



CHALMERS
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Implementing Circularity in the Supply Chain of Used Textiles

An analysis of the textile handling system in Sweden and its potential for enhanced circularity

Bachelor's thesis in Industrial Engineering and Management

LINUS BERG
MOA GUNNARSSON
TOVE LINDSTRÖM

JASMIN MIR HAGH PASAND
ANNA QIAN RUDIN
NIKI SADEGHI

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS

DIVISION OF SUPPLY AND OPERATIONS MANAGEMENT

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and its potential for enhanced circularity

Omställningen till en Cirkulär Försörjningskedja för
Använda Textilier

En analys av textilhanteringen i Sverige och dess
potential för ökad cirkularitet

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Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

Cover: The picture represents collected used textiles for second-hand and recycling.
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Abstract

A transformation to a sustainable textile industry requires circularity. The increase of textile consumption in combination with its highly polluting production phase, places a demand for material circulation. Textile collection, sorting and offset, in terms of the final stage for the used textiles in the supply chain, are critical in enabling increased reuse and recycling of used textiles. These circular practises are today yet to be established, requiring innovative development.

The European Parliament has addressed the challenge through the Waste Framework Directive which calls for advanced waste management in all member states. To accomplish this in the Swedish textile industry, the government has proposed an extended producer responsibility. By 2025, textile producers will be responsible for collection of all material put on the market. This bachelor's thesis from Chalmers University of Technology investigates the different roles of the stakeholders in the supply chain of used textiles. Taking on a Supply Chain Management perspective, this report outlines the textile handling activities of the interviewed actors and presents them in a clarifying flow-chart. Lastly, an analysis of the current system is performed through that same perspective in order to shed light on the obstacles and possibilities in the shift to a circular textile industry.

The theoretical research of the study consists of a literature review where the fundamental pillars of a circular textile industry are investigated and studied, as well as the shortages of information and statistics discovered. Actors from various fields in the supply chain are interviewed regarding their activities as well as what they experience as barriers and enablers in their operations, today and in the near future. Currently, non-governmental organisations stand for the majority of the volumes collected and with a potential producer responsibility, it is expected that the volumes will increase. There are no constraints in regard to the amounts that can be collected, the obstacles rather stem from the sorting and later disposal of the textiles. This being a contributing factor to the vast numbers of volumes exported to developing countries or more efficient sorting facilities in Europe. Actors hope for an alteration in consumers mindsets since their possible demand for used textiles will help its end-of-life and decrease the collected volumes faster. Consumers might also affect the circularity by indirectly influencing the producers to manufacture sustainable goods that are easily recycled, with transparent operations.

In order to enhance circularity in in Sweden, the actors involved in the textile industry, ranging from its production phase to its post-consumer phase, must collaborate in all aspects of the supply chain through streamlined operations. An increase in the capacity of Swedish textile circulation and thereby a transition to a circular economy, requires innovation and widespread information together with sustainable product design. The economic profitability gained from the linear economy has been the reason for its breakthrough, and so the demand for value providing incentives for stakeholders, consumers and society as a whole, is necessary to drive the transition from a linear to a circular economy forward.

Key words: Circular textiles, Waste management, Recycling and Reuse

Sammanfattning

En omställning till en hållbar textilindustri kräver cirkularitet. Ökningen i textilkonsumtion i kombination med dess mycket förorenande produktionsfas skapar en efterfrågan på cirkulära material. Insamling, sortering och avsättning, i termer av slutstationen för de använda textilierna i försörjningskedjan, är avgörande för att möjliggöra ökad återanvändning och återvinning av använda textilier. Dessa cirkulära metoder är ännu inte helt etablerade och kräver innovativ tillväxt och kontinuerlig insamling av data.

Europaparlamentet har adresserat utmaningen genom "The Waste Framework Directive", som kräver utökad avfallshantering i alla medlemsstater. För att uppnå detta inom den svenska textilindustrin har regeringen föreslagit ett utökat producentansvar. Förslaget innebär att vid år 2025 ska textilproducenter ansvara för insamlingen av allt tillverkat material som säljs på marknaden. Denna kandidatuppsats vid Chalmers Tekniska Högskola undersöker intressenternas olika roller i försörjningskedjan för använda textilier. Med utgångspunkt i ett Supply Chain Management-perspektiv, beskriver denna rapport aktiviteterna i textilhanteringen för samtliga intervjuade aktörer samt presenterar dessa i ett förtydligande flödesschema. Slutligen utförs en analys av det nuvarande systemet för att belysa hinder och möjligheter i övergången till en cirkulär textilindustri.

Studiens teoretiska underlag består av en litteraturstudie där fundamenten i en cirkulär textilindustri undersöks och presenteras, tillsammans utpekande av brister i tillgänglig information och statistik. Aktörer från olika delar av försörjningskedjan intervjuas kring sina aktiviteter såväl som vad de upplever som hinder och möjligheter i sina verksamheter, både idag och inom en snar framtid. För närvarande står icke-statliga organisationer för majoriteten av de insamlade volymerna och med ett potentiellt producentansvar förväntas volymerna att öka. Det finns inga begränsningar när det gäller de mängder som kan samlas in, hindren härrör snarare från sortering och senare avsättning av textilier. Detta är en bidragande faktor till att en stor mängd för närvarande exporteras till utvecklingsländer eller mer effektiva sorteringsanläggningar i Europa för vidare hantering. Aktörerna hoppas på en förändring i konsumenternas köpbeteenden, eftersom denna potentiella efterfrågan på använda textilier ytterligare kan bidra till ökade avsättningsmöjligheter samt minska de insamlade volymerna i högre takt. Konsumenterna kommer också att kunna påverka cirkulariteten genom att indirekt påverka producenterna att tillverka hållbara varor som enklare kan återvinnas, med transparens i verksamheten.

För att förbättra cirkulariteten i Sverige måste inblandade aktörer i textilindustrin, från produktionsfasen till dess efterkonsumtionsfas, samarbeta i alla delar av försörjningskedjan genom att effektivisera verksamheten. En ökad kapacitet för svensk textilkirkularitet och därmed en övergång till en cirkulär ekonomi, kräver innovation och omfattande informationspridning i samband med hållbar produktdesign. Den linjära ekonomins lönsamhet har hittills varit orsaken till dess bestånd, och det krävs således värdeskapande incitament för intressenter, konsumenter och samhället som helhet, för att driva övergången från en linjär till en cirkulär ekonomi framöver.

Nyckelord: Cirkulära textilier, Avfallshantering, Återvinning och Återanvändning

Note: The report is written in English.

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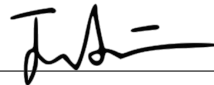
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Linus Berg



Moa Gunnarsson



Tove Lindström



Jasmin Mir Hagh Pasand



Anna Qian Rudin



Niki Sadeghi

Definitions

- EEA - European Environment Agency
- EMF - Ellen MacArthur Foundation
- EPA - Environmental Protection Agency.
The Swedish governmental managing authority within environment with the purpose to support sustainable development with basis in the ecologic dimension.
- EPR - Extended producer responsibility
- FTI - The Packaging and Newspaper Collection Service.
A Swedish limited company responsible for collection and recycling of packages and newspapers.
- GDPR - General Data Protection Regulation
- IVL - Swedish Environmental Research Institute.
An independent Swedish research institute within environment and sustainability.
- NGO- Non-governmental organisation
- OECD - The Organisation for Economic Cooperation and Development
- SATIN - Towards a sustainable circular system of textiles in the Nordic region
- SCM - Supply Chain Management
- SDG - Sustainable development goals
- SMED - Svenska MiljöEmissionsData.
A Swedish consortium with the purpose to long-term collect and develop emission statistics in air, water, waste and polluting chemicals.
- SOU - Statens offentliga utredningar
- SSCM - Sustainable Supply Chain Management
- SVOA - Stockholm Vatten och Avfall
- VSM - Value Stream Mapping
- VTI - The Swedish National Road and Transport Research Institute.
A Swedish governmental research institute within the transport sector.
- WFD - Waste Framework Directive
- WFM - Waste flow management

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1 Introduction

The textile industry today is known to be one of the major polluting industries worldwide (Nørup et al., 2018). The European Parliament (2019) states that the production of clothes accounts for 2-10% of the environmental impact from consumption in the EU. There are many sources for information on the environmental impact by production of garments, however, there is a lack in statistics and information regarding textiles as a whole. Nørup et al. (2018) suggest that an immense environmental improvement potential can be obtained through better treatment of discarded textiles. The environmental impacts and large resource consumption when producing textiles, can be partially resolved by prolonging the life cycle of textiles (Nørup et al., 2018).

1.1 Background

According to Statistics Sweden’s data listed by the Swedish Environmental Protection Agency (EPA, 2019a), the net inflow of textiles has increased rapidly between the years 2000 and 2019. It is also stated that the amount of home textiles, such as bedding, cloths and so forth, stand for the biggest increase per person in Sweden. The net inflow has increased almost 30% during the last two decades, the increase corresponds to approximately 3 kilograms per person (Swedish EPA, 2019a). This had lead to an amounted volume of 13.7 kilograms in 2019 in the textile net inflow (Swedish EPA, 2019b).

In Sweden’s modern day society, an immense number of textiles, over 7.5 kilograms per person and year, end up in the residual waste and are sent straight to incineration (Swedish EPA, 2019b). When an analysis on the collection was made by Svenska Miljö Emissions Data (SMED) on behalf of the Swedish EPA, the assessment was that 59% of the used textiles were in such condition that they could have been reused (Hultén et al., 2016; Nørup et al., 2018).

Consumers get rid of textiles when they have become ragged, unmodern, due to a full closet or when they have outgrown them (Swedish EPA, 2019b). The Swedish EPA (2019b) means that the way consumers choose to get rid of their textiles depends completely on habits, knowledge, finances and collecting opportunities. According to Watson and Palm (2016), a limited part of the textiles are collected separately and the numbers in the Nordic countries vary between 22% in Sweden to 46% in Denmark. Besides the various offset opportunities, in terms of the final stage for the used textiles in the supply chain, great amounts of separately collected textiles are exported to other countries. The aforementioned is due to the high costs in Sweden, such as for all Nordic countries (Watson & Palm, 2016).

The Royal Swedish Academy of Engineering Sciences (IVA, 2020) describe that up until now, there has been a heavy demand for reusable textiles in many countries across the globe, in order to give impoverished people an opportunity to purchase clothes at a low cost. However, the report states that many countries have now set up restrictions on imports of used textiles. The dominant reason for this is to protect the domestic textile industries from competition with cheaper importation from Europe (IVA, 2020). Approximately forty countries worldwide have either stopped or banned the import of used textiles, which puts pressure on finding new ways to make use of the resource (IVA, 2020). The countries that have received the largest quantities from the Nordic countries are in order Poland, Pakistan, Iraq and Bulgaria (Watson & Palm, 2016).

Jawahir and Bradley (2016) explain that to not reuse and recycle used textiles to a greater degree is a waste

of resources, but unfortunately a natural part of the linear economy that has been dominant for a long time. The concept of linear economy ignores the impact on the environment and focuses mainly on economic growth (Sauvé et al., 2016). “Take-make-dispose” is often referred to when discussing linear consumption patterns, but these traditional ways of consuming are now facing constraints due to the scarcity of resources (Ellen MacArthur Foundation, [EMF], 2013). The circular economy according to EMF (2013), is defined as an industrial system, characterised by restoration and regeneration of design and intent. The concept optimises resource needs and creates efficient systems and therefore replaces “end-of-life” approaches (EMF, SUN & McKinsey, 2015). Sauvé, Bernard & Sloan (2016) mean that the concept of circular economy comes about in a closed loop where waste is seen as an input. De la Motte et al. (2019) claim that textiles in Sweden have up until now, not been handled according to the waste hierarchy. According to the authors, priority should be assigned mainly to avert generation of waste, superseded by reuse and recycling, with incineration and safe disposal as a last resort.

According to The Swedish Government Official Reports (SOU, 2020), the most prominent regulatory initiative in order to achieve circularity in textiles is the decision by the European Parliament. The decision will be requiring member states of the EU to make certain that the collection of textiles is done separately from the residual waste. National obligations of separate collection of used textiles and discontinuing incineration will start at the latest in 2025 (SOU, 2020). The Swedish Government has decided to conduct an investigation in order to draw up a proposal regarding producer responsibility for textiles (SOU, 2020).

1.2 Scope

The scope of this study is to investigate the supply chain of used textiles in Sweden categorised as household textiles, which include all types of clothes, cloths and sheets derived from individual households. The entire supply chain ranges from textile production and import of textiles to the different end-of-life stations. However, this study will focus on the flows from the households to the different offset alternatives. The targeted flows that will be investigated are illustrated in Figure 1 below and are divided into three main categories.

Firstly, the amount of textiles that end up in the household waste and in the combustible section at the recycling station will be investigated. Secondly, this study aims to outline the activities of the actors involved in the supply chain of used textiles, primarily in the textile collection and sorting phases. Additionally, the volumes of used textiles handled by the included target groups will be analysed. The operations and capacities of the actors in the supply chain will be examined in order to investigate barriers and enablers of the actor’s processes, as well as potential changes of their role in the near future. The possible routes of used textile goods and associated offset opportunities will also be examined by quantifying and comparing offset flows, as well as potential future development. Lastly, the novel phenomenon of redistribution of used textiles through online platforms will be explored, in terms of volumes, system impact and identified trends.

Additionally to examination of the textile flows, the current circularity of the supply chain and its potential to become more circular will be discussed.

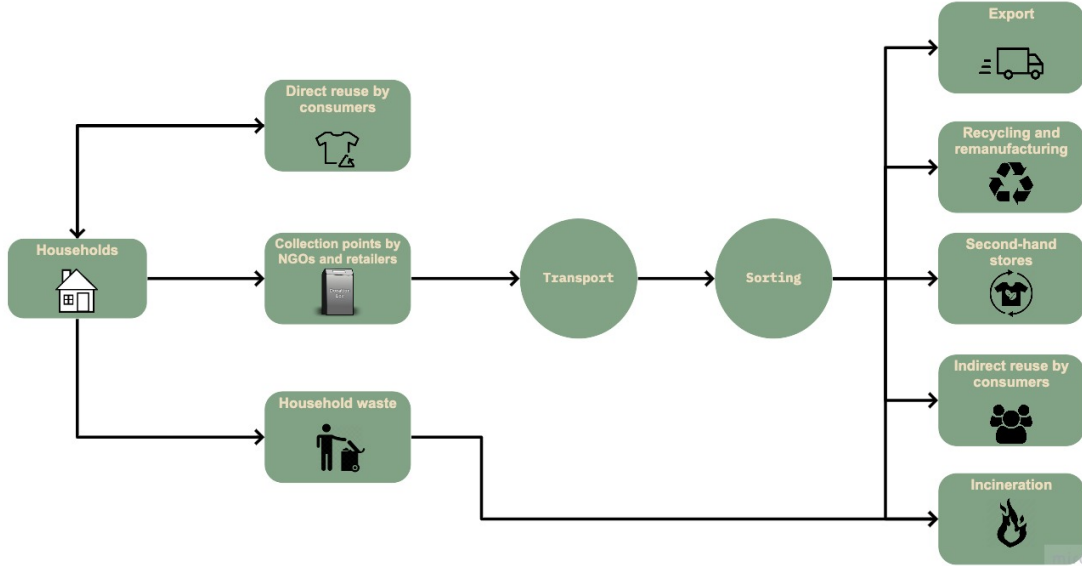


Figure 1: *The focus area in the textile supply chain*

1.3 The SATIN project

This study is conducted in collaboration with the project *Towards a sustainable circular system of textiles in the Nordic region* (SATIN), which is led by Swedish National Road and Transport Research Institute (VTI) and a collaboration between 24 projects partners within the Nordic countries. The aim of the project is to: *"Develop and test new solutions that can address the textile collection and sorting challenges by taking a Supply Chain Management (SCM) perspective"* (Kjellsdotter-Ivert et al., 2020). An ambition with this bachelor's thesis is to collaborate and share knowledge with other student projects connected to SATIN in the Nordic region. As far as supervising is concerned, Linea Kjellsdotter Ivert is representing the SATIN project and will continuously be consulting throughout the project. Furthermore, this study on the supply side of the supply chain of used textiles is complemented by a simultaneously performed master's thesis.

1.4 Purpose

The purpose of the study is to map and analyse the current and future activities in the supply chain of used textiles in Sweden and its potential to become more circular. In the scope of the study, assessment of existing volumes and capacities will be made in order to identify barriers, enablers and future prospects within the dealing of used textiles.

1.5 Problem analysis and Research Questions

According to Stål and Corvellec (2018), a recurring problem in the transformation towards a sustainable society is that established structures, frameworks, legal systems and subsidy systems today are designed according to the functions of the traditional linear economy. This in turn limits the development of circular business models both culturally and materially (Stål & Corvellec, 2018).

The Swedish strategy for a circular economy points out the direction for the long-term work towards a sustainable transformation of the Swedish society (SOU, 2020). One of the four focus areas in the national approach for circularity is to create sustainable ways of consuming and using materials, such as textiles (SOU, 2020). The Swedish government (2020a) has pointed out textiles as one of the six prioritised flows that need to be handled in the transition to a circular and bio-based economy. The government also states that there is an information gap today regarding the handling capacity in the current flow of used textiles that should be addressed. By filling this gap, appropriate measures can be implemented by the actors of the supply chain, to make it simpler for consumers and collectors to reuse and recycle textiles (Swedish Government Offices, 2020a).

In a pre-study to the investigation conducted by Kalantari et al. (2019), it is documented that several actors such as Non-Governmental Organisations (NGOs), clothing companies, waste companies, real estate companies and municipalities are facing numerous challenges in the circular system of textiles in Sweden. These challenges are among other things associated with lack of cooperation regarding solutions between the actors in the supply chain, as stated by Kalantari et al. (2019). The authors further claim that there is not enough knowledge for the time being on the capacities and volumes that are flowing through the textile supply chain, as well as what can be expected in the future. The problem analysis results in the following research questions:

- Which activities and actors are involved in the supply chain of used textiles and how will the actors' roles develop ahead?
- What volumes of used textiles are currently being collected in Sweden and what are the expected changes in quantity and quality?
- What are the barriers, enablers and future prospects in the current system?
- How does the capacity of the different actors in the supply chain match the estimated future volumes of used textiles from Swedish households?

1.6 Limitations

This study is limited by the possibilities of data collection. There is an unknown volume of textiles stored in households during an unspecified period of time without being either used or disposed of. Further, a part of the direct reuse flow is not monitored as it is given away for free to friends or family. Other deficiencies in the statistics of this study can be assumed due to a general lack of transparency and traceability in the textile industry, reinforced by the prevalence of rogue textile collectors whom do not report handled textile volumes.

2 Literature Review

The following chapter provides information regarding the essence of circular economy and supply chain management by introducing the components within the value circle and waste hierarchy. Further, an overall view of the circularity in the textile industry is given as well as policies and regulations for the textile reuse. Lastly, the flow of used textiles in Sweden is presented with the identified barriers and enablers of the current textile system.

2.1 Circular Economy

2.1.1 Foundations of Circular Economy

The utilisation of circularity in modern economy systems has gained a lot of interest since the 1970s (EMF, 2017c). The concept of a circular economy is an industrial and economic system which targets the reusability of raw materials and products in order to preserve value of extracted resources throughout the system. The theory aims at value preservation throughout each layer of the economic system (Angelova, 2020).

Up until now, the linear value chain has had an extensive impact in theory as well as in practise and gained a lot of popularity, however its has been a subject of criticism from environmental economists (Rietz, 2019). Today's industrial economy is substantially permeated by the linear consumption model of resource usage (EMF, 2013). As reported by Angelova (2020), the linear take-make-use-dispose model sees nature as a continuous stock of resources and raw materials that corporations and consumers have extracted without any considerable restrictions whatsoever.

As claimed by Romero and Rossi (2017), circular economy is an industrial economy that promotes a larger resource efficiency. The authors explain how circular economy aims to diminish waste and avert pollution through intention and design of products and goods. The motto should, according to Angelova (2020), instead be take-make-use-return which captures the essence of the concept. A circular economy pursues the rebuild of all sorts of capital whether them being financial, human, natural or social. It is based on the idea of a continuous flow of both biological and technological materials that flow in the "value circle", which can be viewed in Figure 2 on page 6 (EMF, 2017a).

