suggests that digitalisation will influence supply chains in coming years, and create what they call Supply Chain 4.0[3]. With a digitalised supply chain, e.g. through digital receipts, information is more accessible (Alicke *et al.*, 2017). Zhu *et al.* (2016) similarly state that digital information will reshape supply chains, especially concerning information flow. This provides a technological opportunity to enhance recycling.

4.4.2 Sorting, recycling and digitalisation

As presented in section 4.2.3 the current sorting process of textiles and clothes is done manually which is both a costly and labour intensive process (R3; Payne 2015). Through the manual process of sorting it can be difficult to identify each fibre type (R2). For textile-to-textile recycling to be an actual business opportunity, the sorting process needs to be automated (O3). To meet demands, a potential sorting technology must therefore be able to identify different kinds of fibres through a method that is fast and cheap (Carlsson *et al.*, 2015; Nayak *et al.*, 2015). The sorting could be done through surface-scanning, potentially through RFID (O2; O3; O6; O7):

[3] Referring to the Fourth Industrial Revolution – Industry 4.0. The fourth industrial revolution is based on interconnected technologies - physical, digital and biological. Technologies such as artificial intelligence, nanotechnology and big data are predicted to revolutionise business practices (Schwab 2016).

> ‘a sorting-equipment that basically takes finished post-consumer textiles whether that is garments or towels or whatever. It scans the surface and then it can sort those textiles by fibre type’ (O3).

A scanning technology for more efficient sorting can be linked with a chip or and ID-code functioning as digital passports (R1; R2; O7):

> ‘every product has either an ID-code or a chip or something that can identify 100% what is the material in this and what chemicals have been used – the story of the garment, so that at the end of life, it can be easily recycled or put into the circular streams’ (R2).

This aligns with current developments of a EU-project called Trash-2-Cash that have used “tagging” as a digital method and H&M’s Global Change Award winner project Content Thread (O7). The Content Thread is a digital thread that can connect with Radio Frequency Identification (RFID) technology to inform about content (Global Change Award, 2017a).

The purpose of the above-mentioned technologies is to inform sorters and recyclers about the fibres and chemicals that are included in each garment: ‘[digitalisation] enables transparency and it enables the possibility of circular supply chains in a consistent and standardised way’ (O3). The technologies themselves do not have importance; rather it is the function of them:

> ‘Transparency and standardisation are just as important as the sorting technology and the recycling technology. It is all hooked together’ (O3).

The essential functions that must be considered in using technologies in commercial textile-to-textile recycling is traceability (O3: O4), transparency (O1; O3; O4; O7), standardisation (O3), automatisation (O5; O6) and the ability to connect different stakeholders or processes (O3; O4; O6; R3).

Digital technologies can create value and enhance the sorting and recycling processes through greater accessibility of information and increased transparency. Sorting and recycling

technologies must be automatised to be financially feasible. The digital technologies were suggested as a way of addressing the current lack of technology to create auto-sorting.

4.4.3 Connecting technologies

A digital platform could enhance resource availability for recycling of textiles, by connecting supply and demand of "textile waste" (O1; O3; O4; O6; R3):

> 'Basically [a digital platform] will allow people that have textile waste to find places to get it recycled or reused in some sort of way. And it will allow people that are reusing or recycling to find material suppliers – so essentially it is a circular supply chain builder' (O3).

The use of connecting digital platforms is predicted to have increasing influence on industries, both in supply chains but also to connect with consumers in a new way (Alicke *et al.*, 2017; Schwab, 2017; Zhu *et al.*, 2016).

4.5 Systemic change

There is a need for systemic change to create a recovery stream of recycled textiles and adopt circular economy in the fashion industry (Berndtsson *et al.*, 2017; Ellen MacArthur Foundation, 2015; Weetman, 2016). The interviews explored what systemic change means in a practical sense.

4.5.1 Circular business case

Even though there is a need for the whole system to change simultaneously, the identified enablers (Section 4.3) can be used as catalysts for change. An important enabler of textile-to-textile recycling is creating a material stream of used textiles and garments. Despite the lack

of sufficient technology to support the recycling of clothes, companies such as H&M and Bestseller are collecting clothes. Creating a take-back system is a way of training the consumers for when the technology is available (R1). Furthermore it is a way of collecting enough amounts to have a business case for when the technology is available (O5; C1):

> 'that is a question of scale; in order to get the technology, you also need to develop a business case' (C1).

Elander and Ljunqkvist (2016) find that there is currently no business case for textile-to-textile recycling and that there is a '[l]ack of textiles available for recycling due to insufficient collection' (p. 18). A certain volume of collected textiles is needed to create the business case and to push the recycling industry (C1; O1; O3; O4; O5; R1; R2). Allwood et al. (2006, p. 31) state: 'A large and constant stream of a specific material is essential for the economic feasibility of recovery'. This highlights the importance of engaging with consumers in the collection of enough textiles and clothes to support a stream of recycled materials.

4.5.2 Collaboration

As shown in section 4.3.3, collaboration is crucial for change towards circularity (Pal, 2016; Poldner, 2013)(C1; R1; R2; R3; O1; O3; O4; O5; O6; O7). Different kinds of collaboration explored through the interviews is summarised in Table 4.7.

Table 4.7. Types of collaboration for systemic change to support textile-to-textile recycling, identified through primary data.

Purpose of collaboration	**Type of collaboration for systemic change to support textile-to-textile recycling**
Collect	• Collaboration with consumers (C1; O1; O3; O4; O5; R1; R2) • Collaboration with charity (R1)
Recycle	• Collaboration with collectors/recycling industry (R1; R2)

	• Collaboration with researchers (R1; R2; C1)
Change	• Collaboration between designers and recyclers (O1; O5; R1; O7) • Collaboration between small and large companies (O1; O3; O4; O5) • Collaboration between large companies (R1; R3; O1; O5; O6)

4.5.3 Collaboration for collection

In order to ensure a large flow of materials the relationship with consumers needs to be redefined (O3; R2). This could be done by letting consumers be part of the sorting process if companies are allowed to collect through campaigns - this would require a change of the current legal framework (O4). Mathews (2015, p. 56) argue that 'recyclable does not mean that it will be recycled'. Goworek *et al.* (2013) find that consumers do not have enough knowledge about the environmental impacts of their clothes, and that educating consumers is an important element in gaining access to the clothing "waste". Therefore, it is important to ensure that consumers understand the value of their used clothes:

> 'the brands actually have to take the educator role as well, in informing and actively engaging' (R2)

Radhakrishnan (2017) suggests that retailers should promote the return of clothes. As shown, changing consumers' behaviour, even before the technology is in place, is essential to enable a stream of textiles (O5; R1) (Mathews 2015). Furthermore, a source of used textiles could also come from collaboration with charities (R1) or schools, hotels, military etc. (Ulasewicz & Baugh, 2013).