The value circle captures the flow of materials, components, nutrients and products while adding a lucrative value (EMF, 2017a). The illustrated loops each represent their parts of the value circle. The technological cycle illustrated in blue loops in Figure 2, represents recycling and prolonging products' lifespans by designing for maintenance and reuse as well as for repair and durability. It aims to have people share products such as textiles instead of consuming one each, which would be possible if the product's lifespan was prolonged. Also, replacing damaged components or repair the product as much as possible, instead of acquiring a whole new product. The biological cycle illustrated by green loops in Figure 2 represents the materials that can re-enter the natural world harmlessly or be reintroduced to production as recycled natural feed stock, for example textile fibers designed for recyclability. These materials will biodegrade in time, after having gone through one or a couple of use cycles (EMF, 2017a). All textile fabrics can either be divided into natural fibers or synthetic fibers, sometimes a blend of both. While natural fibers such as silk, wool and cotton come from plants and animals, synthetic fibers such as polyester, rayon and spandex are man-made and are made from chemical compositions. Textiles as a whole do therefor not have a specific side in the value circle but

are in both, depending on the composition of the fabric (MasterClass, 2021).

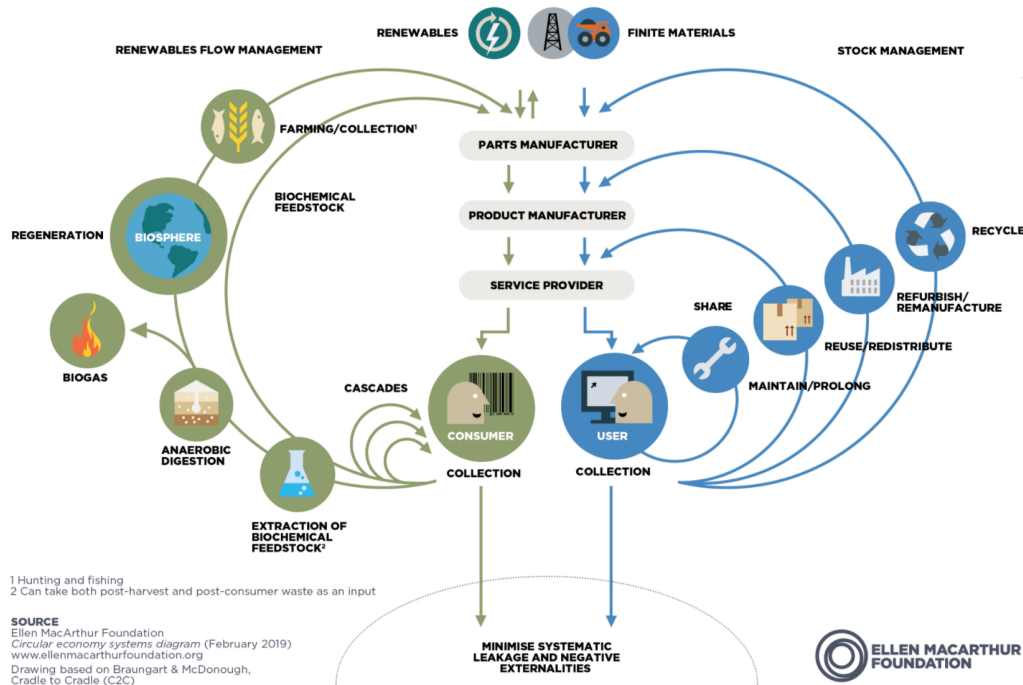


Figure 2: *The value circle* (Ellen MacArthur Foundation, 2017a)

As stated by Tedesco and Montacchini (2020), the transition to the circular model, requires a change in how used materials are viewed and actors having to acknowledge waste as a resource. This in order to renew, reuse and recycle existing materials and products which are essential actions in the shift towards a circular economy (Tedesco & Montacchini, 2020).

2.1.2 Waste Hierarchy

The transition towards a circular economy requires deviation from the throwaway mentality, at the same time as waste must be prevented and consumption of new goods decline (Maitre-Ekern, 2021). During quite some time, retaining the product's primary value has been an objective to waste prevention, which is laid out to be a focal priority of the waste hierarchy as described in EU's Waste Framework Directive (WFD) 2008/98/EC (Maitre-Ekern, 2021).

Pires and Martinho (2019) state that the present waste management directives by the European Union, aim to encourage waste prevention and the utilisation of the so called *waste management hierarchy*. The authors explain that this principle consists of the following operations in a top-down priority order regarding the waste management: preparation for reuse, recycling, other recovery (e.g. energy recovery) and lastly disposal. The European Parliament and Council (2008) defines the different terms in the waste hierarchy in the WFD 2008/98/EC document according to following:

Table 1: *The concepts of the waste hierarchy*

Concept	Definition
Waste	Refers to any object or substance which is discarded or intended to be discarded.
Prevention	Taking measures before the material, substance or product has turned into waste, that reduce the negative impacts of the caused waste on human health and the environment; the waste quantity including through the product's life length or the content of detrimental substances in products and materials.
Preparing for reuse	Cleaning, checking or repairing recovery activities, through which products or parts of products that are considered waste are prepared for reuse in order to avoid any additional pre-processing
Reuse	All operations by which components or products that are not classified as waste are used once more for equal purpose as the original one.
Recycling	All recovery operations through which materials of waste are being reprocessed into substances, materials or product whether for new or the original purposes.
Recovery	Any operation of which the principle result is waste being used for a favorable purpose through replacement of other materials for a given function, or waste being processed in preparation to fulfil that function
Disposal	All operations that are not considered recovery, even if the operation possesses a secondary effect regarding the reclamation energy or substances.

Notable is that there currently are no unambiguous definitions of the aforementioned terms and they rather depend on which perspective one takes. In this thesis, the official definitions acknowledged by the EU above have been considered appropriate, with adoption of the parts relevant for the handling of used textiles.

SMED (2018a) suggests that the waste hierarchy should act as a guideline for the order in which different treatment methods should be used and was integrated in the Swedish Environmental Code in 2016 (SFS 2016: 782). The waste hierarchy is also a part of the foundation in the Waste Framework Directive 2008/98/EC (European Parliament and Council, 2008) drawn up by the European Union, consequently also consolidated into the EU member states' national law (Pires & Marinho, 2019).

The used methods within the concepts may differ depending on which material or waste that is being handled but the overall principle stays the same, as stated by SMED (2018a). The authors further explains that the waste hierarchy principle declares that the higher up the hierarchy one gets, the more resource efficient the use of the waste becomes. Hence, priority should be given from the top down provided that it is economically and environmentally viable (SMED, 2018a). The layout of the waste hierarchy according to Nørup et al. (2019), illustrates the preferred treatments in a top-down order, with reuse as the most desirable solution. Reuse and recycling of textile, predominantly lower the environmental impact in comparison to both incineration and landfills, whilst reuse proves to be more beneficial than recycling (Sandin & Peters 2018 ; Dahlbo et al., 2017 ; Nørup et al., 2019). This is shown in Figure 3.

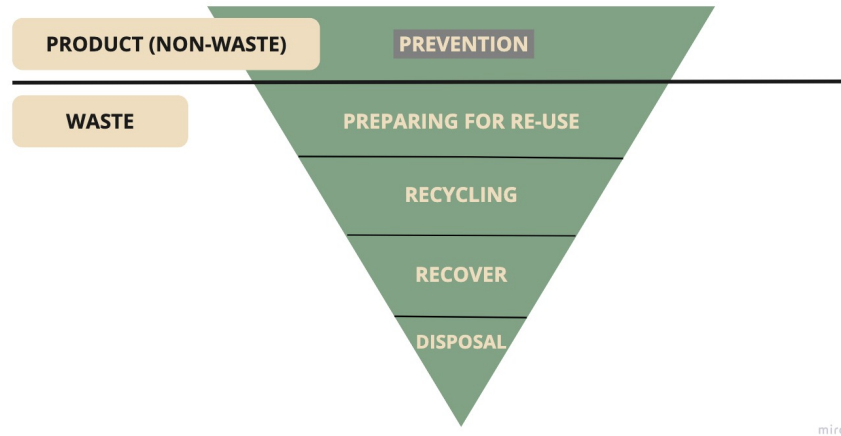


Figure 3: *The Waste Hierarchy*

Worldwide increase in generation of waste creates demand for complex waste management strategies in order to comply with stricter environmental targets and legislation frameworks (Brancoli & Bolton, 2019). About 87% of discarded textiles globally are being disposed of by incineration or landfill, whereof above 90% could be reused or recycled (Moazzem et al., 2021), although this contradicts the estimation of 59% in Sweden (Hultén et al., 2016 ; Nørup et al., 2018). During the disposal of specifically clothing, Moazzem et al. (2021) mean that about 70% of its useful life still remains and hence, priority and attention must be allocated to sustainable managing of discarded apparel.

According to the Swedish EPA (2019a), textile recycling still often require polluting production processes and therefore resemble new production but with different input material. Sandin and Peters (2018) further claim that the benefits with reuse are said to mainly arise due to the assumed evasion of new textile production. It is not known to what extent reuse of textiles in fact compensates virgin production, or if it rather develops new markets and by that increases the general consumption of textiles (Dahlbo et al., 2017 ; Swedish EPA, 2015). Likewise, Dahlbo et al. (2017) argue that uncertainties lay within whether virgin fibers can be replaced by recycled fibers because of the not yet fully developed chemical recycling processes.

2.1.3 Circular Supply Chain Management

The Council of Supply Chain Management Professionals (n.d.) defines the traditional concept of *Supply Chain Management* (SCM) as "the planning and management of all activities in sourcing and procurement, conversion and all logistics management activities". The Council's definition includes "coordination and collaboration with all channel partners" where the term partners refers to suppliers, intermediaries, third party providers as well as customers. The extended concept of SCM elevates the supply chain from solely consisting of logistics, to extend into integration of management elements in the value chain (Larson & Rogers, 1998).

Nasir et al. (2016) describe how sustainable SCM challenges the traditional perception of a supply chain, which is linear and aligns with the economic model of take-make-use-dispose and linear production. The essence of the difference between circular and linear supply chains, lies in the view upon the length of

the product life-cycle (Batista et al., 2018a) and the extent of integration of sustainability concerns in management of supply chain operations (Nasir et al., 2016). Batista et al. (2018b) suggest that connecting supply chains, sustainability and circular economy can be described as *circular supply chain*. By creating circular supply chains, the authors argue that SCM has a prominent potential to drive the transition towards circular economy, addressing both the challenge of resource depletion and contribute to reduction of waste and by-products.

Batista et al. (2018b) emphasise the complexity and extended scope that entails circular systems, due to considerations of sustainable resource-based productivity, new models for value generation and ecosystem-integration. According to Dervojeda et al. (2014), the established linearity in the current supply chains and economy is the root cause of the difficulty in transitioning to circularity. Economic barriers are according to Levering et al. (2019) a major factor in the inertia of the transition. Moreover, Dervojeda et al. (2014) point out large upfront investments and low profitability as initial barriers to circularity. However, progressive management and supply chain ecosystems can promote circular businesses by enabling resource exchange between diverse industries and thereby promote sustainable value generation (Batista et al., 2018a). Pal et al. (2019) further elevate how sharing of information and resources can be invigorated through supply chains, this exchange in turn creating favorable conditions for circular activities such as sustainable design, design for repair and maintenance.

Levering et al. (2019) divide the barriers to circular practices and operations into internal and external components. The internal dimensions are the issues of the focal organisations such as the economic bottom line and coordination, whilst external factors refer to the sustainability impacts of a larger supply chain and the complex inter-organisational collaboration required (Levering & Vos, 2019). Pal et al. (2019) state that a re-design of the logistic system is necessary in order to optimise resource utilisation and circulation. They further describe how the supply chain design has to take responsibility for all environmental impacts, such as pollution, waste and environmental damage. This kind of circular supply chains place demand for inter-firm collaboration, since transformation of production output into valuable regenerated resources require streamlined and innovative operations of logistics (Batista et al., 2018b).

Another aspect of supply chain management connected to circularity, is the environmental impact of supply chains that has proven to be highly influential in the performance on environmental objectives of organisations and companies (Nasir et al., 2016). *Sustainable Supply Chain Management* (SSCM), where the focus primarily has been on operationally reducing the negative impacts of material flow processes, has been extended by considering circular economy to include reverse logistic activities allowing resource circulation (Nasir et al., 2016).

Consecutively, Levering et al. (2019) conclude the challenge of scaling up circular supply chains in terms of cost, coordination and communication. Furthermore, Dervojeda (2014) emphasises how the severity of resource scarcity are ultimately driving circularity and putting pressure on all actors of the supply chain. Nasir et al. (2016) suggest that implementation of circular economy on a practical level is synonymous with transitioning from linear to circular supply chains. This aligns with one of the most important characteristics of SCM, the process perspective, where activities and their relations are analysed as a system (Sandberg, 2007). This in turn facilitates the management of industry-, firm- and governmental relations and interactions (Pal et al., 2019).

2.2 Circularity in the Textile Industry

2.2.1 Circular Textiles

According to Angelova (2020), the circular model applied to textile industries, strives to preserve the value of textiles by decreasing the consumption of natural resources and raw materials. As the attention given to a circular economy is amplified, so is the growing interest in recycling and increased reuse of the textiles (Sandin & Peters, 2018). The butterfly diagram, which can be viewed in Figure 2 on page 6, pinpoints the crucial role of recycling and reuse in what could be a future circular economy (EMF, 2017a).

Recycling routes can according to Sandin and Peters (2018) be divided into fabric recycling and fibre recycling. The authors define recycling of fabrics as when the old fabric of used textiles are reused in new products, while fibre recycling refers to disassembly of textile fabrics consecutive extraction and reuse of the fibers. Recycling includes the recycling routes of upcycling and downcycling as described by Sandin and Peters (2018). Upcycling means that a product made from recycled material has a higher value or quality for the consumer than the original piece, whilst downcycling refers to the recycled product or material being of lower value or quality compared to the virgin product (Sandin & Peters, 2018). Examples of upcycling of used textiles could be successful fiber recycling, usage as composites or as raw material in production of organic compounds or polymers (Stanescu, 2021).

As far as downcycling is concerned, Schmidt et al. (2016) argue that this is the major existing route for textile recycling today. The author exemplifies downcycling output such as low-grade blankets, industrial rags and upholstery. The economic value generated from downcycling is today small and the current methods provide rather limited environmental benefits, due to the low quality of the material being replaced (Schmidt et al., 2016). Hereby, recent investments in the development of feasible technologies for improved textile-to-textile recycling are of great importance (Schmidt et al., 2016). This innovative fibre recycling route aims to achieving full recycling maturity for materials other than 100% polyester, like cotton and fibre mixes (Schmidt et al., 2016).

The complexity entailing textile fiber recycling is discussed by Moazzem et al. (2021), who explain that the natural fibre apparel's landfill process have a higher environmental impact in comparison with synthetic fibre apparel. In the article, natural fibers are defined as mainly cotton, wool, viscose and flax while the synthetic fibres refer to materials such as polyester, nylon, acrylic and nylon (Moazzem et al., 2021). Recycling processes vary depending on the fibre components and therefore, the material composition will be crucial for waste management of used textiles (Roos et al., 2019). Roos et al. (2019) argue that the textile design plays a vital role in ensuring possible recycling at end-of-life, where monomaterial design is pointed out to be the most preferable, as long as it does not shorten the product's life length.

Another aspect of recycling is the take-back system in which the materials to be recovered are involved in. Guide and van Wassenhove (2002) introduce the concept of reverse supply chains and define it as a series of activities, vital in order to recover a used product from a consumer and either reuse or dispose of it. The reverse supply chain can either be an open-loop system or a closed-loop system (Gou et al., 2018). Open-loop recycling is a process in which the materials recycled are transformed into both waste product and new raw materials (General Kinematics, 2018). In an open-loop, the properties of the recycled material noticeably differs from the virgin material which makes them only usable for alternative products

and applications (Huysman et al., 2015). According to Interreg (n.d.), downcycling is a substantial part of the open-loop recycling process. On the other hand, there is closed-loop recycling where the properties of recycled materials' are preserved and suited to replace virgin material in similar products (Huysman et al., 2015). Therefore, the upcycling process can be a part of the closed-loop recycling process (Interreg, n.d.).

Hagoort (2013) states that the reason for the development of open-loop recycling is due to the quality of the used textiles or lack thereof. The quality is mostly too low for it to be used as a resource in a closed-loop and that is the reason why it is downgraded (Hagoort, 2013). Another reason for this is that the process of upcycling is still in its younger phase, lacking established technology and processes. Altogether, these factors contribute to the fact that a large fraction of used textiles are being sent to incineration (Manshoven et al., 2019).

According to EMF, less than 1% of materials that have been used to produce clothing are recycled in closed-loops into new clothing. This in turn results in 100 billion USD in losses in material worth every year (EMF, 2017b). The amount of open-loop recycling was a bit higher with a value of 12% each year on a global scale. Hereby there is an extensive potential for increased circularity when it comes to making use of textile fibers and fabric (Huysman et al., 2015). According to the Swedish EPA (2019a), the environmental profit of recycling will increase along with more optimised recycling processes as well as technologies for separating materials.

Xu et al. (2019) claim that although the WFD applies to all kinds of waste management, there is a certain validity when considering a textile context. This due to the great level of carbon emissions and energy savings that are achieved by an increase in direct reuse and textile longevity (Xu et al., 2019). The results of increasing reuse and recycling of textiles would potentially be reduction of virgin fibre production and, in the matter of reuse, additionally reduce environmental impact by averting manufacturing processes further downstream in the product life cycle of textiles (Sandin & Peters, 2018).

2.2.2 Policies for Textile Handling

In 2020, the Swedish government decided on a national approach regarding a shift towards a circular economy which clarified the course for a long term and sustainable readjustment in today's society (SOU, 2020c). An action plan was later presented in the beginning of 2021 and it takes into account four areas to focus on in order to make a shift to circular economy (SOU, 2021).

The four focus areas of the Swedish strategy according to Swedish Government Offices (2020b):

- Focus area 1: Circular economy through sustainable production and product design.
- Focus area 2: Circular economy through sustainable ways of consuming and using materials, products and services.
- Focus area 3: Circular economy through non-toxic and circular cycles.
- Focus area 4: Circular economy as driving force for business and other actors through measures to promote innovation and circular business models.

Policies and regulations promoting circularity and efficient resource usage is of the essence in the shaping of a sustainable textile industry (IVA, 2020). The government's role is to create favorable conditions for the

continuation and development of current circular initiatives in regions and municipalities, in business, universities and civil society (SOU, 2020c). Furthermore, the government is responsible for the implementation of the global goals for sustainable development in Agenda 2030 (Ministry of the Environment, 2020). Larsson (2020) suggests that transforming the ecosystem of textiles in terms of policy making requires national frameworks on responsible textile waste management, subsidising of circular manufacturing processes and reliefs enhancing profitability of circular business models.

The waste management aspect of the Swedish approach on circularity is regulated within the *Directive of the European Parliament and of the Council on waste and repealing of certain Directives*, which formulates the European ambition on waste management and waste reduction (EU, 2008). Based on the directive, the European Parliament aims to redefine the waste concept and treat waste as a resource through ambitious separation at source, material reuse and highly developed collection systems (EU, 2008). Directives are a form of secondary law, where the overlying objectives oblige enforcement in all Member States although the regulative implementation are allowed to vary between nations (EU, 2021). Hereby, statements of the *Waste framework directive* is highly relevant in analysis of the results of this thesis when evaluating the current textile collection system status and the possibilities to achieve separate textile collection by 2025 (SOU, 2020.)

The European Union (2008) suggests that the transformation into a circular society can be executed by implementation of extended producer responsibility alluding to the accepted polluter-pays principle. According to the Organisation for Economic Cooperation and Development (OECD, 2016), *Extended Producer Responsibility* (EPR) is a commonly deployed policy tool through which the responsibility of a products end-life is assigned to its producer. Relocation of responsibility aims to incentivise waste reduction, sustainable product design and stimulate development of waste collection systems (OECD, 2016).

The Swedish Government have proposed to introduce EPR in the textile industry in order to enforce the circularity transition and take action on the WFD (The Swedish Government Official Reports, 2020). According to SOU (2020), the government is proposing an EPR-model where textile producers are obliged to register themselves to textile collection system, which is nationally available and independently conducted and supervised by the Swedish EPA. All textile producers will then need to announce to the Swedish EPA that they are connected to an approved collection system, and the agency monitor the collection systems to ensure accurate separate collection and national availability (SOU, 2020). However, the responsibility of the establishment and formation of the collection system is assigned to the textile producers in order to optimise prerequisites of cost-efficiency and scalability (SOU, 2020).

2.2.3 Sustainable Development Goals and Ethics

In 2015, the United Nations took on Agenda 2030, which is an universal agenda that consists of 17 global goals for sustainable development (United Nations Development Programme, [UNDP], 2020). The end goal of the agenda is to achieve four major objectives before the year of 2030. These include eradicating extreme poverty, reducing inequalities and injustices, promoting peace and justice and to stop the climate changes (United Nations, [UN], 2019). Agenda 2030 aims to promote and align sustainability efforts in a global context, and should be incorporated on all societal levels (United Nations, 2015b).

Working towards Agenda 2030, the European commission decided in July of 2018 that a new revised waste

package was going into place, consisting of six different directives (SOU, 2020). The purpose of this package is to get the member countries of the EU to move towards a more circular economy with a higher level of resource-efficiency. According to SOU (2020), the existing objectives with regard to the relevance of the textiles, is that by year 2025 the preparation for reuse and material recycling of municipal waste must increase to at least 55 % by weight. Every five years this will increase by five percent until the year 2035, which is how far this goal is set in the directive (SOU, 2020).

Considering the scope of this thesis and the overlying SATIN project, the goal with highest materiality in terms of sustainability impact is Goal 12: *Sustainable consumption and production*. Goal 12 aims to implement sustainable consumption and production patterns, in order to govern sustainable usage of natural resources which interlinks the concept of circular economy with the agenda (UN, 2021). Moreover, the textile industry is problematic due to irresponsible handling of textile waste and generation of polluting chemicals and by-products, which in turn places a demand for improved waste management (Šajin, 2019). Substantial reduction of waste generation may be achieved by handling of used textiles according to the waste hierarchy, with prevention being the primary option (UN, 2021).

The major aspect of the EPR according to de la Motte et al. (2019) is to get the producers to take sustainability in consideration when manufacturing their products, but there are also several other aspects; collection and recycling of used products, economics and information. The 11th goal *Sustainable cities and societies* addresses the challenge of creating sustainable waste management systems (Global Goals, 2021a), and was developed with background in Agenda 2030. Building modern och sustainable infrastructures is among other things crucial for enabling better handling of discarded material such as textiles, thereby establishing a solid foundation for future generations (UNDP, n.d.).

In order to achieve a completely sustainable society, efforts need to be made on an industrial level which in turn leads to Goal 9: *Sustainable industry, innovations and infrastructure* (Global Goals, 2021b). According to the UN, the mentioned goal emphasises the importance of upgrading the infrastructure and industries in order to meet future challenges (UN, n.d.). This report aims to provide knowledge in order to help reduce the climate impact, which further explains the relevancy of Goal 13: *Climate action - Take urgent action to combat climate change and its impacts*. This goal aims to raise the awareness and integrate measures against climate change on a higher level (Global Goals, 2021c).

To obtain a more circular and sustainable textile consumption and waste handling, the public as well as the companies, information is needed in order to be a part of the change (The Swedish Government, 2015). Further, the actors must be informed on what measures to take and what regulations to follow, which starts with decision making on a political level similar to the new EU directive. According to the UN (2015a), the leaders must communicate with the public and increase the knowledge in today's society to provide necessary tools and enable a more sustainable lifestyle and preferable textile waste handling. With the right knowledge and tools given, the modern society will manage climate change better, starting on a political level (UN, 2015a).

2.3 The Supply Chain of Used Textiles in Sweden

The flows of textiles and used textiles are in general globally dispersed (SOU, 2020). The raw material could originate from one country while production is located in another and the final product sold in a third. For a textile product consumed in Sweden, the production stage stands for 80% of the total emissions (Swedish EPA, 2021a). The geographical scattering also affects the collection and offset of used textiles in Sweden. Collection can be done nationally, with textile goods exported to mostly eastern and central Europe for sorting and then further distributed outside of EU for reuse (SOU, 2020)).

According to Swedish EPA (2019b) the net flow of imported textiles amounted to 13.7 kg per person, which results in the total amount of 140 million tonnes. Of the total amount of textiles consumed in the EU countries, 80% of the textiles is imported from countries outside of EU (Kemikalieinspektionen, 2015). Based on the statistics from Statistics Sweden (2020), the volume of imported new produced textiles to Sweden during year 2020 amounted to 377,500 tonnes, which is a decrease from 2019 by 5%. However, the net inflow of textiles has increased by over 30% in the last two decades (Swedish EPA, 2019b). SMED (2018b) states that the amount of imported textiles to Sweden that is being reused outside of Sweden amounted to over 21,000 tonnes in 2016.

2.3.1 Collection Systems

As stated by SMED (2011) there are three main sections of used textile collection in Sweden, namely NGOs, waste disposal- and material recycling companies. Palm et al. (2014) mapped the flow of Swedish textiles based on the collection of the used textiles shown in Figure 4 on page 14. The authors present that approximately 20% is collected by NGOs, 50% is thrown in residual waste and 30% is possibly stored in households or discarded at a recycling centers. Another factor identified in the study is the loss of used textile due to theft. It is calculated that approximately 4% of the collected used textiles by NGOs are stolen from containers (Palm et al., 2014).

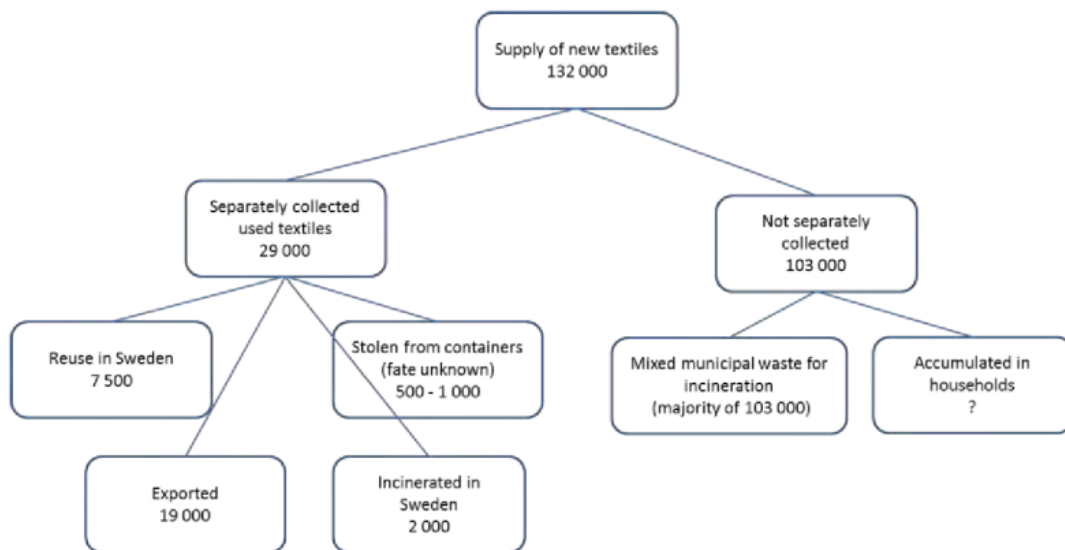


Figure 4: The flow of used textiles in tonnes in Sweden (Palm et al., 2014)

According to Palm et al (2014), NGOs stand for 90% of the separately collected used textiles in Sweden. The majority of the collected textiles in these organisations are from households, and the used textiles that reach Swedish standards are sold on the second-hand market, while remaining textiles are donated, exported or thrown away (SMED, 2011). NGOs collect used textiles directly from the consumer, as well as through clothing brands and other collaborative collection partners (Carlsson et al., 2015). A study by SMED (2018b) shows that the amount of used textiles collected by NGOs in year 2016 was just over 38,000 tonnes, of which more than 70% were exported, mostly unsorted. The same study shows that the amount of reused textiles in Sweden has increased since 2011, however, the reused amount per person has remained the same due to population growth (SMED, 2018b).

SMED (2018b) further explains that 42% of the used textiles collected by NGOs are sorted in Sweden, of which only 0.2% is recycled. Of the collected textiles in Sweden, 5% go to incineration or energy recovery, however that number can be much higher since the exported textiles are not considered. According to Palm et al. (2014), the textile containers found at recycling centers or other public places, is the main way for NGOs to collect used textiles. Another collection point for NGOs are their second-hand stores (Palm et al., 2014). It is calculated that approximately half of the collected used textiles by the Swedish Red Cross has potential to be sold on the second-hand market (Palm et al., 2014). The remaining 50% is either directly incinerated or sold to countries within the EU for reuse or recycling.

The textiles collected by the waste disposal companies are usually mixed together with the household waste and can therefore not be collected separately, which leads to them being incinerated (SMED, 2011). According to RISE (2019b), an average Swedish person buys approximately 13 kg of textiles each year, of which more than 7.5 kg are thrown away in the household waste. This means that a total of around 75,000 tonnes of used textiles is incinerated every year (Swedish EPA, 2019a). Swedish EPA (2019a) further states that about half of the textiles that can be found in the household waste are in such good condition that they could be reused, meaning whole and not worn down (Swedish EPA, 2019a). SMED (2011) further states that the waste disposal companies usually do not have data on the quantities of used textiles in the household waste, besides the data collected from random samples. If the waste disposal companies were able to go through the household waste it would still be difficult to manually sort the used textiles due to lack of knowledge (Swedish EPA, 2020b). According to the Swedish Environmental Research Institute (IVL, 2020a), an automatic sorting facility is necessary in order for the sorting of textiles from the household waste to be profitable.

The third section, material recycling, is executed once the textiles can no longer be sold on the market or reused (IVA, 2020). According to the IVL (2020b), the potential for increased recycling of used textiles in Sweden shows great promise. Today, only 5% of the total amount of new textiles on the Swedish market is recycled. In order to enable the handling of large amounts of textiles and creating a circular supply chain, once again automated recycling processes are necessary (IVL, 2020b).

In addition to the aforementioned ways to collect used textiles, SMED (2019) has later added one further section, namely reuse through online platforms. On these platforms, users can sell or buy used textiles to or from other users (SMED, 2019). On the direct reuse platforms the users themselves manage the advertising, customer contact and sale (Mistra future fashion, 2019b). The amount of textiles that was reused through online platforms in Sweden during 2017 was estimated to 1,300 tonnes, which was an increase of 32% from

year 2016 (SMED, 2019). This amount results in 0.13 kg of used textiles supplied per person in Sweden, which according to the Swedish EPA (2020a) is about the weight of a cap. During the year 2016, the total amount of reused textile through the six largest second-hand platforms corresponds to only 3% of the total amount of used textiles collected by NGOs and 12% of the collected amount used in Sweden (SMED, 2019).

Carlsson et al. (2015) claim that there is one additional flow for used textiles from consumers, namely collection through clothing brands. Clothing brands can either collaborate with NGOs and donate the collected textiles, or collect used textiles from their own brand in order to recycle it (Carlsson et al., 2015). In addition to collecting the brand's own textiles, some companies also accept textiles from other brands, that are worn out or torn (Pyk & Vujicic, 2019). Carlsson et al. (2015) further state that the collection points are often allocated in the clothing brands' stores, from where the textiles are sent unsorted to a sorting facility. However, the amount of used textiles collected by these companies is just a small fraction of the amount collected by NGOs themselves (Carlsson et al., 2015).

2.3.2 Transportation

The textile value chain is globally dispersed (Swedish EPA, 2021a), which makes it a transportation intensive industry. An analysis by Palamutcu (2015) shows that a cotton shirt can travel over 35,000 km from the cotton field to the end user, which is almost the distance of one trip around the world. The most common type of transportation for textiles is by ship when intercontinental and by truck when feasible (Mistra future fashion, 2019b). According to Palamutcu (2015), the transportation of a cotton shirt during the pre-consumer phase constitutes to 3% of the total carbon dioxide emissions of the shirt.

As stated by Mistra Future Fashion (2019a), the consumer's transportation back and forth from the textile selling point is estimated to 11% of the textile's overall life-cycle impact, while the transportation in the production plant is deemed insignificant. Roos and Larsson (2018) support the low environmental impact of transportation in the production, which they estimate to 0.4% of the total emissions of the textile industry. However, they further claim that the consumer's transports stand for 14% of the total climate impact of the industry, and therefore is a great target for improvement. Mistra Future Fashion (2019a) further claims that the transportation between production processes, such as fiber production and garment manufacturing, are according to estimations approximately 750 km per lorry.

The total transportation from consumer to incineration is calculated to be 30 km, where several means of transportation are used in the different steps of the supply chain, but mostly cars and trucks (Mistra future fashion, 2019a). Generally, information regarding the transport during the consumer phase and after disposal today is inadequate and insufficient (Mistra future fashion, 2019a).

2.3.3 Sorting

According to a report by Palm et al. (2014) the sorting of used textiles in Sweden is done manually and differs between organisations. The authors further explain that some perform all the sorting in-house while others only sort a part of the textiles and sell the rest completely unsorted to primarily countries within the EU. About 95% of the unsorted and exported part are reused or recycled while the remaining 5% goes to incineration (SMED, 2018b).

A manual process is one where the personnel performs all of the work by hand including moving, lifting and sorting the textiles and in order to carry out the manual sorting there is a requirement for experienced staff with good knowledge of the second-hand market (Palm et al., 2014). As stated by Carlsson et al. (2015), the sorting in these facilities generally consists of two phases: initial and fine sorting. In the first step, the personnel sort out the textiles that are suitable for distribution on the Swedish second-hand market. The second step consists of sorting the textiles of good quality into different categories, usually 10-20 defined by section, basic category, season and price range (Carlsson et al., 2015).

As aforementioned, Carlsson et al. (2015) claim that the textiles that do not reach the quality required to be sold on the Swedish second-hand market are exported. The exported textiles then get further sorted for reuse, recycle and disposal abroad, as stated by Palm et al. (2014). The larger sorting facilities located in countries of the EU usually have a semi-automatic process instead where only the sorting part is done manually which allows the textiles to be sorted into many more fractions (Palm et al., 2014). The Boer group based in the Netherlands have a sorting process which can sort the textiles into over 350 different categories, of between two to five different levels of quality (Boergroup, 2018).

Until now, the Swedish market for used textiles has been managed almost completely by the NGOs representing around 90% of the market (Palm et al., 2014). In order to achieve a circular textile industry, the activities of the NGOs are as of today not sufficient. A project called SIPTex has consequently been initiated by Sysav in Sweden to improve the opportunities for textile recycling (Sysav, 2020). SIPTex is the world's first automatic large-scale facility for sorting and will have a capacity of 24,000 tonnes per year (Sysav, 2021). As stated by the Swedish EPA (2020a), 38,300 tonnes of used textiles were collected during 2016 in Sweden, which means that this new facility could have sorted around 60% of it. The sorting is done with the help of infrared light and visual spectroscopy, which allow the machine to sort the textiles based on fiber composition and colour. The automated process is able to simultaneously handle three different flows of textiles (Sysav, 2021). This kind of sorting facility has yet been missing within the handling of used textiles, and is a vital part of scaling up the textile recycling process (Sysav, 2020).

2.3.4 Export

According to the Nordic Council of Ministers (2020) there is a great demand for reusable textiles deriving from the Nordic countries, in the Baltic region. In 2018; a quarter of the 90,000 tonnes of used textiles imported to the Baltic states were from the Nordic countries. This makes the Baltic region an important part of the Nordic textile offset alternatives (Nordic Council of Ministers, 2020). The Nordic countries export over 70,000 tonnes of used textiles every year (Nordic Council of Ministers, 2020). Of these textiles; Sweden exported over 27,000 tonnes in 2016 and of which almost 78% were reused (SMED, 2018b). According to Carlsson et al. (2015), 80% of the used textiles collected in Sweden, often of poor quality, are exported to Africa, Asia and Eastern Europe to low handling costs. About 10% of the used textiles are actually reused in the country of origin. Of the amount of used textiles collected by Swedish NGOs in 2016, over 72% were exported (Swedish EPA, 2019a). The textiles are often exported unsorted, because of the significantly lower handling costs off-shore (Nordic Council of Ministers, 2020).

Carlsson et al. (2015) claim that the current export market for used Swedish textiles will significantly decrease in the future. The authors base their argument on the presumption that textile importers will

become self-sufficient in supply of a domestic second-hand market, with an economic growth as root cause. However, the amount of exported textiles from Sweden has increased for the last years, according to SMED (2018b), which implies that development has not yet been finalised.

2.4 Barriers and Enablers of a Circular Textile System

Dervojeda et al. (2014) describe the profound establishment of linear economy as the main inhibitor to the rise of circular systems. Linearity entails distorted pricing, since externalities are ignored in the pricing of produced goods (Govindan & Hasanagic, 2018) and generates the effect that linearly produced goods are cheaper to consume (Dervojeda et al., 2014). Aligning with these overlying structural problems, Sweden's current supply chain of used textiles, experiences barriers and enablers in the transition towards circularity which are identified and elaborated below.

2.4.1 Barriers

About 80% of the climate impact originating from textiles is derived in the production phase and the absolute majority in the production industry. Textiles consumed in Sweden that are not produced domestically, are difficult to trace (RISE, 2019a). Even domestic brands use off-shore production and Sweden today has almost no textile factories (IVA, 2020). Sandin et al. (2018) state that due to this, the impact of the textile industry is hard to regulate and hereby textile consumption needs alteration (IVA, 2020).

A reoccurring challenge for industries when setting out to create long-term viable circular supply chains, is to create an economic surplus for all actors involved (Sandberg et al., 2018). Firstly, there is the economic barrier of textile circularity connected to the lack of profitable business models for reuse, resale and repair (RISE, 2019a). Furthermore, circular business models based on collective clothing usage are facing challenges connected to accessibility. Due to the impact of logistics and transportation, entailing similar "clothing pools" or rental services could potentially overshadow the reduced climate impact from less production (RISE, 2019a).

Awareness among the public is also lacking concerning the product supply derived from the circular field, as well as possible business opportunities of remanufacturing (Govindan & Hasanagic, 2018). Both Govindan (2018) and Levering et al. (2019) stress the information shortage of companies on practices of adoption and implementation of circular practices. Chung-Wha et al. (2020) further emphasise the need of skills and knowledge in conducting a circular business, which is generally missing in the industry.

Additionally, both economical and logistical challenges are experienced in textile collection and management of the grading and sorting processes, mainly due to a lack of standardisation and suitable facilities (Chung-Wha et al., 2020). Sorting and grading activities are resource-intensive in terms of labour and thereby create economic impediments to efficient textile recycling and reuse (Sandberg et al., 2018).

Crucial technologies of waste sorting and textile fiber reuse, which lays the foundation for duration and textile recycling, are currently novel and unestablished (Chung-Wha et al., 2020). Hereby, the costs of circular activities connected to fiber regeneration are yet high and range from solely using fiber-to-fiber recycled textile fibers to development of advanced fiber design processes (RISE, 2019a). Material impurity is also of importance since products with complex mixtures of materials without traceability are more than

often difficult to recycle (Hasanaj & Jansson, 2018). The recycling industry is experiencing a deadlock where the absence of large textile waste streams demotivate development of high-capacity textile recycling and upscaling of textile sorting processes. Altogether, this results in a currently non-competitive market price for recycling (RISE, 2019a).

Improved design for material quality is another important challenge in increasing the re-circulation of used textiles (IVA, 2020), since the poor quality in today's textile goods make them unfit for customer-to-customer reuse (RISE, 2019a). The quality of recycled fiber is in general, lower than virgin materials with existing recycling technology and this combined with the higher price of recycled materials creates a barrier for upscaling the recycling industry (EMF, 2017b). In addition to this, a decrease in quality of collected textiles has been reported, mainly due to the up-rise of competition in the used textile industry. New market entrants that distribute textiles through online platforms such as Blocket or Tradera contribute to this (Palm et al., 2014).

The consumption of textiles has doubled during the last 15 years (IVA, 2020). In light of this, the consumption patterns and consumer's user behaviours in the modern day society are identified as contributing parts of the dilemma (RISE, 2019a). Many consumers advocate the sustainability factor when purchasing goods, although it is found that they will not always practise what they preach. The unbalanced demand and supply is recognised depending on the lack of interest from customers in purchasing sustainable and second-hand textiles (IVA, 2020). There is also a large communication barrier according to Govindan (2018), when discussing the problem regarding perception of circular products among consumers. The linear consumption pattern remains dominant within the textile industry (Pal et al., 2019) and a large dose of transparency and traceability needs to be added to the industry in order to close the loop (IVA, 2020).