4.5.4 Collaboration for recycling

Large clothing companies are currently collaboration with collector I:CO (Stål & Hervé, 2017). This collaboration is important in terms of managing the textile waste stream (R1; R2):

> ‘I:CO provides them the reverse logistics solution and takes care of the sorting and reselling, reuse, recycling’ (R2).

I:CO’s collaboration with large companies creates a stream of used textiles and garments, which is highlighted in the literature and by the participants as crucial to enable textile-to-textile recycling (O1; O5; O4; O3; R1; R2) (Allwood *et al.*, 2006; Elander & Ljungkvist, 2016). Stål & Hervé (2017) thus provide a critical perspective by arguing that collaborating with I:CO is a way for clothing companies to continue their current business models, but create a showcase of decoupling to meet institutional demand.

4.5.5 Collaboration for change

To manage the waste streams and create a new supply of recycled textiles, large and small companies must work together. The collaboration is needed to create logistics (O1; O3; O4), systematisation of access to materials on an industry-wide basis (O5), and to reach scale (Section 4.5.1) to create enough demand for recycling technologies (O1; O3; O4; O5; C1; R3). Poldner (2013) argued that companies can gain from partnership and that ‘strategic alliances’ can create benefit for everyone involved. Poldner uses the Sustainable Apparel Coalition as an example of how companies can work together on creating system-wide knowledge for the larger benefit (Pal 2017; Bommel 2013). While the barrier to this is that ‘[i]t is hard to collaborate with the competitor to make a massive industry shift’(O3).

The interviews indicate that change have to start from large companies due to resource availability and possibility to influence producers and regulation (O1; O5; O6; R1; R3). This perspective aligns with Larsson, Buhr & Mark-Herbert (2013; p. 273) who argues that ‘[a] large corporation will have more resources to become a role model, which may inspire other corporations to follow’. Participant O3 adds:

> ‘I think fast fashion, because of the volume they produce, could be a really important accelerator for the volume of recycled textiles in the market’ (O3).

Large corporations therefore have an important role in creating change, yet the systemic change is not actually happening until the SMEs and the luxury brands are participating (O2; O4; C1). Participant O4 explain it with a metaphor:

> 'there is only a sustainable transition when the grass is green: that is, when all the blades of grass have become green. It might be, that there are a few green spots that represent the large companies, but that won't make the whole field green' (O4).

The production of textiles demands the same processes whether it is from a large or a small corporation and therefore it is not just a matter of large corporations changing their practices:

> 'there is not a very large difference composition wise between fast and slow fashion. If you are not using safe materials nor have a plan or reutilising those materials, your product is still a linear one' (O2).

The findings therefore suggests that large corporations can lead change due to available resources, but the actual systemic change does not happen until the luxury fashion companies and SMEs are participating too (GFA & BCG 2017):

> 'This is a really big system in general, so it is an industry-wide shift, not an individual company shift. A lot of brands have to do this at the same' (O3).

4.5.6 Slow and fast fashion systems

Despite the emphasis on 'pushing in the same direction' and collaboration, the interviews and literature suggest that a division between slow and fast systems might influence strategies applying circular practices (O1; O3; O5) (Earley 2015; Goldsworthy 2017; Earley 2017; Earley & Goldsworthy 2015).

Stahel (2016) suggested two ways of prolonging product life: reuse or recycling. These practices are seen to apply differently; where small niche companies can increase their focus

on services that prolong the life of garments such as repairing or reselling, the larger mainstream companies cannot follow this strategy due to the lower quality (O1; O3; O5).

Earley (2015) believe that the fashion system could have two different kinds of materials: the ones for the "fast" fashion and one for "slow" and quality fashion. One participant reinforces this perspective by suggesting the creation of two different textile systems – one focused on long life and one focused on short life with easy recyclability (O3). The design of the t-shirt, for example, is therefore not just about the materials that are used and technologies available, it is about understanding the current and potential material flow and strategically integrate it as part of the business model. Goldsworthy (2017) explores if it is possible to 'build the notion on speed into the whole cycle to ease the flow, including super-efficient materials recovery' (p. S1968).

Participant R3 calls this strategic and conditional design, where the context that the clothes will be used in is considered. It is about understanding what value the consumer attributes to the product, for example when purchasing a t-shirt. If the perception of the cheap t-shirt is that it is disposable after it is gone out of trend, then the strategic conditional design for this kind of product is about creating a fast take-back to recycle the materials (R2; Joy et al. 2012; Goldsworthy 2017).

4.6 Summary of synthesis

The literature and primary data presented in sections 4.1- 4.5 made it clear that a significant challenge for creating systemic change for textile-to-textile recycling, is that there is not *one* place to start. Processes throughout the value chain are interconnected, and increase the complexity of applying recycling (O3; O7; R1). Figure 4.1 summarises the textile-to-textile recycling system, emphasising the interconnectedness of the elements identified in the findings.

Based on the analysis the main elements of creating a textile-to-textile stream, are ‘building a business case’, ‘stakeholders’ and ‘sorting and recycling technology’ including ‘digitalisation’. The elements are connected through ‘volume/scale’, ‘collaboration’ and ‘infrastructure/logistics’. Together the elements and connections feed into the realisation of a textile-to-textile system.

The analysis made it clear that development of sorting and technology is crucial to enable financially viable textile-to-textile recycling. A constant stream of material is inevitable to reach volume and scale for commercial recycling technology and building a business case. In that way, developing technology and building a business case are interdependent. Yet, collecting enough textiles to build a business case requires collaborations from several stakeholders, for examples collaboration with customers is central to support a stream of textiles. The primary data proposed that companies should work together to create infrastructure and logistic for textile-to-textile recycling.

The interviews showed that digital technologies can be used as an addition to increase transparency and automation and thereby enhance the use of the sorting and recycling technology, and possibly be integrated in the infrastructure. These elements are therefore inevitable for creating a textile-to-textile system.