A more specific collection barrier was identified by Palm et al. (2014) concerning the traditional collection containers. The placement of collection containers requires a permit from the collector, which is given by municipalities or the Packaging and Newspaper Collection Service (FTI) (Palm et al., 2014). The process however lacks standardisation since the mentioned administrations in charge handle the granting of the permit inconsistently. The authors explain that FTI argues that the collection of textiles is not covered by the producer responsibility and will not allow a permit on recycling points. On the other hand the municipalities refer to FTI's recycling points and that the producer responsibility includes the collection of textiles (Palm et al., 2014). This difficulty together with the fact that the consequences of placing containers on recycling points without a permit is insignificant, has lead to the up-rise of many rogue actors and administrative barriers (Palm et al., 2014).

Theft from containers is an additional system challenge observed by Ljungkvist et al. (2018). Palm et al. (2014) further present that about 4% of textiles in the collection containers are estimated to be stolen by organised criminal groups. The containers are broken into with the purpose of stealing textiles with great value for illegal redistribution. This distorts the collection of used textiles, leading to miscalculations of the collected volumes and further potential for reuse or recycling (Palm et al., 2014).

Furthermore, Palm et al. (2014) contend the issue regarding the additional cost of transportation to recycling centers in the EU in contrast to incinerating the used textiles. The estimated price for incineration is approximately SEK 0.50-1.00/kg which aligns with the estimated price for sending the used textiles within the EU for recycling (Palm et al., 2014). This results in relatively low incentives for organisations, considering

the municipalities have the possibility to offer incineration free of charge (Palm et al., 2014)

2.4.2 Enablers

Decreased textile production demands increased reuse and recycling (Sandin & Peters, 2018) which in turn places a need for substantially transformed supply chains and operations (IVA, 2020). Chung-Wha et al. (2020) explain that consumers can affect the stakeholders by expressing a demand for circular production and environmentally friendly product designs. This contributes to designs that meet consumers needs and that are sustainable altogether which paves the way for a circular textile industry. The authors further point out the fact that it is internal stakeholders such as distributors and manufacturers, that can accelerate the transition towards circular fashion. However, the consumers are an essential part of the altered sustainable value creation due to their large influence on the profitability (Chung-Wha et al., 2020). The fact that many consumers wish to make a shift to consuming sustainable goods (IVA, 2020), could strengthen the incentives for producers to design for circularity (Chung-Wha et al., 2020). Another interesting possibility mentioned by Chung-Wha et al. (2020) is the potential in the marketing of circular goods, which can create awareness of the positive impact of sustainable consumption and alter attitudes in a positive direction. Moreover, Svanvik (2017) emphasises the rising marketing value of profiling as a circular brand, reinforced by the gradual changed of consumer attitudes (Svanvik, 2017).

In order to enable circular economy within the textile industry, governmental support is a key aspect (Chung-Wha et al., 2020). Extended reuse, recycling and improved waste treatment can be incorporated to legislation to drive the textile industry towards circularity. Furthermore, regulative tools can facilitate the implementation of economically profitable business models and business model innovation by providing accurate frameworks and economic incentives (European Environment Agency, [EEA], 2021). Chung-Wha et al. (2020) also elevate how laws and regulations can improve the traceability of the textile production, since it is a major enabler of circularity in general. Governmental action can function as an enabler by providing certificates for transparently managed processes (Chung-Wha et al., 2020).

Khan et al. (2020) describe that one of the enablers with the most influence is traceability implementation. Implementation of traceability is achieved by having an effective tracking of the materials used in the products for transparency (Khan et al., 2020). This method extends the control that companies keep of their materials and enables transparency. Overall performance connected to environmental responsibility can then be assessed and clearly communicated to the consumers (Hasanaj & Jansson, 2018).

Sandberg et al. (2018) emphasise the importance of grading and sorting when striving towards maximised value extraction from textile waste. The value of textile waste today is low (IVA, 2020), and value must instead be sustained by further use of existing garments (RISE, 2019a). New materials adapted for recycling and long duration are essential enablers, connected to the design phase they can also contribute to preservation of the value of textile fibers (Svanvik, 2017).

Scaling of alternative reuse business models can be enabled by improved buyer experiences and economically viable quality sorting processes (RISE, 2019a). Additionally, governmental financial support to circular businesses and subsidised innovation processes in the fields of design, recycling and sorting could improve the circular efficiency and establish crucial new technological practices in textile processing (Chung-Wha et al., 2020). Also, governmental support through incentives, legislation and policy-making is crucial to

drive the transition forward. Although emerging trends of consumer awareness on environmental issues and changed consumption patterns are paving the way for persistent change (Lahane et al., 2020).

Chung-Wha et al. (2020) also shed light on the view on the market of used textiles as an unexplored area of business opportunities. Hereby, the profitability aspect can be handled by circular business models (Pal et al., 2019), although these models rely on cost efficient circular supply chain design and well-managed collaboration processes amongst stakeholders (Sandberg et al., 2018). Connected to this, Pal et al. (2019) suggest that efficient circular SCM strategies can be essential enablers of circularity, due to their functions as mediators of material- and information flows internally and inter-organisationally. Collaboration and consequently an alignment of goals in the textile industry could drive the transition towards circular life-cycle designs of products as a joint effort among textile producers (Chung-Wha et al., 2020).

Finally, all producing industries are today facing the external pressure of the increasing scarcity of resources. Enabling and driving the transition towards a circular textile industry is thereby of utmost interest for all stakeholders involved, ranging from upstream suppliers to end-consumer (Svanvik, 2017).

3 Methodology

This thesis is mainly a descriptive study which uses an abductive approach (Blomkvist & Hallin, 2015). According to Wallén (1996), a descriptive study is used in order to investigate the properties of a research object and map its surroundings. Descriptive studies explain and quantify relationships through data gathering and systematisation, which conform with the purpose of this study (Wallén, 1996). Furthermore, Wallén (1996) states that the descriptive character of a study enables investigation of barriers, enablers and future prospects, which is done in the context of the used textile supply chain in this thesis. Applying an abductive approach is, as defined by Wallén (1996), the combined procedure of drawing general conclusions derived from empirical observations whilst incorporating and using established theory. The approach aligns with the intended working methodology of the study and its general purpose, as described below.

The character of the data is both quantitative and qualitative, and the methods to derive empirics have been a combination of literature studies and interviews (Eriksson & Widersheim-Paul, 2008). The quantitative data consists of statistics and numerical data, which mainly concern the assessment of textile volumes and the matching of estimated current handling capacity. Both types of empirical data are used for analysis of barriers, enablers and future prospects in the supply chain of used textiles. In this study, a large emphasis was attached to the qualitative data collected in the interviewing stage, when the qualitative abductive analysis was performed. This study contains a mixture of primary and secondary data, where the primary data was acquired during the conducted interviews (Blomkvist & Hallin, 2015). The secondary data was acquired from the literature review as well as relevant web-pages, information from companies of interest and the SATIN project.

The methodology chapter of this report describes the proceeding of the study, including the method for literature study, interview method, methods for supply chain mapping and collaboration with the SATIN project connected to the overall method.

3.1 Literature review method

In order to expand the knowledge around circular systems of textiles, a literature study has been conducted to create favorable conditions in designing the questionnaires for the company interviews as well as the theoretical analysis (Eklund, 2012). As stated by Blomkvist and Hallin (2015), the literature study aims to identify and summarise the existing knowledge published in the subject area. The literature study is divided into four main categories, namely Circular Economy, Circularity in the Textile Industry, The Supply Chain of Used Textiles in Sweden and lastly, Barriers and Enablers of a Circular Textile System. In order to find relevant literature, Chalmers Library, Scopus and Google Scholar have been used as sources. According to Blomkvist and Hallin (2015), defined search terms are needed in order to navigate in the literature study. The main categories of key words that were used in the search of references in this project were *circular economy*, *circular supply chain*, *textile collection systems*, *textile waste* and *Sweden*. The key words were used in different combinations and elaborated with more specific concepts, related to the topics of the study. In most cases, articles and scientific reports were studied rather than books since those, according to Patel and Davidson (2011), include the most up-to-date information regarding technologies and development. Advice on relevant literature has also been received by supervisor Patricia van Loon as well as the SATIN project supervisor Linea Kjellsdotter Ivert.

3.2 Interview method

To be able to map the circular system of textiles and identify barriers and enablers it was relevant to gather primary data through semi-structured interviews with different actors in the supply chain. This was carried out in collaboration with the project partners within the SATIN project and additional external actors. The project aimed to conduct qualitative interviews based on the companies' knowledge in turn to acquire a deeper insight considering the current resources and capacities with handling of textiles.

According to Eklund (2012), the qualitative interviews seek to attain new observations and phenomena, this is achievable with adequate preparations like literature studies. However, it is noted that previous knowledge and assumptions should not constrain the interviewer from reevaluating and gathering the information objectively (Eklund, 2012). It is of great importance to construct realistic and deliberate questions during the interview to receive qualitative answers (Eriksson & Widdersheim-Paul, 2008).

Furthermore, the interviews have been conducted by the project group in consultation with the supervisor at VTI. Notes were taken and the interactions were recorded and saved in a protected environment for purposes such as being able to revert and analyse the material, as recommended by Eklund (2012). Wallén (1996) emphasises the opportunity for the companies to remain anonymous when results are presented which will be taken into consideration and discussed before the interview. However permission was granted from the actors to present their private and company names following the general GDPR rules. As directed by Wallén (1996), transcription of video recordings has preferably taken place shortly after the interview by the interviewees to retain the relevance.

The interview questions were formulated with inspiration from an existing interview template created by VTI in regards to the SATIN project. A general template can be found in Appendix A, however the questions were specified based on each company or organisation interviewed. In order to answer the research questions and fulfill the purpose of the study, the questionnaire aims to gather information about the current and future volumes of textile flows, actors, resources and capacities. Blomkvist and Hallin (2015) describe that the questions posed are often formulated during the interview, although in order to achieve a semi-structured interviewing process most questions were prepared in advance.

Hedin (1996) explains that in a qualitative study, semi-structured interviews are mostly used when gathering empirical data. Semi-structured interviews consist of question areas or themes, structured in a questionnaire, rather than fully specified questions separately (Hedin, 1996). These themes were determined in an interview guide for the interviewer to follow in the order that fits the specific interview the best (Blomkvist & Hallin, 2015). Through use of this technique, the possibility for the interview to be more natural, increases and the goal of the interview, which is to receive the interviewee's view on reality, is easily achieved (Hedin, 1996).

Blomkvist and Hallin (2015) present that the number of interviews conducted should be based on their quality and if empirical saturation is achieved. Since this was unpredictable, the ambition was to interview at least 10-20 project partners and approach external companies to attain the needed information to be able to answer the research questions. The aforementioned ambition resulted in 19 organisations being interviewed during the data collection, which is seen as a sufficient number suitable for the thesis' scope. With this in mind the decision on the actors interviewed depended on the purpose of the interviews stated in chapter 2.2.1.

3.2.1 Sample selection

The selection of organisations to interview was based on a supply chain management perspective by identifying the key business processes of the supply chain. The project partners of SATIN consist of key stakeholders in the transition towards a circular textile system, which in this thesis was divided into different target groups and complemented with external actors. Due to similarities in activities, the categorisation into target groups resulted in real estate companies, municipalities, sorting facilities, NGOs and retailers, direct reuse actors and waste disposal companies. Since the SATIN project is based in Gothenburg, the examined area was mainly in Västra Götaland.

As previously mentioned, other organisations were contacted in order to obtain a comparative and comprehensive perspective of the value chain in addition to existing partners of SATIN. Initially, the selection consisted of a larger number of companies than what was intended for the interviews, which was consecutively narrowed down depending on the response. Some of the external actors were chosen for data collection during the interviewing process, due to recommendations from the already integrated actors. This to get an even broader perspective of the supply chain, enabling for a more nuanced discussion. As Hedin (1996) mentions it is significant to interview various people or organisations with knowledge in the area to achieve a greater depth and detailed perception. Hence, the selection shown in Table 2 on page 25 is based on what kind of information that is relevant to seek in each activity related to the scope of the study.

The purpose of interviewing the different target groups varied internally as discussed below. The aim with interviewing real estate companies was to collect data and examine the current used textiles collection in buildings. Information was gathered from waste companies, collection and sorting companies, as well as retailers to map the current resources and capacities of the textile flow and cooperation on handling of textiles. Since the study also intended to examine the used textile collection on the second-hand market it was considered crucial to interview actors within both e-commerce and existing stores. The NGOs conduct the majority of today's textile collection and were therefore a main target group in the mapping of the system.

Table 2: *Interviewed stakeholders in the textile supply chain*

Actor	Target Group	Date	Interviewee
Balder	Real Estate company	16-03-2021	Camilla Holten
Poseidon	Real Estate company	11-03-2021	Malin Taalomi
The Swedish Red Cross	NGOs and retailers	24-03-2021	Martina Bozic
Human Bridge	NGOs and retailers	12-03-2021	Klaus Rosinski and Christofer Ståhlgren
Myrorna	NGOs and retailers	11-03-2021	Urban Bohlin
Björkåfrihet	NGOs and retailers	25-03-2021	Magnus Nilsson
Nudie Jeans	NGOs and retailers	15-03-2021	Kevin Gelsi
Ragn-Sells	Waste Disposal company	17-03-2021	Linnea Sellberg
Avfall Sverige	Waste Disposal company	12-03-2021	Jon Nilsson-Djerf
Kretslopp och Vatten	Waste Disposal company	19-03-2021	Natali Kjernell
Stockholm Vatten och Avfall	Waste Disposal company	29-03-2021	Karin Sundin
Göteborgsregionen	Municipality	08-03-2021	Hanna Hellström
Kungälv kommun	Municipality	10-03-2021	Dan Gorga and Helen Olsson
Mölndals Stad	Municipality	09-03-2021	Stina Moberg
Wargön Innovation	Sorting Facility	18-03-2021	Maria Ström
SIPTex	Sorting Facility	17-03-2021	Erik Perzon
Blocket	Direct Reuse actor	15-03-2021	Tero Marjamäki
Tradera	Direct Reuse actor	19-03-2021	Sofia Hagelin
Swedish EPA	Other	31-03-2021	Yvonne Augustsson

3.2.2 Analysis and processing

In order to map the circular system of textiles, the conducted interviews were thoroughly analysed. The results from the interviews were first summarised in a separate Excel-sheet seen in Appendix B and then compiled in a chart to achieve an overall picture of the supply chain of used textiles, due to the large amount of interviewed actors. Since more than one actor from each target group was interviewed, the collected data was categorised based on the research questions and compared to one another. The categorisation of interviewees was useful in order to distinguish eventual patterns between them, which was favorable in the analysis of the interviews (Patel & Davidson, 2011).

To ensure the validity of the interview results, each interview was recorded to enable repetition. According to Blomkvist and Hallin (2015), the validity is connected to if the collected data lays within the purpose of the project. After the interviewer analysed the result, at least one more group member also inspected and validated the result (Blomkvist & Hallin, 2015). As stated by Hedin (1996), the result from the interviews should be processed more than once in order to notice eventual patterns and themes in the interviewee's answers. The questionnaire that has been used in the interviews however, was validated before the interviews were conducted by dialogue with the SATIN project supervisor. A summary of each interview was returned to the interviewee for examination, in order to verify that the interviewee was correctly interpreted. According to Eriksson and Wiedersheim-Paul (2008), reliability as well as relevance are parts of the critical examining in addition to validity. As stated by Leung (2015) reliability in qualitative studies is the essence of consistency, however there is no clear definition of the term in this kind of research. According to Noble and Smith

(2015), methods for ensuring reliability in a qualitative study include awareness of personal bias. This has been taken into consideration by communication between the group members participating in the interviews together with reviews of the recorded interviews by the remaining members.

3.3 Mapping method

A part of this study's purpose is to outline the activities of the textile flow that is being addressed. The study maps the flows from households to the final offset, for example incineration, recycling or material reuse. The mapping will primarily focus on the activities of NGOs, but will also include the direct reuse of textiles among customers which mainly is channeled through digital marketplaces and e-commerce.

The mapping process results in different flow charts. Gardner and Cooper (2003) state that supply chain charts are powerful tools with the effect of displaying dynamics, illustrating the importance of members in the supply chain and enabling analysis of bottlenecks. Moreover, the process of map development highly contributes to profound understanding of the system for the makers which provides a palpable overview (Gardner & Cooper, 2003). In their article *Supply Chain Mapping Approaches*, Gardner and Cooper (2003) also state that continuous supply chain improvement is benefited by meticulous documentation, which lies in the corresponding aim of investigating barriers and enablers.

The focus of the map is on the flow of textile goods on a societal level. Gardner and Cooper (2003) recommend breaking down the scope of the map. Regarding the aim of the study from a strategic supply chain analysis perspective, the primary aspects examined are the tracking of volumes and corresponding coping capacities in the current supply chain. Additionally, the scope of the mapping is of a high-level character. High-level in this case means to define which different flows and actors that the textile flow, from household towards end point, constitutes of. Gardner and Cooper (2003) emphasise that using standardised attributes and icons is an essential aspect of general mapping. These conventions have been determined further on in the process. When more insight in the characteristics of the textile flow was gained, as well as appropriate levels of detail, aggregation and information density were obtained.

The aim was to create several supply chain maps, illustrating linkages between the actors in the textile supply chain. This study uses a framework called Value Stream Mapping (VSM), which suits the scope appropriately. According to Kurdve et al. (2017), VSM is a method of identifying inefficiencies in processes, and is generally used to find opportunities of improvement.

Langstrand (2016) summarises the steps of VSM as follows:

1. Specify the scope of the map
2. Identify the processes of the operations and extend it with information of external sources
3. Determine how materials and information flows, including storage and transport
4. Add process data (modified level of process data)

The aforementioned steps of VSM, aligns with the framework proposed by Williams (n.d.), and the study has taken different sources mapping methods into consideration when creating an adequate map.

3.4 Quality of Research

The research study constituted discoveries regarding the limited amount of prior studies on the topic. Currently, there is a lack of updated information regarding for instance the transportation in the supply chain of used textiles and the current barriers of the activities. Substantially there were difficulties in identifying statistics and data considering the environmental impact of the textiles. The identified gaps in the theoretical foundations indicate the relevancy of this bachelor thesis and need for further research in the area of study.

Another quality of findings reviewed was the categorisation of the conducted interviews. Based on the quantitative and qualitative character of the bachelor thesis, the immense amount of data derived were divided into subject areas seen in Appendix B. Certain information may be sifted out due to too narrowly selected areas, nevertheless the chosen results presented were based on the relevancy to the scope. To increase the quality of the method, the group worked carefully with the choice of subject areas to answer the research questions. Further, the aspect of biased information of the interviewed actors should be taken in consideration. The actors as well as researchers could have biases toward information that only support their arguments. The tendency to focus on beneficial information as well as the general deficiency of transparency in the industry can affect the study's legitimacy.

The empirical data collection was also restricted by the time frame of the project, which limited the time for interview conduction and data analysis. Consequently, the group chose to use an interview sample of 19 actors, which are mainly collaboration partners of the SATIN project. Naturally, limitations in data collection entailed decreased comprehensiveness of the result analysis. Lastly, the interview with SIPTex was only conducted by the masters' thesis group hence uncertainties regarding the data as a secondary source, which should be taken into consideration.

4 Result

In the following sections the results from the interviewed actors is presented within the different target groups. Initially, the target groups are briefly described with following information about each actor and their current collection or sorting activities. The identified barriers, enablers and future prospects of the textile collection activities related to each target group are elaborated and summarised in Appendix B.

4.1 Real estate companies

Real estate companies owns and manages real estates (Bolagsformer, 2018). The companies that have been interviewed in this project all own their properties and serve households. The headquarters of the companies are located in the Gothenburg region, although one of the companies is global. Real estate companies are responsible for handling the household waste and the households themselves are obligated to sort their waste, which can be simplified by the real estate company (Länsstyrelsen, 2008). Göteborgs Stad offers collection of used textiles free of charge for the real estate companies in Gothenburg (Göteborgs Stad, n.d.). This offer is in collaboration with the NGOs Human Bridge, Björkåfrihet and Myrorna. However, the NGOs themselves decide how many companies they can provide with textile collection (Göteborgs Stad, n.d.).

4.1.1 Interviewed real estate companies

Poseidon is owned by Göteborgs Stad and provides approximately 60,000 households with apartments in Gothenburg (Poseidon, 2021b). According to Poseidon themselves, their close collaboration with Göteborgs Stad means that they are working towards a sustainable city and creating living and safe places for their customers (Poseidon, 2021a). As stated by Malin Taalomi (personal communication, March 11, 2021), Poseidon collaborates with the NGO Human Bridge towards the goal to provide curb-side collection of used textiles for all of their households in approximately two years. In the collection bins, all kinds of textiles is allowed. Taalomi (personal communication, March 11, 2021) further explains that during the year 2020, 141,219 kg of used textiles were collected through this collaboration with 68 collection bins placed in Poseidon’s seven districts. Poseidon attempts to influence their tenants by spreading knowledge and information campaigns, with the aim to reduce the household waste in general as well as decreasing purchase of new produced products (Taalomi, personal communication, March 11, 2021). However, it is challenging to change people’s behavior from what they are used to do. An additional barrier, according to Taalomi (personal communication, March 11, 2021), is the lack of space to place the collection bins, especially in the city center.