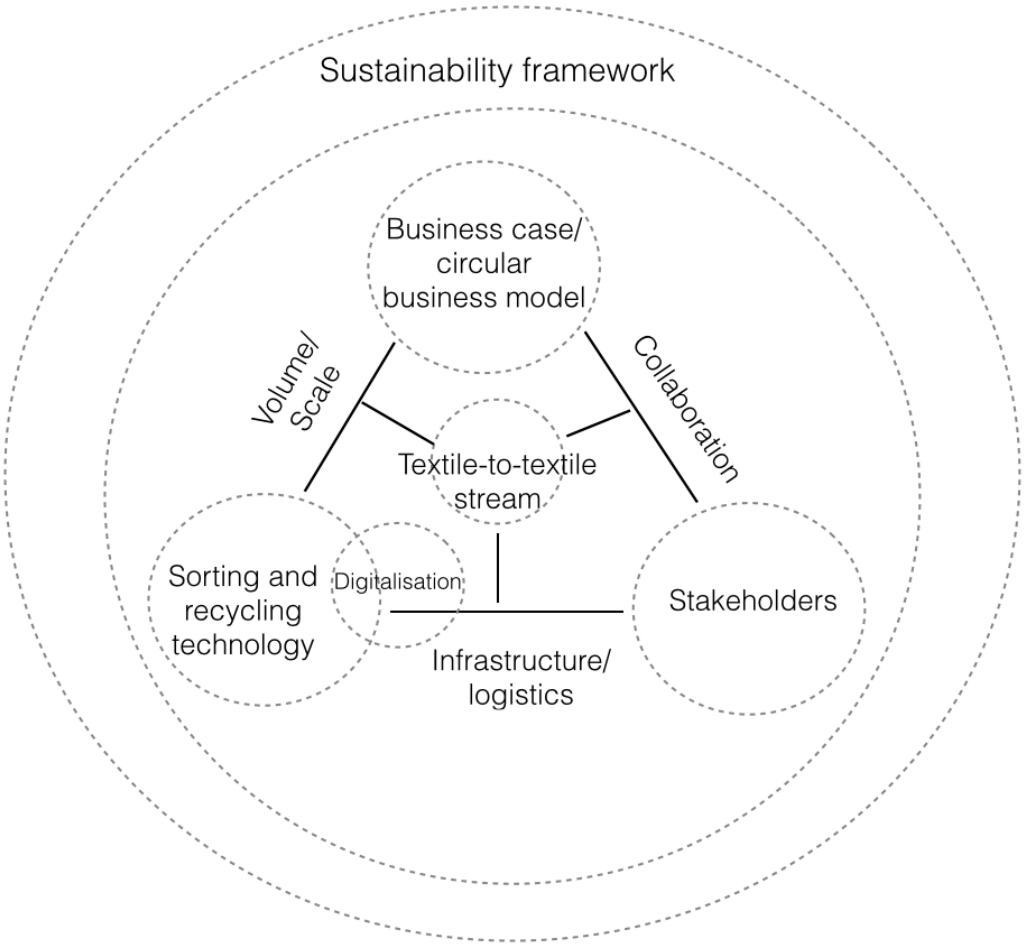

Figure 4.1 Systemic change for textile-to-textile recycling, based on literature and primary data. Source: Author.

CHAPTER 5: Conclusion

The fashion industry has significant environmental impacts and contributes to major amounts of waste (Fletcher, 2010; Greenpeace, 2011; Minney, 2011). One approach to addressing waste issues is the adoption of circular production models e.g through recycling (Moreno *et al.*, 2016). However, little is known about how the fashion industry can utilise textile waste in a system of textile-to-textile recycling. The aim of this research was to explore how the Scandinavian fashion industry can create a system of textile-to-textile recycling. A conceptual framework was derived from the literature to guide the analysis. The study used a qualitative research design and interviews to identify drivers, inhibitors and enablers of creating a system of textile-to-textile recycling. Furthermore, the primary data provided insights and suggestions for needed technology and systemic change to support recycling. Table 5.1 summarises where the primary data reinforces current literature, and furthermore how the primary data enhances and contributes to contemporary knowledge in the field of textile-to-textile recycling. This chapter summarises the research findings (section 5.1), and identifies limitations and future research directions (section 5.2).

5.1 Summary of findings

In summary, the literature provided examples of current practices of applying circular approaches in the fashion industry. Examples of companies that have adopted circular economy through reselling and repairing were presented. Yet, these practices alone were not sufficient to address the increasing issue of textiles accumulating in landfills. Drawing on literature and primary data, this research found that climate change and a growing global population puts pressure on the amount of available resources for the fashion industry to maintain their clothing production. In relation to this, companies can tap in to new business

opportunities by utilising textile waste as a resource for production. This was enhanced by the increasing value of textile waste.

Literature and primary data found that implementing textile-to-textile recycling in current business operations is inhibited by the lack of recycling technology. Developing a recycling technology is challenged by separation of blends, additives to clothes, restoring quality, lack of knowledge of material and chemicals in garments. Furthermore, recycling processes must be kept within a framework of sustainability. The costs related to using recycling was also highlighted both in the literature and primary data, while the interviews enhanced this by suggesting that the initial cost of research, development and building supporting infrastructure is another inhibiting factor. Furthermore, the interviews found that the lack of a sufficient market for recycling makes it difficult to reach a scale of material to support production.

Literature and primary data found that the lack of connection between design and recycling was an inhibitor, this was related to the complexity of supply chains. Primary data reinforced this by suggesting that there are many decision-makers in large organisations that influence the creation of products. Participants argued that recyclers and designers should collaborate more closely, to enable design for recyclability. The primary data also suggested that companies are challenged by the fact that there is no specific path or standard to follow.

Despite of the current technological barrier, participants and current initiatives from the industry indicate that technology to sort and recycle are being developed and will enable textile-to-textile recycling; technology, design and new materials can enable the recyclability of garments. Yet, introduction of new materials must be considered in terms of the accompanying recovery stream, this finding added to current knowledge. The usage of technology is crucial to make sorting and recycling processes economically feasible for mainstream fashion companies that compete on price as found in both literature and primary data. Interviews enhanced current knowledge by suggesting different ways of integrating digital technologies in sorting and recycling. Furthermore, the interviews found that the

purpose of using digital technologies is to provide information and thereby create a higher level of transparency. Digital technologies can also be used to connect stakeholders e.g. supply and demand of "textile waste".