Balder on the other hand is a global company based in Gothenburg and other larger cities in Sweden (Balder, 2021a). Balder provides apartments for households, offices for companies as well as hotel facilities (Balder, 2021b). According to Balder (2021b), they aim for a social, environmental and economic responsibility. As stated by Camilla Holten (personal communication, March 16, 2021), household waste is important for the company in the residential areas, however, textile waste has up until now not been a prioritised fraction, mainly since it has not been able to include this in the pick-up of other fractions. Currently, Balder provides space for textile collection bins owned by NGOs in close proximity to several of the properties and in some cases on the company’s premises (Holten, personal communication, March 16, 2021). However, there are difficulties finding suitable places for the collection bins for extended collection. These bins are completely

handled by the NGOs and are not a part of Balder's ordinary waste management process, further, there are no contracts between Balder and these organisations. Additionally, Holten (personal communication, March 16, 2021) explains that Balder experiences similar challenges as aforementioned, with the lack of suitable placement for textile collection bins.

4.1.2 Barriers, enablers and future prospects of real estate companies

Based on the answers from the conducted interviews with the real estate companies it was clear that there were both similarities and differences in the collection of textiles. Both interviewees experience complication regarding lack of space for textile collection bins. However, one company is trying to solve this problem through curb-side collection, so the bins can be placed outside the buildings instead. The collection bins are managed by a collaborative partner, which as mentioned above, are offered free of charge for real estate companies in Gothenburg.

Further, the lack of suitable space for textile collection seems to be the main reason why the textile collection is not used or developed to a greater extent. However, the general view of the real estate companies is the lack of knowledge regarding which textile fractions should be collected as well as the offset of the collected textiles. If the companies received more information about what happens to the textiles after the collection, this could be used in targeted information campaigns with the aim to increase the sorting of household waste (Taalomi, personal communication, March 11, 2021). If there additionally was a standardised way of practice of how the collection could be designed, it would be less of a barrier to begin with separate textile collection. Trends however shows a decrease in the amount of household waste, which might imply an increased awareness among the tenants. A summary of the barriers, enablers and future prospects identified in the Real estate companies interviews is presented in Table 3.

Table 3: *Summary of barriers, enablers and future prospects of real estate companies*

Target Group	Collection/Sorting activities	Capacities	Barriers	Enablers	Future prospects
Real estate	<ul style="list-style-type: none"> - Textiles are or can be collected through collaborative partners - Provides or can provide space for textile collection boxes 	<ul style="list-style-type: none"> - Not applicable 	<ul style="list-style-type: none"> - Lack of space for collection bins - Collection must be placed in order to enable emptying by truck - Difficult to influence the households to sort their waste - Lack of knowledge regarding the textile offset complicates dissemination of information 	<ul style="list-style-type: none"> - Discussion regarding textile collection in laundry rooms - Discussion with eventual collaborative partners for textile collection - Changing consumer behaviour through spread of knowledge - Conducting advocacy work through e.g. projects like waste-efficient apartment buildings and information campaigns 	<ul style="list-style-type: none"> - Trends show a decrease of household waste in general - Introduction of accessible curb-side collection points

4.2 Municipalities

The municipalities interviewed in the frame of this project are currently responsible for all household waste except for the waste within the producer responsibility, according to Avfall Sverige (2021a). Göteborgsregionen, Mölndals stad and Kungälv kommun collaborate with NGOs and retailers by providing or coordinating textile waste disposal in Gothenburg for inhabitants. The main way of collecting textiles by the municipalities is through recycling centers and recycling stations, although a more profound description of each actor is to follow (Mölndals Stad, 2021).

4.2.1 Interviewed municipalities

The organisation **Göteborgsregionen** is a collaboration between 13 municipalities in the area of western Sweden (Göteborgsregionen, 2020), including the aforementioned, and was interviewed due to the collected data that the organisation possesses. Göteborgsregionen do not collect textiles themselves, as stated by Hanna Hellström (personal communication, March 8, 2021), but have a coordination role in the collaboration whereas the municipalities have the operative role. Further, Hanna Hellström (personal communication, March 8, 2021) explained that their goal is mainly to prevent textiles waste by information campaigns. Göteborgsregionen works towards a sustainable future by the initiative ”FACT Movement” to raise awareness regarding circular fashion and which textiles to reuse and recycle (personal communication, March 8, 2021).

Kungälv kommun is a municipality with about 50 000 inhabitants. Kungälv kommun, together with Mölndals stad and Göteborgsregionen has implemented a plan for waste disposal including one subgoal to reduce the amount of textile in residual waste with 60%. In order to fulfill this goal the municipalities engage and inform the inhabitants of the value of disposing textiles separately. Dan Gorga and Helen Olsson (personal communication, March 9, 2021) explain that they mainly cooperate with Björkåfrihet and their collection is mainly at four recycling centers. They receive all types of textiles such as clothing and home textiles and the sorting is done in Björkåfrihet’s facilities. According to given statistics, the municipality collected 73,543 kilograms in 2020. As stated by Dan Gorga and Helen Olsson (personal communication, March 9, 2021), the used textiles of lower quality are shipped abroad, recycled into new raw material or incinerated.

Mölndals stad is a neighboring municipality to Gothenburg, with 70,000 inhabitants (Mölndals Stad, 2020). According to Mölndals stad’s official website (2020), the regulations for sorting executed by households at recycling centers have been sharpened. This resulting in that garbage bags with mixed combustible waste no longer can be thrown into the container for incineration with energy recovery directly, but instead must be sorted separately first. In an interview with Stina Moberg (personal communication, March 9, 2021), it is stated that Mölndals stad acts as a junction between textile collectors and households in Mölndal. Mölndals stad has two collaborative partners for the collection of used textiles; Björkåfrihet and Human Bridge (Moberg, personal communication, March 9, 2021). Moreover, Stina Moberg (personal communication, March 9, 2021) states that Björkåfrihet, Human Bridge and Myrorna both manage the collection and further handling of used textiles, where in this context used textiles refer to all types of textiles as long as these are clean enough. Collection containers are placed by the NGOs at different locations provided by Mölndals stad and the pickup rate is consecutively adjusted according to the degree of filling (personal communication, March 9, 2021).

4.2.2 Barriers, enablers and future prospects of municipalities

The identified barriers, opportunities and future prospects discussed with the aforementioned municipalities lay a foundation for further analysis of the current system. The municipalities find the producer responsibility problematic since it has contributed to confusion regarding their role in the system. Without a clear framework, some municipalities paused their planning of future textile waste disposal and collection until further information is announced. However, Göteborgsregionen believes that the municipalities will be given a role as collection provider in the future. For the time being, the municipalities interviewed believe they

can collect textiles to a greater extent, although it is uncertain whether the collaborative partner can handle the increased volumes. Mölndals Stad also discovered that the quality of collected textiles has decreased over time, specifically in rural areas compared to the city. This leads to economic barriers since the price the actors get for collecting textile has decreased. The aforementioned municipality has noticed that the households have difficulties with understanding which textiles could be reused or recycled, thereby pointing towards a lack of communication with the inhabitants. Although, much pleads for a disinclination to deposit rags for recycling in the same bin as fine garments which could be reused. Additionally, the absence of contacts between producers and those responsible for waste disposal aggravates feedback considering for an example the difficulties with handling mixed materials.

As a result of the aforementioned the municipalities recognise opportunities such as increasing consumer awareness through campaigns and strategic information about textile collection possibilities. The purpose with the campaigns is to inform households about the value of textile waste and which textiles that could be collected. Göteborgsregionen found a potential in reoccurring collection campaigns since it contributed with a larger amount of collected textiles and economic viability. Another opportunity to facilitate the disposal is investing in expansion through additional recycling centers but mostly mobile recycling centers which collect textiles around the city. Further, cooperation with sorting facilities such as SIPTex could be a possible opportunity if volumes would increase. Municipalities recognise potential in engaging in projects such as SATIN to discuss with actors to enhance the current system.

The theme of future prospects identified by the municipalities is increasing the curbside collection points at for an example laundromats and various real estate companies. In combination, the actors predict increased volumes handed in by inhabitants and will proceed with accessibility and further information campaigns. Kungälv kommun will for an example cooperate with Göteborgsregionen with the purpose of diminishing the amount of textiles from the residual waste.

It was made clear during the interviews that the volumes of collected textiles could increase substantially with better marketing and information spread. The problem, according to Kungälv kommun is that not many residents in their municipality are aware of the collection points available. The challenge is to find a way to fill the information gaps and to supply information through different channels depending on the target group, in other channels than the traditional ones such as radio, TV and newspapers. Kungälvs kommun mentioned that their work with marketing was not very established and that they were expecting a rise in volumes when they started which they have capacity for. A summary of the barriers, enablers and future prospects identified in the municipalities' interviews is presented in Table 4.

Table 4: *Summary of barriers, enablers and future prospects of municipalities*

Target Group	Collection/Sorting activities	Capacities	Barriers	Enablers	Future prospects
Municipalities	<ul style="list-style-type: none"> - Coordinating role in gathering used textiles in Gothenburg - Collection through recycling centers and recycling stations - Collaborations with NGOs for sorting and sale - Used textiles of low quality is exported, incinerated or recycled. 	<ul style="list-style-type: none"> - Kungälv's Kommun have endless capacity while Mölndals Stad experience uncertainties regarding the capacity. 	<ul style="list-style-type: none"> - The uncertain producer responsibility has put long-term ambitions of the collection on pause - Communication with inhabitants regarding which textiles to recycle or reuse. - Decreased quality of the collected used textiles - Economic barriers - Increased volumes of textiles, unclear if partners have the capacity 	<ul style="list-style-type: none"> - Focus on more information campaigns - Informing households about the value of textile waste - Mobile recycling centers - Make disposal more accessible and with additional reuse and recycling centers 	<ul style="list-style-type: none"> - Cooperation with NGOs, second hand stores and other municipalities - Creating collection points in laundromats, curbside and at real estate companies - Increased volume of collected textiles based on trends

4.3 Sorting facilities

Sorting facilities enable an accurate sorting process for used textiles. In this project, two sorting facilities have been investigated; namely Wargön Innovation and SIPTex. The investigation has been done in order to gather data on the amounts of textiles being sorted as well as the opportunities in using their methods commercially and enabling textile recycle.

4.3.1 Interviewed sorting facilities

Wargön Innovation's aim is according to themselves, enabling production of sustainable materials of the future and the organisation operates mainly in the region of Västra Götaland. (Wargön, 2021b). During the interview with Maria Ström (personal communication, March 18, 2021), it was explained that they have a pilot sorting facility. This is the Nordic region's only test and development facility for textile sorting that sorts for reuse, redesign and material recycling (Wargön, 2021a). The sorting is done by the usage of a fibre scanner which with the help of near infrared light can sort the textiles by colour, pattern and material (Wargön, 2021a). The facility is currently used for various projects, where the largest one is a collaboration with the Red Cross (Ström, personal communication, March 18, 2021). Every other week three tonnes of used textiles arrive to the facility to be sorted from the four Red Cross stores that are included in the collaboration (Ström, personal communication, March 18, 2021). Of these three tonnes about 30% is shipped back to the stores to be sold whilst the rest is exported to facilities in Europe (Ström, personal communication, March 18, 2021).

SIPTex is the world's first automated large-scale sorting facility for used textiles. By using near infrared light and visual spectroscopy the facility is able to sort the textiles by fibre composition and colour (Sysav, 2021). As explained by Erik Perzon (personal communication, March 17, 2021), the SIPTex project is based on a consortium with several Swedish brands. The brands inquire for more sustainable materials but an automatic sorting is necessary to reach greater amounts of these materials (Perzon, personal communication, March 17, 2021). The facility has the ability to sort up to 4.5 tonnes per hour which results in 24,000 tonnes every year (Perzon, personal communication, March 17, 2021). The expected suppliers for the facility is according to Perzon (personal communication, March 17, 2021) mainly laundries, NGOs and production spill from industries. A pre-sorting from these suppliers will be necessary for the machine to be able to handle the textiles and the requirements are no textiles longer than two meters, clean and no multi-layer textiles (Perzon, personal communication, March 17, 2021).

4.3.2 Barriers, enablers and future prospects of sorting facilities

The investigated sorting facilities appeared through the interviews to have different approaches, SIPTex is a large-scale facility for huge amounts of used textiles whilst Wargön focuses more on small scale projects for innovation in order to streamline the sorting. The actors experienced both differences and similarities regarding the barriers, opportunities and future prospects of textile sorting. Wargön mentioned that there is a lack of sorting in Sweden where the majority of the used textiles are sorted by NGOs today. SIPTex agrees that sorting needs to be further scaled up and that there is a need for automated sorting to secure feedstock for recycling facilities and to make the sorting process more affordable for the textile collectors. Also mentioned by SIPTex was that in order to scale up the recycling technology for used textiles there has to be a secure feedstock for these facilities. To achieve this there is a need for a correct and automated sorting. An opportunity and challenge connected to sorting which was mentioned by Wargön is that the pricing of the sorted used textiles could be more accurate and efficient. The solution for this according to the company could be the use of AI technology and increase of digitisation which would make the sorting even more effective. One of the future prospects with automated sorting facilities is to have a competitive price for sorting in relation to the price of textile incineration. When the SIPTex facility is up and running they will be able to offer this. A summary of the barriers, enablers and future prospects identified in the sorting facilities' interviews is presented in Table 5.

Table 5: *Summary of barriers, enablers and future prospects of sorting facilities*

Target Group	Collection/Sorting activities	Capacities	Barriers	Enablers	Future prospects
Sorting facilities	<ul style="list-style-type: none"> - Automatic sorting machines - The facilities obtains textiles differently, small amounts through various projects or larger amounts from laundries, NGOs and production spill - Use of sorted textiles differs, some gets resold or exported whilst some goes only to material recycling - Technology is used to detect fibre type and colour 	<ul style="list-style-type: none"> - Siptex have a maximum capacity of 24 000 tonnes of used textile each year and a maximum storage of 20 containers - Wargön has a capacity of 500-1000 tonnes per year 	<ul style="list-style-type: none"> - Pre-sorting is nessercary for some facilities - Need political and decisive actors support to be able to scale up the operation of circular textiles further 	<ul style="list-style-type: none"> - Looking on the use of AI technology for price detecting - Increased demand for sustainable materials from many brands - Increased demand for smoother sorting due to higher volumes of collected textiles 	<ul style="list-style-type: none"> - Development and innovation of the circular supply chain of used textiles - Be able to offer a price for sorting lower than incineration

4.4 NGOs and retailers

The non-governmental organisations include organisations with a social and political purpose which are not bound to a government (Cambridge Dictionary, n.d.). The actors within this target group play a crucial part in textile handling, as of today being the main collector and distributor of used textiles (Carlsson et al., 2015). The interviewed NGOs and retailer are presented more elaborately below, together with empirically derived data on handled volumes and related activities. NGOs deal with the entire post-consumer phase of used textiles including collection, sorting, re-selling and export and offset of unusable material (Swedish EPA, 2015 ; Carlsson et al., 2015). This section will also include the empiric gathered from an interview with the retailer Nudie Jeans, in order to provide a producer perspective on closing the loop of used textiles.

4.4.1 Interviewed NGOs and retailers

The Red Cross was founded in 1865, with the aim to help people in need by offering food, water and medical aid (The Red Cross, 2021). The humanitarian voluntary organisation consists of 272 physical stores where furniture, gadgets and textiles in the shape of clothes are gathered (The Red Cross, 2019). The donations made by individuals are sold in store and the sales surplus results in payments for food and healthcare for those in need (The Red Cross, 2019). Martina Bozic describes the organisation's operations in an interview (personal communication, March 24, 2021). The Red Cross collects around 3,000-4,000 tonnes of textiles each year and these are mainly collected by counter in store. All types of textiles are received by counter and then further sorted. Approximately 40-50% are of such quality that they can be reused. The rest is exported to either Germany or The Netherlands by lorry, and in the year of 2020 these volumes amounted to approximately 1000 tonnes. Bozic (personal communication, March 24, 2021) also explains that they have a collaboration with Wargön Innovation and their pilot sorting facility.

Björkåfrihet runs five second hand stores in-house and 14 stores in collaboration with different municipalities (Björkåfrihet, 2020b). Björkåfrihet gathers clothes, shoes and textiles at 500 collection points located in Sweden at recycling stations, refuse stations and laundry rooms (Magnus Nilsson, personal communication, March 25, 2021). Björkåfrihet sorts 55% of the collected textiles at a centralised sorting terminal located near Gothenburg and at 23 LSS-units in Sweden, and runs all transportation logistics internally. The remaining 45% are outsourced and shipped to Poland for sorting and further handling. The sorted textile volumes are either resold in Björkåfrihet's second-hand stores or exported within Europe, in the latter case primarily for reuse and secondary for down-cycling. Of the collected textiles in Sweden, approximately 10% is sent to incineration. During 2019, 3,412 tonnes of textiles and shoes were collected. Together with reusable gadgets and other materials a total number of 5,032 tonnes of goods was recycled and reused (Björkåfrihet, 2020a). These textile volumes are estimated to be 8% of the total amount of textile collection in Sweden (Nilsson, personal communication, March 25, 2021).

Human Bridge was created by Läkarmissionen and Erikshjälpen as a Swedish aid organisation collecting discarded medical equipment and second hand textiles. The textiles are in turn donated to the non-profit organisation Lindra Second Hand, exported or sold to partners (Human Bridge, 2020). As stated by Klaus Rosinski and Cristofer Ståhlgren (personal communication, March 12, 2021), the textile collection was mainly an income to finance the aid activities. Human Bridge collaborates with multiple municipalities, real estate companies, as well as wholesale companies and accept all kinds of textiles in their collection bins (Rosinski, personal communication, March 12, 2021). The bins are distributed throughout Sweden and there are currently over 2,500 collection points. During 2020, a total volume of 12,600 tonnes used textiles were collected, of which 1,000 tonnes were then sorted in Sweden (Rosinski, personal communication, March 12, 2021). The sorting of textile volumes is partly conducted by Human Bridge's five sorting facilities located in Sweden or sold to sorting enterprises in Europe (Human Bridge, 2019). Of the collected material, an average of 79% goes to reuse, 14% to recycling, 5% to energy recovery and 2% ends up in other materials such as packaging. In 2019, 911 tonnes of textiles were sorted and exported for charity to Africa, the Middle East and Eastern Europe (Human Bridge, 2019).

Myrorna is the leading Swedish second-hand brand and the company's business model involves collecting textile donations and gadgets from physical self-owned stores, recycling centers and clothing boxes (My-

Myrorna, 2017a) located at 756 collection points in Sweden (Urban Bohlin, personal communication, March 11, 2021). Textiles are also gathered as donations from textile retailers, such as Lindex and KappAhl, and 123 municipalities in Sweden (Myrorna, 2017b). Myrorna are also involved in the SIPTex-project, where textile collection actors collaborate with textile recycling developers (Myrorna, 2019). All sorting of the collected material is conducted in-house at Myrorna's sorting terminals in Sweden (Bohlin, personal communication, March 12, 2021). 9.7% of the textiles which are suitable for reuse returns to stores in Sweden. Moreover, 77.3% is exported and 13% ends up in energy recovery (Myrorna, 2019). An average of 7,000 tonnes of used textiles is collected in a year, which amounts to 19 tonnes each day (Bohlin, personal communication, March 12, 2021). Of the collected textiles suitable for reuse, 15% are sold in Swedish boutiques.

Nudie Jeans AB is primarily a jeans retailer with 34 shops globally and in-house clothing production (Kevin Gelsi, personal communication, March 15, 2021). The brand has a vision of being entirely sustainable, and works continuously with sustainable material sourcing for instance using 100% organic cotton, supply chain development and design for reuse and recycle (Nudie Jeans Company, 2019). Nudie Jeans strives towards having circular business model through extending the garments' lifespan, for example by offering repair services in-store, and reselling of used jeans (Nudie Jeans Company, 2019). Yearly, Nudie Jeans sell approximately 600,000 pieces, while collecting roughly 11,000 (Gelsi, personal communication, March 15, 2021). Repaired jeans in-store amounted to 63,218 in 2019, although the resales of used jeans 3,500 pieces. Collection of jeans is conducted by-counter in repair-stores, while the sorting activities are divided between being performed in a central warehouse in Borås and the allocated shops. Nudie Jeans has a scattered supply chain, however transportation in Europe is made by trains and trucks, outside shipping is primarily used although flight transport occur (Gelsi, personal communication, March 15, 2021).