The literature advocated for systemic change by diverging from the linear production model, this requires stakeholders in the industry to work together. These findings were reinforced by the primary data that contribute to current knowledge by defining types and purposes of collaboration. For example, to gather enough textiles to build a business case and construct the infrastructure, stakeholders within the industry must work together, as well as engage with consumers. This especially accounts for large companies that have the capacity to invest and restructure through collaborations. This research study also reinforced findings from the literature by suggesting two approaches to addressing clothes' end-of-life based on quality and speed. Introducing two different systems of fashion production and handling of end-of-life suggest a divide between larger corporations producing for recyclability and SMEs producing for life-extension.

5.2 Limitations and future research directions

This research is limited by the sample size of only eleven interviews, which limits the ability to generalise these findings. However, as an exploratory study, the findings provide insights that can be further tested and expanded with larger sample sizes and in different country contexts. Another limitation of the sample, was that only one large clothing corporation participated. Therefore, the clothing industry's views are under-represented. Furthermore, the literature and primary data suggested that there is a need for an industry-wide collaboration, therefore more stakeholder groups could have been involved. This study is limited by not including manufactures and other stakeholders within the supply chain.

Closed-loop recycling requires not just material recovery, but also resource recovery (Payne, 2015). This research was limited to only looking at the materials, and thereby excludes energy and chemicals that also need to be considered to create a fully circular system.

The suggestions for technological and digital solutions for sorting and recycling were limited to be discussed from a hypothetical view, with a few working examples. Therefore, this research suggests a number of aspects for future research to address these limitations:

- Further elaboration of practical inhibitors and enablers of textile-to-textile recycling from all involved stakeholders' perspective.
- Technological development in relation to sorting and recycling. Correspondingly how digitalisation or digital tool can contribute to better information flow.
- Further examination of systemic changes in relation to support textile-to-textile recycling.

Table 5.1. Findings reinforcing current literature and new findings that extend current literature

	Reinforce current literature	**New findings that extend current literature**
Drivers	• External pressure • Securing future resources • Value of textile waste • Marketing as a circular company • Potential extended producer responsibly	• New business opportunities • Reach climate goals • Engage with consumers • Competition

Table 5.1. Findings reinforcing current literature and new findings that extend current literature		
	Reinforce current literature	**New findings that extend current literature**
Inhibitors	• No technology to support textile-to-textile recycling on a commercial scale • Separation of materials • Costs • Recycling of textiles must fit within sustainability framework • Design for recyclability – lack of connection between design and recycling • Size and complexity of supply chain • Lack of systemic support	• Initial cost of innovation restructuring and cost of research and development of materials and technology • Many decisions-makers influence the creation of products in big organisations • There is not the legal support to create textile waste streams through the companies • No sufficient market for recycling • Scale • Not a clear definition/path to follow
Enablers	• Technology • Design and new materials • Collaboration • Garment collection	• Digitalisation • Diverge: New materials creates a challenge with recycling stream companies that chose to introduce new materials must take responsibility for the recycling of them

Table 5.1. Findings reinforcing current literature and new findings that extend current literature

	Reinforce current literature	**New findings that extend current literature**
Needed technology	• Recycling technology • Sorting technology/auto-sorting	• Innovation/digitalisation: surface-scanning • 3D printing • Decentralised production and digital recipes • Digital passport (ID-code or chip) • Material scanning for easy and commercial sorting • Radio Frequency Identification (RFID) • H&M Global Change Awards – Content Thread • Tagging • Connecting sorting and recycling • Connecting demand and supply of "textile waste" • Informing consumers about production (Barcode, QR-code) • Functions of technologies: · Traceability · Transparency · Standardisation · Automatisation · Commercialising
Needed systemic change	• Replace linear production models/build circular business case • Collaboration • Slow and fast production systems	• Scale/volume to create business case • Redefine consumer relationship for access to resources • Collaboration between designer and recycler. Design for recyclability • Products is the means, change of production is the goal

REFERENCES

Adidas 2017, *Adidas Knit for You*, viewed 28 sep 2017, <http://adidasknitforyou.com>.

Alicke, K, Rexhausen, D & Seyfert, A 2017, 'Supply Chain 4.0 in consumer goods', <https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/supply-chain-4-0-in-consumer-goods>.

Allwood, JM, Laursen, SE, Rodriguez, CM & Bocken, NMP 2006, 'Well dressed?: The present and future sustainability of clothing and textiles in the United Kingdom', *Journal of the Home Economics Institute of Australia*, vol. 22, no. 1, p. 42.

Ananas Anam n.d., *Ananas Anam presents Piñatex™*, viewed 25 sep 2017, <http://www.ananas-anam.com/>.

Andersen, KR 2017, 'Stabilizing Sustainability: In the Textile and Fashion Industry', Denmark: Copenhagen Business School, (PhD Series, No. 05.2017)

Ashby, A, Smith, MH & Shand, R 2013, 'From Principle to Practice: Embedding Sustianability in Clothing Supply Chain Strategies', in MA Gardetti & AL Torres (eds), *Sustainability in Fashion and Textiles*, Sheffield : Greenleaf Pub.

Baker-Brown, D 2017, *The re-use atlas : a designer's guide towards a circular economy*, London : RIBA Publishing.

Barnes, L & Lea-Greenwood, G 2006, 'Fast fashioning the supply chain: shaping the research agenda', *Journal of Fashion Marketing and Management: An International Journal*, vol. 10, no. 3, pp. 259-71.

Benn, S, Dunphy, DC & Griffiths, A 2014, *Organizational change for corporate sustainability*, Third edition. edn, Abingdon, Oxon New York Routledge, London : Routledge.

Benyus, JM 1997, *Biomimicry : innovation inspired by nature*, New York : Perennial, New York.

Berndtsson, M, Drake, L & Hellstrand, S 2017, 'Is Circular Economy a Magic Bullet?', in E Dahlquist & S Hellstrand (eds), *Natural Resources Available Today and in the Future*, Springer.

Birtwistle, G & Moore, CM 2007, 'Fashion clothing - where does it all end up?', *International Journal of Retail & Distribution Management*, vol. 35, no. 3, pp. 210-6.

Bourdieu, P 2013, *Distinction: A Social Critique of the Judgement of Taste*, Taylor & Francis.

Brooks, A 2015, *Clothing poverty : the hidden world of fast fashion and second-hand clothes*, Zed Books, United Kingdom.