4.4.2 Barriers, enablers and future prospects of NGOs and retailers

In interviewing Swedish NGOs and retailers, similarities and differences regarding barriers, opportunities and future prospects experienced in operations were examined. A common perception discovered was that the supply of used textiles collected in Sweden exceed the national demand for reuse through second-hand. Furthermore, the possibility to domestic recycling is insufficient considering the large demand for textile offset. Material recycling is aggravated by the poor quality of currently produced textiles and their mixed material compositions, and these aspects have a deteriorating trend. Another challenge connected to textile collection is the accessibility of collection points, irrespective of if NGOs uses by-counter collection or collection bins, the placement has to be convenient in order to reach donors. Concerning collection bins, there is an issue of transparency and insecurity originating from the prevalence of fraudulent actors and the information shortage of textile end-life. In addition to this, collection bins are subject to theft, rain and damage by damp making the system insecure. Moreover, the logistics of NGOs need to be further developed and the processes standardised, since the handling today is demanding in terms of both monetary resources and human capital. This ranges from uniformly designed collection containers, transportation and sorting. Regulative issues concerning placement of collection points and rights to collect complicates the operations of Swedish NGOs.

The established role of Swedish NGOs in the supply chain of used textiles entails opportunities, and paves the way for synergies with the academy, policy makers and the industry in general. This is enforced by

an increased demand for quality second-hand goods in combination with their wide geographical coverage. Additionally, there is also great potential for innovation in sorting and recycling processes. Existing partnerships with SIPTex and Wargön Innovation play a vital role in developing new technologies, which for example enable automation of sorting processes. Progress within the fields of upcycling and fiber-to-fiber recycling are also promising alternatives for future textile offset.

The EU directive of 2025 will most likely increase the amount of collected textiles and therefore create a higher demand for the collection services of NGOs. Business opportunities within the online second-hand market are yet to be discovered, since digital market places in general are growing rapidly. In addition to this, the directive will force textile producers to ensure higher quality and better longevity of new textiles put to market and obtained by NGOs. Lastly, there is an ambiguity regarding the implementation of EU's directive by the Swedish government and its effect on the role of NGOs within the collection of used textiles. A summary of the barriers, enablers and future prospects identified in the sorting NGOs and retailers' interviews is presented in Table 6.

Table 6: *Summary of barriers, enablers and future prospects of NGOs and retailers*

Target Group	Collection/Sorting activities	Capacities	Barriers	Enablers	Future prospects
NGOs and retailers	<ul style="list-style-type: none"> - Commonly textiles are collected by-counter, in collection bins or in collaboration with different partners e.g. retailers, municipalities and waste disposal companies - Sorting processes differ, many combines in-house and outsourced sorting. Independent of the sorting, a large fraction of collected textiles ends up being exported outside Sweden - The reuse fraction constitutes a small component of the total amount of collected textiles. A majority is being handled according to the lower levels of the waste hierarchy - Means of transportation vary between different actors 	<ul style="list-style-type: none"> - Human Bridge claims to have endless expansion capacity, given opportunities for offset - Myrorna has no capacity to expand - Most actors has no data concerning capacities 	<ul style="list-style-type: none"> - More textiles are being handled in comparison to the amount that's actually resold nationally - Lack of recycling opportunities - Material quality and purity are too low and decreasing - Accessibility and convenience of different collection points vary - Transparency regarding the end-of-life stations of textiles and seriousness of collection actors in consumers is lacking - Standardization and security of collection bins needs improvement in order address the issues with theft, damage of damp and water. - Logistics within the handling of used textiles is demanding of human capital and monetary resources - Ambiguity regarding the regulations which apply to collection of used textiles 	<ul style="list-style-type: none"> - Improvement of sorting technologies by collaboration with e.g. Wargön Innovation and SIPTex to decrease the need for manual labour - Synergies through collaboration with the academy, policy makers and the industry - Trends towards increasing demand of quality second-hand goods, change of mind-set on reuse - Wide geographical coverage of Swedish NGOs - Upcycling activities may increase due to disruptive recycling processes 	<ul style="list-style-type: none"> - EU directive of 2025 will possibly increase the amount of collected textiles and demand for collection services - Textile producers will be forced to increase the quality in new production of textiles, thereby enabling for more second hand sales - Growing market for second-hand textiles and reuse online

4.5 Direct reuse actors

Direct reuse in this report refers to online marketplaces with consumer-to-consumer approach. According to SMED (2019), an online marketplace works as an intermediary between the suppliers and the buyers, whom are both consumers. The platform based marketplaces enable distribution of textile for reuse (SMED, 2019). The second-hand market is growing every year, because of the increase in environmental awareness as well as the accessibility through the platforms (SMED, 2019).

4.5.1 Interviewed direct reuse actors

Tradera is identified as an actor working towards circular consumption by enabling a marketplace for consumption and reselling of used items (Tradera, 2020). The company's aim is to shift from a linear production to circular consumption by building the best second-hand experience and changing consumption patterns (Tradera, 2020). According to Sofia Hagelin (personal communication, March 19, 2021), textiles to

a value of SEK 350 million was sold on the platform during 2020, an increase by 7% from 2019. The capacity of the platform and the amount of textiles sold through it is unlimited, since Tradera is a digital intermediary (personal communication, March 19, 2021). In order to decrease the freight distances for sold products on the platform, Tradera recommends products closer to the buyer as well as packing products in the same package when several goods are bought by the same buyer from one supplier (personal communication, March 19, 2021). Hagelin (personal communication, March 19, 2021) further explains that the biggest challenge is to compete with the new produced textiles. However, Hagelin (personal communication, March 19, 2021) predicts a sharp increase of textiles sold through their platform, based on the growing trend for second hand clothes and other textiles.

Blocket is Sweden's largest online marketplace for second-hand trade, with approximately 5 million visitors to the website each week (Blocket, 2019). According to the company's website (2019), Blocket aims to become a positive force in society by enabling an accessible second-hand market and climate compensation. Blocket collaborates with several companies, according to Tero Marjamäki (personal communication, March 15, 2021), with the aim to inform the users regarding sustainable choices as well as collaboration with schools in order to influence the younger generation. Marjamäki (personal communication, March 15, 2021) further states that the sale of used textiles has increased during the past years, however, Blocket has to provide a user friendly platform that can compete with the simpleness of online market places for new produced textiles. In similarity with Tradera, the capacity of textiles distributed through Blocket is unlimited since there is no maximum amount of ads on the platform (personal communication, March 15, 2021).

4.5.2 Barriers, enablers and future prospects of direct reuse actors

There are clear similarities between the interviewed direct reuse companies. A huge possibility with these companies is that they are platform based, meaning an unlimited capacity. However, it is difficult to compete with the new production industry of textiles. Fast fashion has increased during the past years, which has lead to poor quality and a decreased second-hand value, thereby making the textiles difficult to sell. Another barrier experienced by the platform based companies is the lack of consumer awareness regarding the environmental impact of textile production. Both actors are working actively with this problem, through information campaigns and more attractive ads in order to communicate the importance of circularity in consumer behaviour. Additional development in environmentally friendly shipping and transport alternatives is executed by both companies in order to make the whole process more sustainable and reduce transportation emissions. The direct reuse companies predict increased sale of used textiles, especially an up rise in the amount of cheaper goods, and a promising opportunity for upscaling in order to meet customer needs. A summary of the barriers, enablers and future prospects identified in the direct reuse actors' interviews is presented in Table 7.

Table 7: *Summary of barriers, enablers and future prospects of direct reuse actors*

Target Group	Collection/Sorting activities	Capacities	Barriers	Enablers	Future prospects
Direct reuse	<ul style="list-style-type: none"> - Provides an online platform for the sale and distribution of used textiles - Makes the second hand market more accessible 	<ul style="list-style-type: none"> - Unlimited 	<ul style="list-style-type: none"> - Further communicate the importance of circularity in consumer behaviour - Changing attitudes about second-hand shopping - Concurrence with the new produced textile industry 	<ul style="list-style-type: none"> - Transition to sustainable shipping options - Information campaigns regarding upcycling - Collaboration partners to spread knowledge and increase market - Develop a smoother shopping experience 	<ul style="list-style-type: none"> - Trend towards increased sale of used textiles, especially an uprise in the amount of cheaper goods - Develop the work with goods which do not find buyers on the platform, e.g. through collaboration with other actors and information to customers

4.6 Waste disposal companies

The actors in this business area focus mainly on the waste management after its primary collection and also on the streamlining of the collection and sorting. The activities range from collection through collaborations with partners to collection at recycling centers. Some actors such as *Avfall Sverige* and *Kretslopp och vatten* do not directly work with the textile collection but operate by advising, doing advocacy work and having agreements with outside actors that handle the textile collection.

4.6.1 Interviewed waste disposal companies

Ragn-Sells is a corporate group in the field of environment and recycling industry, they operate in four different countries including Sweden and offer new and effective ways to minimise and convert waste into resources (Ragn-Sells, 2021). In the matter of textiles, the company mainly operates through projects, one of these is for the moment with Wargön Innovation. The vast mass of Ragn-Sells' business has established flows according to Sellberg (personal communication, March 17, 2021). It is explained that the reason for this is that textile materials are not homogeneous materials with obvious outlets.

Ragn-Sells also has collections at recycle centers and collaborates with actors such as Myrorna for receiving used textiles but this collaboration has been on pause for sometime. 90% of the collection is done at recycling centers where the municipalities are the clients. Collection is also done through local textile containers and the pickup is done according to agreements with the customer and takes place either through groupage by Ragn-Sells or by the customer handing in the waste (personal communication, March 17, 2021). The company spotlights recycling, treatment detox and new value chains. In the year of 2020, it collected 325 tonnes of textiles, although most of it was incinerated. They hope to increase their capacity by collaborating with external actors for sorting (personal communication, March 17, 2021). Sellberg clarifies that the company has no plan to invest in textile collection more for the time being since it is yet not clear how the EPR will develop, it is also stated that the collection can be expanded without investments. It is the handling that may require investments such as sorting equipment and weather-protected storage areas. Ragn-Sells is open for collaborations with textile producers in the future (personal communication, March 17, 2021).

Avfall Sverige is an industry organisation that represents municipalities and municipal companies, they do not work directly with the textiles themselves but conduct advocacy work both nationally and within the EU (Avfall Sverige, 2021b). They have a general overview over the waste industry. As described by Jon Djerf, their work consists of advising, advocacy work, policies and representing its members in

government investigations (personal communication, March 12, 2021). According to Avfall Sverige, the current textile collection is built up by municipalities and non-profit organisations entering into formal and informal agreements on the placement of textile containers. Collection of used textiles is not the main obstacle. Collected volumes could be increased but the main challenges are the disposal of the collected materials, this includes both the reuse and recycling. Another challenge is the lack of facilities and large scale material recycling (personal communication, March 12, 2021).

Kretslopp och vatten is a municipal administrator in Gothenburg. They are for the most part financed by fees paid by customers but they also have certain assignments financed by taxes (Kretslopp och vatten, 2021). Kjernell (personal communication, March 19, 2021) explains how there are two main tasks for this administration, securing drinking water and maintaining the pipe networks, while the second part is about waste disposal since Kretslopp och vatten are responsible for the collection of household waste (Natali Kjernell, personal communication, March 19, 2021). They do not collect used textiles themselves but have collaborations with Human Bridge, Myrornas and Björkåfrihet. The collaborations include collection close to properties where real estate companies themselves form agreements with Kretslopp och vatten's partners. The volumes of collected textiles have decreased a small part during the pandemic but the decrease is not substantial (personal communication, March 19, 2021).

Stockholm Vatten och Avfall has been working towards improving the textile collection at recycling centers in Stockholm. In comparison to other waste disposal actors, SVOA have been taking on an ambitious approach in textile handling. Its responsibility is to collect textiles in recycling centers but also to solve the logistics revolving the transportation, sorting and quality, this will be achieved through collaboration with other actors (Sundin, 2018). The amounts collected daily by SVOA are as stated by Sundin, 1.5 tonnes. These volumes are collected at the recycling center in Bromma which is the largest center in Sweden (personal communication, March 30, 2021). The textiles are collected in large sacks with a weight of 250-300 kilograms and later moved to containers to be transported with trucks (personal communication, March 30, 2021). The actors SVOA collaborate with are Human Bridge, Emmaus Stockholm and Myrorna, these partners sort the collected textiles based on their quality and decide what garments can be sold in stores and what should be exported for further sorting in Europe (personal communication, March 30, 2021). They have also performed several collection analyses which reveal that approximately 4-5 kg of used textiles per person and year, end up in the residual waste. Sundin points out a trend in reduced quality in the garments since the beginning of the 21st century, however a possible shift could be on the rise, due to increased ambitions of many designers and actors towards making materials that are more sustainable and of better quality (personal communication, March 30, 2021).

4.6.2 Barriers, enablers and future prospects of waste disposal companies

As stated by Sellberg at Ragn-Sells, what limits many actors capacities is economic profitability since the processing demanded is immense (personal communication, March 17, 2021). Alternative issues are the lack of space and the fact that the sorting requires manual handling and human intelligence to be the judge of which textiles that are appropriate to be resold, recycled or exported. An opportunity for Ragn-Sells would be if sorting facilities were developed in such a way that textiles could be sorted automatically without the help of manual labour, possibly enabling lucrative recycling of textiles in a longer perspective.

Similarly to Ragn-Sells, the actors that are members of Avfall Sverige, face difficulties with the handling of larger volumes of used textiles. One of the contributing reasons in the case of Avfall Sverige's actors, is the lack of second-hand consumption (personal communication, March 12, 2021). Approximately 20% of the collected textiles are resold and the rest has been shipped to Germany, Poland and Lithuania due to the lack of capacity for material recycling in Sweden. Consumers are also most often unaware of the fact that even their ragged textiles have a value left. A majority of the public, donate and sell their used textiles but consume second-hand goods less than new ones. The lack of data collected on how much used textiles are collected is another challenge. As well as Ragn-Sells, Avfall Sverige state that the material recycling in Sweden is inadequate and this is the reason the material is exported to foreign countries. The material recycling is today in its infancy and needs to be developed technically and on a larger scale. Avfall Sverige wish to upscale the material recycling with help from actors such as Renewcell and SIPTex (personal communication, March 17, 2021).

Equivalently, *Kretslopp och vatten* express that there are always ways to collect more textiles, but the problem lies primarily within the question of final offset. For the time being, collaborative partners of waste disposal companies report that their maximum capacity has been reached. One of the goals of Kretslopp och vatten is to decrease the amount of textiles in the residual waste by 60% by 2030. If the producer responsibility comes into being, the municipality believes that this, along with some form of waste tax will help create change in the society. In order to be able receive more volumes, the actor must dispose of more and it must become normalised among the public to purchase second-hand clothing and home textiles. That way, maximum capacity will not have to be reached. It is certainly a challenge to change the consumer patterns but necessary so that the textiles do not end up exported, dumped or have their value wasted.

Stockholm Vatten och Avfall also speaks of the insufficient capacity in the Swedish textile sorting and that an increase in outlets such as downcycling and material recycling is fundamental. Sundin (personal communication, March 20, 2021) indicates that the amount of collected volumes will increase with 10% each year. SVOA hopes for sustainable transportation and to preserve Swedish materials in Sweden and to work out good offsets that sell reused textiles to consumers or to second hand shops. A summary of the barriers, enablers and future prospects identified in the waste disposal companies' interviews is presented in Table 8.

Table 8: *Summary of barriers, enablers and future prospects of waste disposal companies*

Target Group	Collection/Sorting activities	Capacities	Barriers	Enablers	Future prospects
Waste disposal	<ul style="list-style-type: none"> - Collection at recycling centers or through collaboration with partners - Collections are sometimes arranged in agreements with partners or customers - Collaboration with actors such as second-hand retailers and also NGOs for sorting activities - Some operate through advising, advocacy work and do not handle the textiles directly 	<ul style="list-style-type: none"> - Avfall Sverige have no collection activities - Kretslopp och Vatten can collect in the municipality but are not sure what the textiles offset station would be - Their actors have a maximum capacity - SVOA collect 1.5 tonnes/day, they believe their collection of used textiles will increase yearly by 10% 	<ul style="list-style-type: none"> - Textile collection in many cases requires manual sorting and quality checking, which is inefficient and costly - Actions must be lucrative to be pursued, downscaling is sometimes done due to economic difficulties - Low demand for used textiles, viewed as waste by consumers - Lack of space for containers along with damp conditions result in damages 	<ul style="list-style-type: none"> - Engaging in projects and collaborations with outside partners - Ambition to increase capacity by developing automatic sorting - Municipal collection - Sustainable transportation 	<ul style="list-style-type: none"> - EU directive will lead to a different distribution of used textiles - Opening up for collaborations with producers to find more commercial solutions - More pressure on material recycling and brands already have requirements to use reused fibers. - Aim to reintroduce textile production to Sweden - An increase in collected volumes with 10 % yearly

4.7 The role of the Swedish Environmental Protection Agency

The Swedish Environmental Protection Agency is a state authority which works with environmental affairs. They work on behalf of the Swedish government regarding environmental issues within the EU, in Sweden and internationally (Swedish EPA, 2012). Their focus on textiles includes the whole value chain and their role is mainly to provide information and support actors within the textile industry (Swedish EPA, 2021b).

During an interview with Yvonne Augustsson (personal communication, March 31, 2021), she expressed the importance of making the whole textile value chain sustainable. The impact on the environment occurs the most during the production of textiles, a total of 80%. Improvements made in the waste phase will only decrease these numbers by about 5-10%. But to be able to achieve circular flows, one must close the loops and combine the production part with the waste management (Augustsson, personal communication, March 31, 2021). Furthermore, the interviewee emphasises the importance of changed consumer behaviour in order to permanently achieve circularity within the textile industry.

In the new EU-directive, which will be implemented by the year of 2025 it is stated that all used textiles must be collected separately (Augustsson, personal communication, March 31, 2021). According to the Swedish EPA this will drastically increase the amount of used textiles being collected. The projected number, based on how much textiles that gets thrown in the household waste, is that Sweden will collect around 80,000 tonnes every year (Augustsson, personal communication, March 31, 2021). The role of the agency will be as an administrative supervisor, inspecting the textile handling within the companies that are affected by the EPR. If any actors are not reporting what they are collecting and recycling, they will be contacted by the agency and in some cases, measures will be taken for their cooperation and responsibility. This also includes international actors due to e-commerce (Augustsson, personal communication, March 31, 2021).

4.8 Volumes

In this section the volumes of collected or handled used textiles, gathered from the interviews are presented in Figure 5 on page 42. The volumes represent the total amount of collected textiles by each target group annually, however, not all of the interviewed companies are currently collecting used textiles, meaning that the total volume can not be generalised. A majority of the NGOs in Sweden were interviewed in this study, however, only a few of for example municipalities and waste disposal companies were interviewed. This result in that a comparison between the target groups in this context is not representative for the overall picture, since the numbers represent unequal shares of the total market. Additionally, the actors stand for themselves and the volumes therefore represents the flow of textiles in that specific sector, even if the same textiles might flow through other actors as well.

The gathered data regarding collected textiles from the target groups were in some cases transcribed to yearly estimations based on weekly collection rates. Due to this, assumptions concerning a steady collection rate were made to be able to quantify and compare the results. The results generated from the assumptions should be considered an approximate estimation of the total volumes. A clarification of assumptions and calculations can be seen in Appendix C.

The direct reuse companies do not collect used textiles through their platform themselves and therefore there are no data on which volumes of textiles being distributed through the platform. However, the numbers of

used textiles sold on the interviewed platforms amounted to over 3 million sold pieces each year. Since some of the collected data through the interviews only contained the number of ads uploaded and did not describe the amount of sold textiles, some assumptions were made in the total volume estimation.

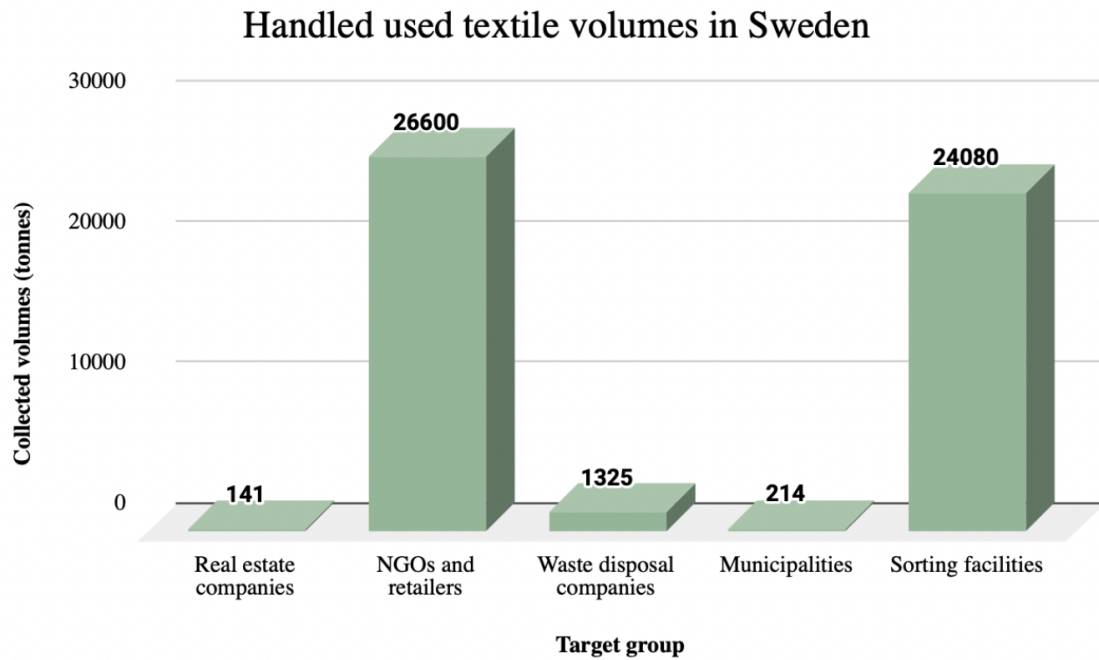


Figure 5: Total collected volumes of used textiles through the interviewed target groups per year. Note that the presented volumes only consist of fractions of the used textiles in Sweden.

5 Discussion

This section discusses the general trends that were identified considering the literature review, empirically gathered data through interviews and analyses these findings. This is done in order to compare and contrast, consecutively answering the research questions as well as couple with the purpose of the thesis. Lastly, the section is concluded with summarised answers to the research questions based on the discussion.

5.1 Activities and actors in the system

This thesis has taken its starting point in examining the key activities of the supply chain of used textiles, aiming to place the operations of included target groups in an overlying systematic structure. As stated in chapter 3, *Methodology*, the mapping procedure has been performed with guidance from the VSM framework, in order to summarise the handling of used textiles in Sweden. As outlined in chapter 1.2, *Scope*, the textile quantities and associated activities have been investigated, starting from the initiation of a used textile to the supply chain, ranging to its final offset destination. The concluding picture derived from the interviews has after an analysis resulted in the flowchart in Figure 6. Note that the flowchart is excluding occasional collection initiatives such as campaigns.

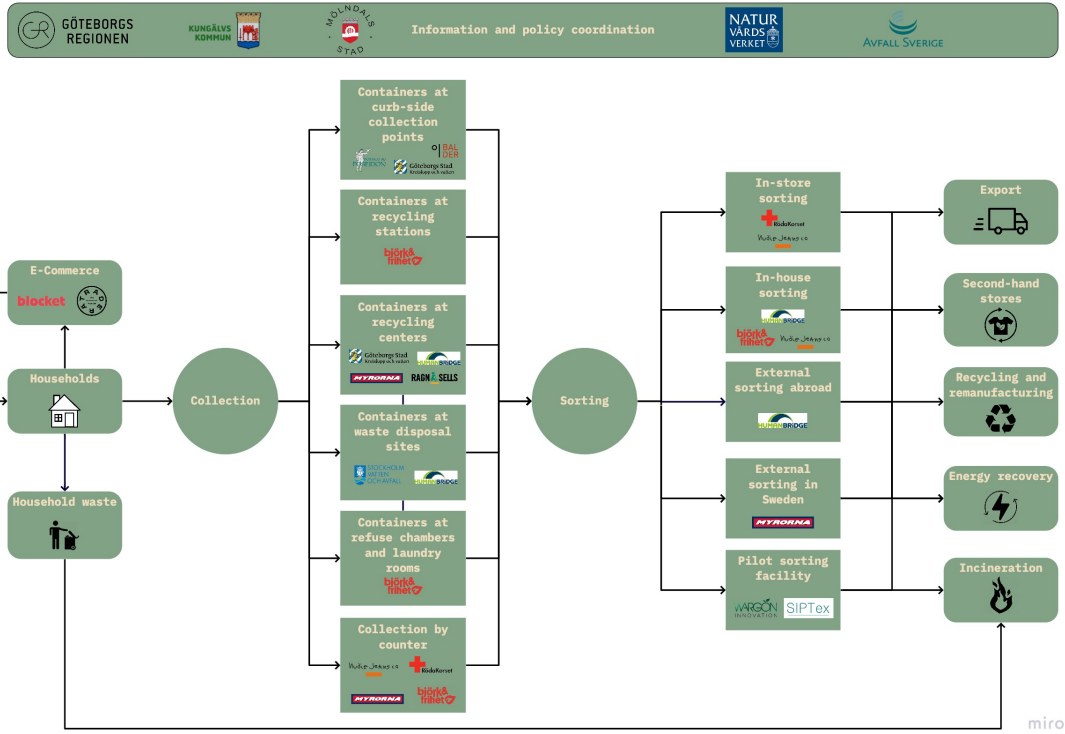


Figure 6: Mapping of the supply chain of used textiles in Sweden

A textile included in the scope of this thesis, will start its journey into the supply chain of used textiles as a residual product from a household. Generally, circular handling of used textiles is dependent on the key activities of collection and sorting, as identified in interviews with textile redistributors. All used textile

flows, except for direct reuse, is passing through one of the alternative options for collection and sorting, as illustrated in the flowchart. The round symbol is illustrating an activity, while the boxes describe in what way the particular activity is performed. Which type of procedure that are conducted by which of the interviewed actors can be understood by identifying the logos associated with the actors on the flowchart. Furthermore, the identified offset alternatives are lined up in falling order with respect to handled volume quantity. The lines connecting the arrows from the different sorting options imply that all sorting practices can be finalised through any of the identified offset alternatives.

Today, municipalities own all material regarded as waste, including discarded textiles (SOU, 2020). The general pattern observed from interviewed municipalities was that their main textile collection today is conducted in collaboration with NGOs, for instance by granting permits for placement of collection containers at recycling stations. Both Mölndals Stad and Göteborgsregionen have paused their efforts in planning a future system for separate textile collection, due to the possible redistribution of responsibility on the issue. The future role of municipalities will depend on whether the EPR is actually introduced by 2025 or if the accountability for implementing the WFDs demand of separate collection will fall on the municipalities. Currently, the interviewed municipalities primarily aim to contribute by informing inhabitants on circular practices and the importance of recycling and reuse. In the future, the responsibility for dissemination of information could possibly continuously be assigned to the municipalities.

When shifting focus towards the real estate owners, a similar mindset to the one of municipalities can be found regarding the consequences of the EPR. Real estate companies principally provide locations at which the collection containers can be placed, and therefore hold no responsibility of the actual collection. Instead, as stated by Balder and Poseidon, all collaborative activities concerning separate collection of used textiles, are conducted with the purpose of improving possibilities of textile hand-in for the residents. Poseidon declared a goal of having curb-side collection points within two years for all facilities, whilst Balder has discussed possible collaborations with NGOs further on. Hence, the future role of real estate companies is to act as intermediaries of collection points by facilitating the available locations, rather than actually enforcing the directive.

The current role of waste disposal companies in the circulation of textiles is internally varying. To the extent that Ragn-Sells and Kretslopp och Vatten are indeed separating textiles from the remaining household waste, this is almost exclusively done in collaboration with either NGOs or through temporary initiatives, as for instance in a project with Wargön Innovation. On the contrary, SVOA daily collects 1.5 tonnes of textiles at recycling centers which also in this case ultimately are handled in collaboration with NGOs. Both SVOA and Avfall Sverige claim that increased textile collection, possibly conducted on waste disposal sites, could be upscaled as long as the textile offset opportunities increase. According to Ragn-Sells, profitability is a condition for taking a larger role in the collection.

Hence, a majority of interviewed target groups both rely on and are involved in the collection and sorting activities provided by Swedish NGOs. NGOs perform 90% of the Swedish textile collection, where the latest total amount reported was 38,300 tonnes (SMED, 2018b). As illustrated in the flowchart, interviewed NGOs mainly use containers placed in different surroundings to perform collection. The collection is conducted in a similar manner among NGOs, apart from The Red Cross who mainly collect textiles by counter in second-hand stores.

Transportation and sorting of the collected textiles vary to a greater extent. Myrorna, Human Bridge and Björkåfrihet own sorting facilities, from which textiles are redistributed to stores or exported. External sorting in Sweden is used by Myrorna, while Human Bridge is selling textile volumes to the international sorting industry, The Red Cross on the other hand manages all sorting in-house. Collaborations between NGOs and the interviewed pilot sorting facilities of Wargön Innovation and SIPTex have also been examined. The role of conventional sorting in the regime of NGOs clearly plays an essential part in the extraction of value from used textiles, since 90% of the collected volumes currently are manually handled. However, innovative sorting facilities have the potential to introduce larger profit-margins to the used textile industry as well as to NGOs. Sandberg et al. (2018) emphasise the impact of sorting due to its resource-intensity and automated high-capacity sorting facilities as the SIPTex pilot project could possibly entail economic relief for NGOs in their role as textile redistributors. Despite the NGOs significant function in textile sorting today, the fact that textile volumes generally are exported unsorted due to high domestic handling costs (Nordic Council of Ministers, 2020) supports the assumption that their key role as performers of sorting can be altered.

Concerning the transport of textiles between the facilities of NGOs, third-party logistic companies are the primarily used option. Björkåfrihet and The Red Cross conduct domestic transports with their own vehicles, while Human Bridge and Myrorna completely rely on external transportation services. These variations could be an effect of different logistical layouts of the NGOs, which in turn can be a consequence of differing geographical coverage. The Red Cross is present throughout Sweden as a geographic whole with stores in remote locations causing uneconomical transports, whereas Björkåfrihet, based in the south-west of Sweden, does not experience this to the same extent.

The transportation patterns of NGOs resemble those of the rest of the textile industry, with dispersed value chains raising needs for transport, lorries dominating domestically and shipping as major intercontinental transport means (Palamutcu, 2015). Considering the results from interviews and the literature review, it is evident that the statement of Mistra Future Fashion (2019a) remains relevant; namely that information on the transports of the post-consumer phase is currently inadequate and at times non-existent. The role of NGOs as textile transporters varies as well as the degree of transport outsourcing, although Myrorna and Human Bridge who primarily use third-party logistic companies place requirements of environmental friendliness on their collaborative logistic partners, which The Red Cross and Björkåfrihet do not report on.

In conclusion, the future role of NGOs in the supply chain of used textiles is yet to be traced out. Björkåfrihet mentions the opportunity to act as a future collection provider, although it is unclear if this lies within the framework of the suggested Swedish EPR. In the proposition, it is stated that the responsibility of shaping a functional collection system will fall on textile producers (The Swedish Government Official Reports, 2020). This alludes to uncertainties expressed by Avfall Sverige, Kretslopp och vatten and Göteborgsregionen regarding the design of the future textile collection system and what role it will give NGOs, municipalities and waste disposal companies in the supply chain of used textiles.

In context of the previously discussed target groups, the activities of direct reuse actors Blocket and Tradera are deviant. The distinction lies within the removal of intermediary logistic steps, a consequence of the direct redistribution of single pieces from one consumer to another. Despite having removed the critical logistic steps of collecting and sorting, the direct reuse actors report on remaining challenges concerning

distribution of goods between platform users. Both Blocket and Tradera aim to extend their responsibility through introducing sustainable transport options, working with co-freight and encourage reuse of goods locally. Enforced by this, it can be assumed that increased reuse of textiles through online platforms, could possibly improve and decrease textile transportation. This development is altering textile consumption in a positive direction, since according to the Swedish EPA (2021a), globally dispersed textile value chains result in wide transports of newly produced garments.

Furthermore, extended reuse through online platforms, circumvents the problems of resource-intensive and underdeveloped procedures of sorting and collection (Chung-Wha et al., 2020). The phenomenon retains textile product value efficiently, keeping materials on desirable levels of the waste hierarchy and aligning with the ambition of the WFD (European Parliament and Council, 2008). The new role of direct reuse from consumer-to-consumer hence shows potential to meet policy requirements and decrease the need of logistic activities connected to textile reuse, in comparison to reuse through reselling in store. If the linear consumption patterns described by RISE (2019a) could be changed, e-commerce might play an important part in making reuse more local and in the long-run replace import of newly produced textiles. Although, in effect, reuse through online platforms could be regarded as an example of successful circular business models, something Chung-Wha et al. (2020) otherwise reports to be consistently missing in the textile industry.

Finally, the operations of Nudie Jeans was included in this study, in order to provide a relevant comparison between circular activities of a textile producer and the other target groups. Nudie Jeans is the actor investigated that comes closest to operating in a closed-loop system, repairing ragged garments and creating new collections with their used textiles in storage. In contrast to NGOs, waste disposal companies and direct reuse platforms there is a high predictability in the quality and character of the textile goods that Nudie Jeans collect. This could possibly facilitate subsequent value extraction from used garments, since the traceability of Nudie Jeans supply chain could enhance the opportunities for recycling (Hasanaj & Jansson, 2018). In promoting repair and reuse as a part of their business model, Nudie Jeans activities are aligning with the waste hierarchy and thereby the WFD (European Parliament and Council, 2008). The retailer could be regarded as having the role of a predecessor in the textile industry, primarily in the fields of circular product design as well as stating and communicating example of circular practices. This alludes to the perception established among interviewees and in the literature, namely that a key component in order for the society to achieve a sustainable future, is starting with a change in consumer behaviour (RISE, 2019a).

5.2 Future volumes

Sandin et al. (2018) claim that the interest in reuse and recycling of textiles is increasing as the attention given to circular economies is expanding. According to the interviews with Blocket and Tradera, the latest known amount of textiles directly redistributed and reused through their e-commerce services was above 3 million pieces each year, as stated in Appendix C. Both interviewed actors report trends of increased sales of used textiles from consumer-to-consumer and claim to have unlimited capacity to expand.

The summarised volumes collected by the NGOs derived from the interviews amounted to 26,600 tonnes, which is 11,400 tonnes below the total volume reported by SMED (2018b). However, the SMED study included data from 36 NGOs and the volumes of this study are calculated solely from the collection by Human Bridge, The Red Cross, Myrorna and Björkåfrihet. No conclusion concerning a change in volumes

collected by NGOs can hereby be drawn, and of the interviewed NGOs only The Red Cross reported an increase of collected volume. In contrast to this, the proposed introduction of EPR (The Swedish Government Official Reports, 2020) has led all interviewed NGOs to expect increased textile collection accordingly, but this has not yet been experienced.

As EPR takes place, the textile producers will be responsible to make sure the used textiles are being collected (OECD, 2016). OECD (2016) explains that a relocation of the responsibility to the producers from the municipalities will decrease the total amount of waste, as well as increase the waste collection, including the collection of used textiles. When the producers are responsible for the textiles' end-life, they will probably want to keep the post-consumer value as high as possible in order to gain income on the used pieces. de la Motte et al. (2019) claim that making the producers take sustainability in consideration in the production phase is a key aspect of the EPR. Increased quality of the produced textiles will enable a higher circular value, and the amount of used textiles reaching the standards of the Swedish second-hand market will most likely grow. Ljungkvist et al. (2018) state that the volumes of collected textiles will increase when the EPR is implemented. However, the authors further elevate concerns regarding the potential decrease of quality in the increased textile collection, therefore generating lower value per piece.

Common for all interviewed actors involved in reuse of textiles in this study, is the realisation of the decrease in quality of used textiles as the fast fashion market expands. This is an indicator why the EPR is essential right now, since it has the possibility to change this trend. If the EPR is designed in such way that the producers are responsible for not only collecting the textiles, but making sure they are properly managed according to the waste hierarchy, the quality might increase. If not, this trend and the fast fashion market might continue to grow and the offset opportunities will decline. Hereby, it is clear that the current declining trend of quality is as for today quite far away from the policy-makers ambition of quality elevation through the EPR.

As stated by RISE (2019a), the poor quality makes the used textiles unfit for consumer-to-consumer reuse. Therefore, the increased collected volumes might not lead to an larger share being reused, but rather contrariwise with a smaller amount reaching the second-hand standards. Carlsson et al. (2015) claim that the textiles that do not reach the quality required on the Swedish market are exported, which is approximately 80% of the collected amount. A larger amount of used textiles being collected might therefore increase the export rate. However, Carlsson et al. (2015) further state that the amount exported will decrease in the future since textile importers will become more self-sufficient in supply of a domestic second-hand market, resulting in increased need for Swedish textile handling.

Interestingly, there is a discrepancy between volumes of textiles discarded in household waste reported by Gothenburg and Stockholm. SVOA report 4.6 kg of textiles in the residual waste in 2020, while Kretslopp och Vatten estimates a number of 7 kg in Gothenburg during the same period. Considering that the Stockholm region currently offers collection on their larger recycling sites, this implicate an possible positive impact of waste disposal companies including textile collection in their waste handling. However, all waste disposal actors interviewed express incertitude in the future handling of textiles induced by the ambiguities of the EPR. According to the interview with the Swedish EPA, it is predicted that if the requirement for separate collection comes into force, textile volumes in the used textile system will amount to 80,000 tonnes. In comparison with the latest measurement on collected textile volumes, 38,300 tonnes, the new collection

system will have to double its capacity.

5.3 Barriers

5.3.1 Economic barriers

As stated in the conducted interviews, the NGOs as well as the waste disposal companies experience difficulties in finding profitability in the collection of used textiles. Interviewed profit-driven companies declare that they have a hard time motivating an implementation of a collection since there are no incentives for doing this, except for the environmental. For the waste disposal companies, it is often more cost-efficient to incinerate the used textiles rather than sorting them for reuse or recycling, as stated by SMED (2011). These companies assert that with today's technology, manual sorting is needed, which is inefficient and costly.

Chung-Wha et al. (2020) claim there is a deadlock in the recycling and sorting industry since there are not yet any large-scale textile flows in this sector, leading to a non-competitive price. This contributes to the fact that almost all textiles collected by the waste disposal companies are sent to incineration, at least until there are more developed and cost-efficient methods to sort them. A majority of the used textile handling by the waste disposal companies lays within the household waste. Until there is an affordable automatic sorting technique, sorting of textiles from the household waste will not be profitable, a perception stated by IVL (2020b) and shared by the waste disposal companies. They claim to lack resources to sort the textiles out of the residual waste and most of it then goes to incineration, which aligns with the statements of SMED (2011). However, there are often separate bins for the textiles at recycling centers, but since the second-hand market value of textiles is generally low and the textiles still need to be manually sorted, there is almost no profit to gain.

Another barrier identified is the lack of investment capability, especially for the NGOs, since their work is non-profitable. As stated by Dervojeda et al. (2014), the low profitability among these actors complicates the establishment of a circular supply chain of used textiles. The lack of equity limits the possibilities to invest in development of the collection and sorting logistics. Further, Dervojeda et al. (2014) point out the large upfront investments as identified barriers in the circular transition. Without further development, it is difficult to upscale and increase market shares, which leads to a non-significant change in incomes. If the volumes of used textiles would increase rapidly, it might be difficult for the NGOs to match the capacity needed and adapt their operations. Therefore, a rise in collected textiles in this sector might not contribute to an increase in reuse. This argument is supported by RISE (2019a), who claims that there is a lack of profitable companies in the reuse and recycling sector, which would potentially have the opportunities to invest more in circularity. Chung-Wha et al. (2020) believe that governmental financial support could support the development of circular businesses, especially in the case of NGOs, which might enable a more efficient collection and sorting as well as upscaling. RISE (2019a) states that alternative reuse business models in addition to the current ones should be considered, for instance quality sorting processes, which would require larger investments. These investments could be generated by governmental support or by profitable businesses willing to finance an development of the circular system.