C&A 2017, *Cradle to Cradle Certified™**, C&A, viewed 10 oct 2017, <https://www.c-and-a.com/uk/en/corporate/company/materials/>.

Caniato, F, Caridi, M, Crippa, L & Moretto, A 2012, 'Environmental sustainability in fashion supply chains: An-exploratory case based research', *International Journal of Production Economics*, vol. 135, pp. 659-70.

Carlsson, J, Torstensson, H, Pal, R & Paras, MK 2015, *Re:Textile - Planning a Swedish Collection and Sorting Plant for Used Textiles, Feasibility study*, Re:textile; Högskolan i Borås; Region Västra Götaland Sweden.

Cassidy, TD & Han, SL-C 2013, 'Upcycling fashion for mass production', in MA Gardetti & AL Torres (eds), *Sustainability in Fashion and Textiles*, Sheffield : Greenleaf Pub.

Chapin, FS, III, Kofinas, GP, Folke, C, Chapin, MC, Kofinas, GP & SpringerLink 2009, *Principles of ecosystem stewardship : resilience-based natural resource management in a changing world*, 1st ed. edn, New York : Springer, New York.

Chertow, M 2007, '"Uncovering" industrial symbiosis', *Journal of Industrial Ecology*, vol. 11, no. 1, pp. 11-30.

Choi, TM, Chiu, C, Govindan, K & Yue, X 2014, 'Sustainable fashion supply chain management: the European scenario', *European Management Journal*, vol. 32, no. 5, pp. 821-2.

Choi, TM, Guo, S, Ho, SSY & Li, WY 2015, 'Effects of Used Garment Collection Programs in Fast-Fashion Brands', in TM Choi & TCE Cheng (eds), *Sustainble Fashion Supply Chain Management*, Springer International Publishing, Switzerland.

Choi, TM, Li, Y & Xu, L 2013, 'Channel leadership, performance and coordination in closed loop supply chains', *International Journal of Production Economics*, vol. 149, pp. 371-80.

Circle Economy 2017, *Fibersort*, Circle Economy, viewed 10 oct 2017, <https://www.circle-economy.com/case/fibersort/#.WcstQ3dh0qI>.

Claudio, L 2007, 'Waste Couture: Environmental Impact of the Clothing Industry', *Environmental Health Perspectives*, vol. 115, no. 9, pp. A448-A54.

Cobbing, M & Vicaire, Y 2017, *Fashion at the Crossroad*, Greenpeace, Hamburg, Germany.

Cradle to Cradle Product Innovation Institute 2017, *Get on the Path*, Cradle to Cradle Product Innovation Institute,, viewed 28 Sep 2017, <http://www.c2ccertified.org/get-certified>.

Crandall, R 2006, 'How Green Are Your Supply Chains?', *Industrial Management*, vol. 48, no. 3, pp. 6-11,4.

Crofton, SO & Dopico, LG 2007, 'Zara-Inditex and the Growth of Fast Fashion', *Essays in Economic & Business History*, vol. XXV.

Dissanayake, G & Sinha, P 2015, 'An examination of the product development process for fashion remanufacturing', *Resource, Conservation and Recycling*, vol. 104, pp. 94-102.

Earley, R 2017, 'Designing Fast & Slow. Exploring fashion textile product lifecycle speeds with industry designers', *The Design Journal*, vol. 20, pp. 2645-56.

Earley, R & Goldsworthy, K 2015, 'Designing for Fast and Slow Circular Fashion Systems: Exploring Strategies for Multiple and Extended Product Cycles', paper presented to Product Lifetime And The Environment, Nottingham Trent University.

EEA 2015, *The European environment - state and outlook 2015: synthesis report*, European Environment Agency, Copenhagen.

Elander, M & Ljungkvist, H 2016, *Critical aspects in deign for fiber-to-fiber recycling of textiles*, Mistra Future Fashion, Sweden.

Elander, M, Tojo, N, Tekie, H & Hennlock, M 2017, *Impact assessment of policies promoting fiber-to-fiber recycling of textiles*, Mistra Future Fashion, Sweden.

Ellen MacArthur Foundation 2015, *Towards a Circular Economy: Business rationale for an accelerated transistion*, Ellen MacArthur Foundation, United States.

Ellen MacArthur Foundation n.d., *Circular Economy Overview*, Ellen MacArthur Foundation,, viewed 20 oct 2017, <https://www.ellenmacarthurfoundation.org/circular-economy/overview/concept>.

European Commission 1976, *The Potential for Substituting Manpower for Energy; study no. 76/13, for DG Manpower*, European Commission, Brussels.

European Commission 2017, *Circular Economy*, viewed 13 oct 2017, <http://ec.europa.eu/environment/circular-economy/index_en.htm>.

Ewen, S 1976, *Captains of consciousness : advertising and the social roots of the consumer culture*, New York : McGraw-Hill, New York.

Ewen, S 1999, *All Consuming Images: The Politics of Style in Contemporary Culture*, Basic Books.

Fletcher, K 2010, 'Slow Fashion: An Invitation for Systems Change', *Fashion Practice*, vol. 2, no. 2, pp. 259-66.

Fletcher, K 2013, *Sustainable Fashion and Textiles: Design Journeys*, Taylor & Francis.

Fransson, K, Brunklaus, B, Sverker, M & Zhang, Y 2013, 'Managing chemical risk information: The case of Swedish retailers and Chinese suppliers in textiles supply chain', in MA Gardetti & AL Torres (eds), *Sustainability in Fashion and Textiles: Values, Design, Production and Consumption*, Sheffield : Greenleaf Pub.

Frosch, RA & Gallopoulos, NE 1989, 'Strategies for Manufacturing', *Scientific American*, vol. 261, no. 3, pp. 144-53.

Gam, HJ, Hauntian, C, Farr, C & Kang, M 2010, 'Quest for the eco-apparel market: a study of mother's willingness to purchase organic cotton clothing for their children', *International journal of consumer studies*, vol. 34, pp. 648-56.

Gardetti, MA & Torres, AL 2013, *Sustainability in fashion and textiles values, design, production and consumption*, Sheffield : Greenleaf Pub.

GFA & BCG 2017, *Pulse of the Fashion Industry*, Copenhagen: Global Fashion Agenda; The Boston Consulting Group.

Ghemawat, P, Nueno, JL & Dailey, M 2003, *ZARA: Fast fashion*, vol. 1, Harvard Business School Boston, MA.

Global Change Award 2017a, *Content thread*, Global Change Award, H&M Foundation, viewed 10 oct 2017, <http://globalchangeaward.com/winners/content-thread/>.

Global Change Award 2017b, *Grape leather*, Global Change Award, H&M Foundation, viewed 10 oct 2017, <https://globalchangeaward.com/winners/grape-leather/>.

Global Change Award 2017c, *Manure couture*, Global Change Award, H&M Foundation, viewed 10 oct 2017, <https://globalchangeaward.com/winners/manure-couture/>.

Goldsworthy, K 2014, 'Design for Cyclability: pro-active approaches for maximising material recovery', *Making Futures*, vol. 3.

Goldsworthy, K 2017, 'The Speedcycle: a design-led framework for fast and slow circular fashion lifecycles', *The Design Journal*, vol. 20, pp. 1960-70.

Goworek, H, Hiller, A, Fisher, T, Cooper, T & Woodward, S 2013, *Consumers' attitudes towards sustainable fashion: Clothing usage and disposal*, Sheffield : Greenleaf Pub.

Graedel, TE, Comrie, PR & Sekutowski, JC 1995, 'Green Product Design', *AT&T Technical Journal*, vol. 74, no. 6, pp. 17-25.

Greenpeace 2011, *Dirty Laundry - Unravelling the corporate connections to toxic water pollution in China*, Greenpeace, Amsterdam, The Netherlands.

Gulich, B 2006, 'Designing textile products that are easy to recycle', in Y Wang (ed.), *Recycling in Textiles*, Woodhead Publishing Limited, Cambridge.

H&M 2017, *Sustainability Report 2016*, H&M Group, Stockholm, <http://sustainability.hm.com/content/dam/hm/about/documents/en/CSR/2016%20Sustainability%20report/HM_group_SustainabilityReport_2016_FullReport_en.pdf>.

H&M Group 2017, *Successful methods found for recycling blend textiles into new fibres*, H&M Group, viewed 11 sep 2017, <https://about.hm.com/en/media/news/general-2017/Successful-method-found-for-recycling-blend-textiles-into-new-fibres.html>.

Ha-Brookshire, JE & Hodges, NN 2009, 'Socially responsible consumer behaviour? Exploring used clothing donation behavior', *Clothing and Textiles Research Journal*, vol. 27, no. 3, pp. 179-96.

Haug, A & Busch, J 2015, 'Towards an Ethical Fashion Framework', *Fashion Theory*, pp. 1-23.

Hawley, JM 2006, 'Textile recycling: a system perspective', in Y Wang (ed.), *Recycling in Textiles*, Woodhead Publishing Limited Cambridge.

Heidebrecht, SE & Kozar, JM 2013, 'Development and the garment industry: Commonwealth of the Northern Mariana Islands', in MA Gardetti & AL Torres (eds), *Sustainability in Fashion and Textiles*, Sheffield : Greenleaf Pub.

Hutchison, PD, Nyks, K, Scott, JP, Chomsky, N & Francis, M 2015, *Requiem for the American Dream*, PP Naked City Film, United States. Distributed by Gravitas Ventures.

Hvass, KK 2015, 'Business Model Innovation through Second Hand Retailing: A Fashion Industry Case*', *The Journal of Corporate Citizenship*, no. 57, pp. 11-32.

ILO 2016, *Regional Model Competency Standards: Garment Work*, International Labour Organization, Geneva.

Interreg 2016, *Fibersort: Closing the loop in the textiles industry*, European Union, viewed 15 Jun. 2017, <http://www.nweurope.eu/projects/project-search/bringing-the-fibersort-technology-to-the-market/downloads/>.

Iris van Herpen n.d., *About*, viewed 15 oct 2017, <http://www.irisvanherpen.com/about>.

Jackson, T 2017, *Prosperity without growth: foundations for the economy of tomorrow*, Abingdon, Oxon ; New York, NY : Routledge, an imprint of the Taylor & Francis Group

Joule, E 2011, 'Fashion-forward thinking: Sustainability as a business model at Levi Strauss', *Global Business and Organizational Excellence*, vol. 30, no. 2, pp. 16-22.

Joy, A, Sherry, JF, Venkatesh, A, Wang, J & Chan, R 2012, 'Fast Fashion, Sustainability, and the Ethical Appeal of Luxury Brands', *Fashion Theory*, vol. 16, no. 3, pp. 273-96.

Kahneman, D 2012, *Thinking, fast and slow*, Penguin, London.

KappAhl 2016, *KappAhl 2016 - Annual Report Part 1 Operations/ Sustainability/ Earnings*, KappAhl, Sweden.

Köhrer, E & Schaffrin, M 2016, *Fashion Made Fair: Modern--Innovative--Sustainable*, Prestel, United Kingdom: United States.

Korgen, JO & Gallanger, VA 2015, *The True Cost of Low Prices - The Violence of Globalization*, 2nd edn, Orbis Books, New York.

Kumar, S & Malegeant, P 2006, 'Strategic alliance in a closed-loop supply chain, a case of manufacturer and eco-non-profit organization.', *Technovation*, vol. 26, no. 10, pp. 1127-35.

Laws, S, Harper, C, Jones, N & Marcus, R 2013, *Research for Development : A Practical Guide*, 2nd ed. edn, London : Sage, London.

Lee, KE 2017, 'Environmnetal Sustainability in the Textile Industry', in SS Muthu (ed.), *Sustainability in the Textile Industry*, Springer, Hong Kong.

Leonas, KK 2017, *The Use of Recycled Fibers in Fashion and Home Products*, 3, Springer, Singapore.

Mathews, B 2015, *Closing the Loop*, MCL Global, <https://www.circle-economy.com/wp-content/uploads/2016/05/CTL-Samples-Circle-Economy-1.pdf>.

McCorquodale, D, Hanaor, C & Siegle, L 2006, *Recycle: The Essential Guide*, Black Dog.

McDonough, W & Braungart, M 2002, *Cradle to cradle : remaking the way we make things*, 1st edn, North Point Press, New York.

McKinsey&Co. 2016, *The State of Fashion 2017*, McKinsey & Co.

MEA 2005, *Ecosystems and Human Well-being: Synthesis.*, Wachington DC: World Resources Institute.

Miljøstyrelsen 2014, *Mindre affald og mere genanvendelse i tekstilbranchen*, Miljøstyrelsen, Copenhagen.

Minney, S 2011, *Naked fashion : the new sustainable fashion guide*, Oxford : New Internationalist Publications Ltd, Oxford.

Mistra Future Fashion n.d.-a, *sustainable fashion*, Mistra Future Fashion, viewed 10 oct 2017, <http://mistrafuturefashion.com/sustainable-fashion/>.

Mistra Future Fashion n.d.-b, *What we do*, Mistra Future Fashion, viewed 16 May 2017, <http://mistrafuturefashion.com/what-we-do/>.

Moorhouse, D & Moorhouse, D 2017, 'Sustainable Design: Circular Economy in Fashion and Textiles', *The Design Journal*, vol. 20, pp. 1948-59.

Moreau, V, Sahakian, M, Griethuysen, P & Vuille, F 2017, 'Coming Full Circle: Why Social and Institutional Dimensions Matter for the Circular Economy', *Journal of Industrial Ecology*, vol. 21, no. 3, pp. 497-506.

Moreno, M, Rios, C, Rowe, Z & Charnley, F 2016, 'A Conceptual Framework for Circular Design', *Sustainability*, vol. 8, no. 9, p. 937.

Müller-Christ, G & Gandenberger, C 2006, 'Sustainable Resource Management - Illustrated at the Problems of German Textile Industry', paper presented to IFSAM VIIIth World Congress, Berlin.

Nayak, R, Singh, A, Padhye, R & Wang, L 2015, *RFID in textile and clothing manufacturing: technology and challenges*, Springer Science & Business Media, Heidelberg.

Niinimäki, K 2015, 'Ethical foundations in sustainable fashion', *Textiles and Clothing Sustainability*, vol. 1, no. 3.

Niinimäki, K & Hassi, L 2011, 'Emerging Design Strategies in Sustainable Production and Consumption of Textiles and Clothing', *Journal of Cleaner Production*, vol. 19, no. 16.

Nudie Jeans n.d. , *This is Nudie Jeans*, Nudie Jeans, viewed 1 Jun 2017, <https://www.nudiejeans.com/page/this-is-nudie-jeans>.

Orange Fiber n.d., *Orange Fiber*, viewed 24 sep 2017, <http://orangefiber.it/>.

Packard, V 1961, *The waste makers*, London : Longmans, London.

Pal, R 2016, 'Extended responsibility through servitization in PSS', *Journal of Fashion Marketing and Management*, vol. 20, no. 4, pp. 453-70.

Pal, R 2017, 'Sustainable Design and Business Models in Textile and Fashion Industry', in SS Muthu (ed.), *Sustainability in the Textile Industry*.

Palm, D, Elander, M, Watson, D, Kiørboe, N, Salmenperä, H, Dahlbo, H, Rubach, S, Hanssen, O-J, Gíslason, S, Ingulfsvann, A-S & Nystad, Ø 2015, *A Nordic textile strategy : Part II: A proposal for increased collection, sorting, reuse and recycling of textiles*, 2015:513 vols., TemaNord, Nordisk Ministerråd, Copenhagen.

Palme, A 2017, 'Recycling of cotton textiles: Characterization, pretreatment, and purification', Degree of Doctor of Philosophy thesis, Gothenburg., Sweden: Chalmers University of Technology.

Pasquinelli, I & Ravasio, P 2013, 'Ethical fasion in Western Europe: A survey of the status quo through the digital communications lens', in MA Gardetti & AL Torres (eds), *Sustainability in Fashion and Textiles: Values, Design, Production and Consumption*, Sheffield: Greenleaf Pub.

Paulitsch, K, Baedeker, C & Burdick, B 2004, 'Am Beispiel Baumwolle: Flächennutzungskonkurrenz durch exportorientierte Landwirtschaft: welche Globalisierung ist zukunftsfähig?', *Wuppertal Papers - Institute für Klima, Umwelt, Energie*, vol. 148.

Payne, A 2015, 'Open- and closed-loop recycling of textile and apparel products', in SS Muthu (ed.), *Handbook of Life Cycle Assessment (LCA) of textiles and clothing*, Cambridge, UK : Woodhouse Publishing

Pearce, DW & Turner, RK 1989, *Economics of natural resources and the environment*, New York : Harvester Wheatsheaf, New York.

Pedersen, ERG & Andersen, KR 2015, 'Sustainability Innovators and Anchor Draggers: A Global Expert Study on Sustainable Fashion', *Journal of Fashion Marketing and Management*, vol. 19, no. 3, pp. 315-27.

Poldner, K 2013, 'Zigzag or interlock? The case of the Sustainable Apparel Coalition', in MA Gardetti & AL Torres (eds), *Sustainbility in Fashion and Textiles*, Sheffield : Greenleaf Pub.

Qureshi, MI, Iftikhar, M, Bhatti, MN, Shams, T & Zaman, K 2013, 'Critical elements in implementations of just-in-time management: empirical study of cement industry in Pakistan', *SpringerPlus*, vol. 2, no. 1, p. 645.

Radhakrishnan, S 2017, 'Denim Recycling', in SS Muthu (ed.), *Textiles and clothing sustainability : recycled and upcycled textiles and fashion*, Springer, Singapore.

Ræbild, U & Bang, AL 2017, 'Rethinking the Fashion Collection as a Design Strategic Tool in a Circular Economy', *The Design Journal*, vol. 20, pp. 589-99.

Ragnarsdottír, V & Sverdrup, H 2015, *Limits to growth revisited*, Geoscientist online, viewed 20 aug 2017, <https://www.geolsoc.org.uk/Geoscientist/Archive/October-2015/Limits-to-growth-revisited>.

Realff, M 2006, 'Systems planning for carpet recycling', in Y Wang (ed.), *Recycling in Textiles*, Woodhead Publishing Limited Cambridge, pp. 46-57.

Roberts, P 2014, *The Impulse Society*, Bloomsbury Publishing, London: .

Rockström, J, Steffen, W, Noone, K, Persson, Å, Chapin, F, Lambin, E, Lenton, T, Scheffer, M, Folke, C, Schellnhuber, H, Nykvist, B, de Wit, C, Hughes, T, van Der Leeuw, S, Rodhe, H, Sörlin, S, Snyder, P, Costanza, R, Svedin, U, Falkenmark, M, Karlberg, L, Corell, R, Fabry, V, Hansen, J, Walker, B, Liverman, D, Richardson, K, Crutzen, P & Foley, J 2009, 'Planetary Boundaries: Exploring the Safe Operating Space for Humanity', *Ecology and Society*, vol. 14, no. 2, p. 302.

Roth, G & DiBella, AJ 2015, *Systemic change management : five capabilities for improving enterprises*, New York, NY : Palgrave Macmillan.

Sachs, J 2015, *The age of sustainable development*, New York : Columbia University Press.

Saldaña, Ja 2016, *The coding manual for qualitative researchers*, Third ed. edn, London : SAGE.

Schwab, K 2017, *The Fourth Industrial Revolution*, Crown Publishing Group.

Sheldon, R & Arens, E 1932, *Consumer Engineering: A New Technique for Prosperity*, Harper.

Shen, B 2014, 'Sustainable Fashion Supply Chain: Lessons from H&M', *Sustainability*, vol. 6, no. 9, pp. 6236-49.

Soex Group n.d., *Soex Group*, Soex Group, viewed 18 Sep 2017, <http://www.soexgroup.com/>.

Stahel, WR 2010, *The performance economy*, 2nd ed. edn, Basingstoke, England. New York : Palgrave Macmillan.

Stahel, WR 2016, 'The circular economy', *Nature*, vol. 531, no. 7595, p. 435.

Stål, H & Hervé, C 2017, 'A Decouple Perspective on Circular Business Model implementation: illustrations from Swedish apparel', *Journal of Cleaner Production*, vol. Vol. 171, pp. 630-43.

Turker, D & Altuntas, C 2014, 'Sustainable supply chain management in the fast fashion industry: An analysis of corporate reports', *European Management Journal*, vol. 32, no. 5, p. 837.

Ulasewicz, C & Baugh, G 2013, 'Creating new from that which is discarded', in MA Gardetti & AL Torres (eds), *Sustainability in Fashion and Textiles*, Sheffield : Greenleaf Pub.

Veblen, T & Mills, CW 1965, *The Theory of the Leisure Class*, Augustus M. Kelley.

Vigga n.d., *Om Vigga*, viewed 10 oct 2017, <https://vigga.us/om-os-presse/om-os/>.

Wackernagel, M 1996, *Our ecological footprint : reducing human impact on the earth*, Gabriola Island, B.C. : New Society Publishers, Gabriola Island, B.C.

Wang, Y 2006a, 'Carpet recycling technologies', in Y Wang (ed.), *Recycling in Textiles*, Woodhead Publishing Limited Cambridge, pp. 58-70

Wang, Y 2006b, 'Introduction', in *Recycling in Textiles*, Woodhead Publishing Limited, Cambridge, pp. 1-3.

Watson, D, Kiørboe, N, Palm, D, Tekie, H, Ekvall, T, Lindhqvist, T, Tojo, N, Salmenperä, H, Hanssen, OJ, Rubach, S, Lyng, K-A & Gíslason, S 2015, *EPR-systems and new business models : Part II: Policy packages to increase reuse and recycling of textiles in the Nordic region*, 2015:514 vols., TemaNord, Nordisk Ministerråd, Copenhagen.

Weetman, C 2016, *A Circular Economy Handbook for Business and Supply Chains: Repair, Remake, Redesign, Rethink*, Kogan Page.

Worn Again n.d., *Home*, Worn Again, viewed 10 Oct 2017, <http://wornagain.info/>.

ZARA n.d., *Clothing collect*, ZARA, viewed 9 Jul 2017, <https://www.zara.com/us/en/sustainability-collection-program-l1452.html>.

Zhu, X, Song, B, Ni, Y, Ren, Y & Li, R 2016, *Business trends in the digital era : evolution of theories and applications*, Shanghai, China : Shanghai Jiao Tong University Press, Singapore : Springer.

APPENDIX 1.

Overview of drivers, inhibitors and enablers identified in literature and empirical data.

	Category		**Additional findings**
Drivers	External pressure		
	Securing future resources		
	Value of textile waste		+ New business opportunities
	Marketing as a circular company		
	Potential extended producer responsibly		
			+ Reach climate goals + Engage with consumers + Competition
	Category	**Sub-category**	**Additional findings**
Inhibitors	No technology to support textile-to-textile recycling on a commercial scale	Lack of automatic sorting	
	Separation of materials	Separation of blends /Technical and biological nutrients /Chemical and mechanical recycling	
		Additives	
		Lack of information about textiles (fibres, chemicals)	
		Ensure there is no chemical pollution	
	Recycling of textiles must fit	Environmental	

	within sustainability framework	Social	
	Costs	Restoring quality of the fibres	
		Price on virgin materials vs. Recycled materials	
		Of sorting and recycling at present stage	
			+ Initial cost of innovation restructuring and cost of research and development of materials and technology
	Design for recyclability – lack of connection between design and recycling		+ Many decisions-makers influence the creation of products in big organisations
	Size and complexity of supply chain		
	Lack of systemic support		+ There is not the legal support to create textile waste streams through the companies + No sufficient market for recycling
			+ Scale + Not a clear definition/path to follow
Enablers	Technology	Potential recycling technology	+ Digitalisation

		Potential sorting technology	
	Design and new materials	Design for recyclability/disassembling	
		Biodegradable materials	
		Recyclable materials	
		Mono-materials	
			+ New materials creates a challenge with recycling stream companies that chose to introduce new materials must take responsibility for the recycling of them
	Collaboration		
	Garment collection		
Needed technology	Recycling technology		
	Sorting technology/auto-sorting		
	Innovation/digitalisation: surface-scanning		+ 3D printing + Decentralised production and digital recipes + Digital passport (ID-code or chip) + Material scanning for easy and commercial sorting + Radio Frequency Identification (RFID)

			+ H&M Global Change Awards – Content Thread + Tagging + Connecting sorting and recycling + Connecting demand and supply of "textile waste" + Informing consumers about production (Barcode, QR-code)
			+ Functions of technologies: + Traceability + Transparency + Standardisation + Automatisation + Commercialising
Needed systemic change	Replace linear production models/build circular business case		+ Scale/volume to create business case
	Collaboration	Collaboration to collect and manage waste stream with a collector like I:CO or with charity or innovators or researchers/academia	
			+ Redefine consumer relationship for access to resources + Collaboration between

			designer and recycler. Design for recyclability
	Slow and fast production systems		
			+ Products is the means, change of production is the goal