As aforementioned, the quality of the collected textiles is currently decreasing. As claimed by IVA (2020), the second-hand value is already relatively low on the collected pieces and as the quality diminishes further, there will be more textiles that do not reach the standard required for second-hand reselling. The poor

quality in the collected textiles by NGOs also depends on the up-rise in competition on the second-hand market, which is supported by Palm et al. (2014), since quality pieces can be sold on direct reuse platforms instead. On these platforms, the seller receives the whole amount the customer pays, which gives more incentives than leaving the textiles free of charge in a collection bin. This however does not indicate that less textiles are being reused, rather that it will be more difficult for the NGOs to find an economic feasible business model when quality textile goods are resold online. The overall circularity will therefore not decline, but if the NGOs' incomes decrease further, their businesses might not be able to match the capacity needed. Additionally, fast fashion conduces to lower price of newly produced textiles, which leads to a lower second-hand price, and thereby lower income for the NGOs. The textiles that can not be sold is one additional cost for the actors, in handling and processing.

At last, the Swedish Red Cross explains that there are difficulties for the second-hand actors to price the textiles since the willingness to pay varies in different parts of Sweden, as well as abroad. As previously mentioned, the pricing along with sorting is done manually and a great amount of knowledge in the area as well as identification of trends is needed in order to set a suitable price. The sorting and grading processes are according to Sandberg et al. (2018) resource-intensive, and the actors involved are often NGOs who could increase their surplus by replacing the need of manual sorting of the collected pieces. However, the investment for such a sorting system must be conducted by profitable actors since the NGOs do not have the financial muscles.

All the aforementioned barriers experienced by the actors in the supply chain of used textiles, are indicators of the challenges in developing a circular supply chain. As stated by Dervojeda et al. (2014), the established industry's linearity complicates the transition to a circular economy, as well as the economic barriers in the circular supply chain, as claimed by Levering et al. (2019). The long-term goal of circularity is to contribute with lucrative resource efficiency (EMF, 2017a), but it is evident that the industry is currently lacking the economic incentives needed to accelerate supply chain transformation.

5.3.2 Information barriers

Pervading trends and patterns identified in the interviews were the lack of information, transparency and communication. Among the target groups in the supply chain of used textiles, the dissemination of information is nearly non-existing. There are uncertainties regarding how a proper textile collection should be designed, what fractions could be collected and how the textiles actually are handled at the different alternatives of offset. Even though the actors collaborate amongst target groups, there are still evident difficulties with information sharing and a lack of organised informational flows. There is a natural communication barrier exists which Govindan (2018) sheds light on. For instance, Kungälv's kommun believe that their collaborative partners such as Human Bridge have low capacity, although Human Bridge themselves state that they have unlimited capacity. Since they are in a position of dependency, communication is required to achieve an optimal resource utilisation, increased efficiency and quality assurance. Hence, there is an informational gap created by the several steps in communication where information is easily lost along the way.

Pal et al. (2019) emphasise the importance of overcoming the information barrier through supply chain management. The actors could benefit from additional communication by gaining knowledge in developing

circular activities internally. Govindan (2018) and Levering et al. (2019) acknowledge the aforementioned by confirming the knowledge gap in implementation of circular business models. Although, there is no established framework or given solution to the challenge, the industry is in need of developing both skills and gain knowledge (Chung-Wha et al., 2020). This goes together with Govindan's findings (2018) concerning the consumers perception of circular products. The interview with Myrorna confirmed the concerns with informing the inhabitants regarding their consumption behaviours. A common theme is that many donate and few consumers in fact buy second-hand which results in wide supply yet low demand.

Another finding is that the ambiguity in the information regarding producer responsibility causes precariousness. Target groups as for instance municipalities and waste disposal companies, are pausing their plan to further invest in textile collection in anticipation of clear instructions. Palm et al. (2014) recognise the uncertainty upon which actor the responsibility lies on. The authors present the consequences of the dilemma as more time consuming in form of administrative work and low barriers to entry for rogue actors (Palm et al., 2014). The actors are in need of transparent directives regarding their future role in the supply chain to be able to continue planning their textile collection.

The insufficient information coverage of the supply chain activities such as the transportation, which Mistra future fashion (2019a) state as an issue, could be conquered by inter-organisational coordination and collaboration. Additionally, Levering et al. (2019) recognise the complexity of the cooperation which could be facilitated by greater information-sharing.

5.3.3 Collection barriers

A common problem experienced with the collection of used textiles is the difficulties in finding suitable locations for the collection bins and containers. This barrier is identified by all actors handling or considering handling a collection point. In this area, there is a great lack of published information, although it is such a common problem among the interviewed real estate companies as well as NGOs. The textiles are sensitive to moisture because of the risk of mold, which would make the collected textiles unsalable. Therefore, the bins need a site protected from the weather if they are placed outdoors. In those cases where collection boxes are placed inside, difficulties often arise with finding enough space for them.

Chung-Wha et al. (2020) claim that the logistic challenges regarding the collection mainly depend on the lack of standardisation as well as suitable facilities. When having a textile collection in the same location as the residual waste, the textiles absorb the smell of the garbage and are once again unsalable, as stated by the waste disposal companies. Further, the container placement needs to be optimised with regards to availability, in order to minimise the inconvenience of disposal of used textiles responsibly. This leaves very few options for where to place the collection bins. The difficulties in finding a suitable spot for the collection makes the implementation complex and is one of the reasons why some of the interviewed real estate and waste disposal companies do not currently collect used textiles.

An additional barrier connected to the lack of suitable locations identified from the interviews, is the difficulties in emptying the bins. There must be enough space for the vehicle, often a truck, to reach the bins. When the collection of textiles is placed indoors, the collector needs access to the building and it is often confined. The interviewed real estate companies state that the bins often are placed outside, since they want their tenants to feel safe and no more people than needed to have access to the facilities. Further, there are

no standardised measures for a collection bin and different collecting organisations often have different sizes of bins, which supports the argument by Chung-Wha et al. (2020) regarding non-standardised processes contributing to logistical challenges.

Palm et al. (2014) shed light on the difficulties regarding permits needed in order to place a collection bin. The interviewed actors connected to the collection of used textiles agree on the problem, since the contracts are difficult to acquire. Still, there are troubles with many rogue actors placing collection bins close to the contracted ones. As stated by the NGOs, the illegal containers previously used to be scattered throughout the city, where they became obstacles for everyday maintenance and other activities. Therefore, many municipalities have limited the space where it is allowed to place collection bins, which decreases the total amount of bins and thereby the total volume of collected textiles. Palm et al. (2014) claim that the insignificant consequences for these actors have led to an up-rise of illegal textile collection. A clearer and more assertive plan for how illegal actors are handled could improve the collecting companies views on the permits. In order to get there, the NGOs providing the bins could collaborate to put pressure on the contract holders, since their goal is the same. Further, the permits are either received by municipalities or FTI, and according to Palm et al. (2014) there is ambiguous information regarding who will be responsible for the collection if the producer responsibility is implemented.

An additional problem that NGOs experience, is the loss of collected textiles due to theft. Palm et al. (2014) claim that 4% of the collected textiles are stolen with the purpose to sell the pieces. Another problem is claimed to be vandalism of the containers, since this increases maintenance costs. NGOs providing the bins, acknowledge this as a serious problem since they are responsible for the cost added by vandalism, which is supported by Ljungkvist et al. (2018). Placement of the bins indoors or at a lighted up place where many people walk by outside, might decrease this problem.

5.3.4 Technological barriers

As stated by Chung-Wha et al. (2020) the technological operations of waste sorting and textile fiber recycling are currently novel and non established. Today's sorting methods require a vast amount of human resources, resulting in the manual sorting of used textiles not being long-term scalable. According to all interviewed NGOs and sorting facilities, the sorting competence is a determining factor when it comes to segmentation of used textiles. Further, to make the grading activities more efficient, Sweden is in need of developing more large-scale and automatised sorting facilities. Even if all the used textiles that end up in the household waste had been collected today, sorting them in Sweden would have been a bottleneck due to the manual process. Consequently, this results in export to other countries where the price for sorting is significantly lower (Nordic Council of Ministers, 2020).

The development of an automated sorting facility is already in progress by Siptex, which will have a capacity of 24,000 tonnes per year when up and running (Sysav, 2021). As stated by the Swedish EPA (2020a) there currently is 38,300 tonnes of used textiles being collected by NGOs. Since the NGOs perform a majority of Swedish textile collection, this facility will be able to handle about 60% of these volumes, indicating that further development of sorting operations is needed. Moreover, this would likely enable a desired increase of domestic handling of used textiles, as stated by each interviewed NGOs and sorting facilities. The establishments of these types of facilities will require profitable incentives for the parties involved in

the development work, as well as the actors whom are to send their collected textiles for automated sorting rather than incineration. RISE (2019a) and Chung-Wha et al. (2020) both argue that financial support provided by the government along with subsidised innovation processes, could facilitate the advancement of technological practices connected to textiles.

The recycling and re-manufacturing opportunities for mixed materials are as of today insufficient, meanwhile the poor quality of numerous textiles produced also contributes to difficult challenges within re-manufacturing. According to IVA (2020) improved design for material quality is an important aspect in ensuring and increasing the re-circulation of used textiles. As stated by Hasanaj and Jansson (2018), material purity is also of importance since products with complex mixtures of materials without composition traceability usually are difficult to recycle. Moreover, to overcome the barriers of material composition it should be interesting for stakeholders to invest in the development of technologies, with purpose of separating the mixed materials and layered textiles. If acceptable profit margins could be attained within a reasonable time frame of the investment, the separation technology has potential to act as an eye-opener for several actors within the textile industry. Furthermore, SIPTex mentioned that the feed stock quality or rather lack thereof is a common problem at the re-manufacturing facilities, which further emphasises the necessity for improved sorting methods.

However, it is quite difficult to predict the potential of new technologies since there is an imminent risk of having too high expectations regarding what can be accomplished. New and non established technological operations have so far not been fully developed, although there is a positive outlook to further expand the actors' businesses by introducing automated options. For instance, Schmidt et al (2016) presents an improved fibre recycling route which could achieve full recycling maturity for fibre mixes and other materials consisting of other than 100% polyester. Due to the challenges with achieving high productivity and profitability, Wargön as an example are investigating the possibilities to implement AI for pricing of the sorted textiles. Although the technology is still in an early phase, it should be developed further since could be established as a valuable part of the circular economy (Ellen MacArthur Foundation, 2017a). A future successful implementation might help reduce the sorting bottlenecks and contribute to increased domestic offset opportunities, as discussed below.

5.3.5 Offset barriers

A consistent trend among the interviewed target groups, especially NGOs, is found to be the limitation in offset opportunities mainly in Sweden but also abroad. The lack of domestic recycling possibilities together with an increasing demand for textile offset, are regarded by Björkåfrihet, Myrorna and Human Bridge as contributing factors which need to be addressed. Aggravation of material recycling is the result of the declining trend concerning textile quality as well as the widespread prevalence of mixed material compositions. Direct reuse actors in association with the greater part of interviewed NGOs further report a somewhat recent up-rise in the collection and redistribution of low quality textiles.

Existing recycling technologies are insufficient when it comes to handling the vast majority of textile fabrics that are collected today, which relates to the claims by Ellen MacArthur Foundation (2017b) regarding lower quality of recycled fibers compared to virgin ones. Dahlbo et al. (2017) further emphasise the uncertainties concerning whether replacement of virgin fibers can be made by recycled ones, with background in the lack

of adequate recycling practices. Moreover, offset barriers within the recycling industry are attributable to the higher pricing of recycled materials, which accordingly create less incentives for upscaling as discussed by EMF (2017b). The inability to properly recycle the sorted textiles in-house, as stated by all interviewed NGOs along with the sorting facilities, leads to a larger amount being exported elsewhere, where the most common type of recycling technology according to Schmidt et al. (2016) is downcycling.

When looking at the offset issue from a waste management perspective, an increase of downcycling has the potential to reduce the overall textile waste but is simultaneously inferior compared to the use of upcycling (Schmidt et al., 2016). Although in many cases, upcycling is better for the purpose of minimising textile waste, the applied technologies are currently not lucrative enough for stakeholders to be implemented on a larger scale. In order to increase the amount of upcycled textiles, feasible methods for fiber-to-fiber recycling have to be further developed, as opined by Schmidt et al. (2016). This along with textile design play a crucial part in the waste management of used textiles, which aligns with the claims by Roos et al. (2019) and IVA (2020) whom emphasise the vital role of original textile quality and monomaterial composition. Successful upcycling also includes the utilisation of used textiles as raw material or as composites in new production, which according to Stanescu (2021) could be achieved to a greater degree by ensuring better end-of-life recycling through sustainable product design.

Another interesting finding is that the problem with offset seems to be greater in Sweden compared to other European countries. All interviewed NGOs declare that there are concerns regarding the fact that the supply of used textiles exceeds the demand for reuse in Sweden, which according to IVA (2020) is based on a lack of interest in second-hand purchasing among consumers. As stated by the Red Cross, a large fraction of unsold and poor-quality textiles are transported to textile recycling partners in either Germany or the Netherlands by lorry. Likewise, Myrorna and Björkåfrihet report that almost half of the collected amount of textiles are exported for further handling, while Human Bridge on the other hand export the lion's share. This likely devolves upon the availability of cheaper labour and overall lower handling costs, since economic impediments often derive from sorting and grading activities being resource-intensive in these terms, as claimed by Sandberg et al. (2018) and Carlsson et al. (2015). In several countries, usually characterised by poorer socioeconomic status and less developed infrastructure, the offset opportunities from a Swedish perspective still remain quite prosperous. This can further be strengthened by the large demand for reusable textiles from the Nordics in various parts of the world, notably the Baltic region (Nordic Council of Ministers, 2020). Although, questions remain regarding the humanitarian aspects of exploiting cheap labour as well as allocating the textile treatment activities elsewhere.

Future offset barriers include predictions by Carlsson et al. (2015) concerning an apparent decrease in export of used textiles from Sweden, caused by diminishing demand. The authors' forecast is based upon the presumption of an approaching self-sufficiency in the domestic supply of a second-hand market for import nations, which is due to excelling economic growth. IVA (2020) affirms that less developed countries in comparison to Sweden, recently have begun to decrease their imported volumes of used textiles, of which forty nations have already imposed import bans. As the domestic textile quality improve in these countries, the need for imported second-hand pieces is predicted to decrease correspondingly.

Nonetheless, the exported amounts of Swedish textiles have increased in recent years according to SMED (2018b), indicating a delay in this shift. With the aforementioned offset restrictions in mind, several actors

are presently working on finding ways to reduce the exported volumes and thereby keep the used textiles in Sweden. In the interviews, numerous actors within the different target groups announced that the possibilities for upscaling of the textile collection show rather great promise. The insufficient demand for second-hand garments along with difficulties in localising suitable sorting and offset opportunities, is brought up to attention by the waste disposal companies and NGOs. Although, the same problems are addressed by the two, there are minor differences regarding underlying incentives for capacity increase, where the NGOs generally deem lack of investment capital and the availability of sustainable handling methods of used textiles as constraining factors.

5.4 Enablers

5.4.1 Collaboration

When working towards a circular textile industry, Chung-Wha et al. (2020) emphasise collaboration among stakeholders as a key enabler and driver towards a transformed industry. In accordance with this, plenty of the interviewed actors have stated opportunities connected to inter-organisational collaboration in a wide range of activities. A usual type of collaboration can be exemplified by the municipalities Kungälv kommun and Mölndals Stad, who both have established procurements of textile collection with Björkåfrihet, Myrorna and Human Bridge. Göteborgsregionen claims that outsourcing textile collection to NGOs is a common way municipalities in the region deal with the issue of textile discardment. Additionally, internal collaboration between NGOs, where they assist each other in the time-consuming sorting phase, is mentioned as an opportunity by Human Bridge. These collaborative activities in collection are aligning with the, by Björkåfrihet mentioned, opportunity for NGOs to act as collection providers in the context of a possible future EPR.

It is possible that a collaborative collection network for textiles, supervised by the Swedish EPA, could be an important component of a circular textile industry in Sweden. This alludes to the suggestions by Pal et al. (2019) concerning the needs for transformed logistic systems when striving towards higher resource efficiency and circular supply chains. Apparently, this is highly applicable on the supply chain of used textiles and in this case, the inter-firm collaboration mentioned by Levering et al. (2019) will involve stakeholders ranging from policymakers down to the provider of curb-side collection bins. A reflection concerning the intricate coordination problem of textile circulation is that, due to the multitude of stakeholders and their internal differences, a process perspective of SCM-character could as proposed by Sandberg et al. (2007) beneficially be used to manage a circular system of textiles.

Göteborgsregionen mentions the potential upstream collaboration with textile producers to improve quality of textiles, which according to Moazzam et al. (2021) is a critical issue in the enabling of textile fiber recycling. This is connected to the possibilities of creating an economically viable market for used textiles and textile fibers, which SVOA mentions as desirable. Moreover, Sandberg et al. (2018) elevate the importance of collaboration amongst actors in the creation of profitable circular business models and cost-efficient supply chain operations. For instance, Tradera mentions co-freight as a more sustainable transporting option and Human Bridge addresses the opportunity of collaborative maintenance of collection points. Both The Red Cross and Human Bridge emphasise the important collaborative effort of establishing efficient textile sorting facilities. Wargön Innovation, from the perspective of an innovative textile sorter, strengthens the necessity

of logistical collaboration when expressing a demand for improved coordination of textile flows. Hence, the interviews are showing a lot of evidence that collaboration is an important enabler of future circularity in a multitude of activities.

Chung-Wha et al. (2020) argue that this type of collaboration has the potential to unite the textile industry in working towards common goals, enabling a more circular industry. As stated by (Angelova, 2020) a complete and functional circular model will recover the value of the product and re-add it in the next and upcoming chain. In order for the circular model to work in the best possible way and to be able to drive it forward, it is of great importance that there is an open dialogue and cooperation between policymakers, research institutions and the industry. Collaborative knowledge-sharing was a present theme throughout the literature review, however none of the interviewed actors mentioned increased information sharing inter-organisationally as an enabler. This reinforces the assumption that the identified information barrier concerning deficient communication in the circular system of used textiles might be an overlying transparency problem.

5.4.2 Dissemination of information

Kretslopp och vatten are a prominent example of an actor that has found new methods for educating its consumers about the environmental impact of the textile production as well as encouraging them to purchase more second-hand goods. With the help of influencer marketing, they have been able to target a different audience and reach out. Greater flows of information and informing consumers that even ragged textiles can be separately collected, could lead to an increase in collected volumes (Palm et al., 2014).

Well-informed consumers are more likely to dispose of their textiles in a sustainable way, in addition to this consumers possess the ability to affect stakeholders and producers by demanding circular production and environmentally friendly designs (Chung-Wha et al., 2020). Tradera mentioned during their interview that they have noticed a shift in the attitude towards second-hand, and that people are beginning to question their consumption habits. Björkåfrihet supports this statement by emphasising the importance in changing consumer patterns and also the public's view on second-hand goods. Further, it is implied that the transition to circularity starts with the producers and that they will always have the trends of customers demand in mind (Chung-Wha et al., 2020). Nudie Jeans is an example of a brand that is striving to close their material loop, for instance through clothing collections produced with organic cotton and traceable, post-consumer fibers. The collection gained a lot of popularity with its high-quality and durable denim (Nudie Jeans Company, 2019). This could be interpreted as an example of a shift in the consumers mindsets and a changed response to environmental friendly marketing. On the contrary, Myrorna claims that consumers often express that they could imagine themselves consuming second-hand textiles, but not as many actually do it. Potentially, the market communication of retailers such as Nudie Jeans, who implements circularity by repairing and reusing garments (Nudie Jeans Company, 2019), can help change the public's behaviour and inspire to sustainable consumption.

This alludes to the aspects of transparency and traceability, which is becoming important for companies in the new era. By having an effective tracking of the input materials to the production, transparency is enabled (Khan et al., 2020). The consumers will potentially feel that they can rely on companies that are transparent and whose materials can be traced, while the companies themselves gain control of their supply chain and its environmental impact. Therefore, both transparency and traceability are possible ways to be

able to close the loop and enhance consumers knowledge within the area (IVA, 2020).

During the interview with Kretslopp och Vatten, it was stated that to create change, a waste tax could be helpful but it was not a suggestion, rather an opinion. Governmental interference similar to this could help communicate the importance of responsible waste handling to the public, whereas traditional information outlets are insufficient. The governmental influence is powerful in encouraging consumers and recycling actors and to create a post-consumer behaviour (Chung-Wha et al., 2020).

5.4.3 Extended collection points

Extending the opportunities of collection can create accessibility, and thereby possibly increase collected textile volumes. Available collection helps avoid postponement of textile disposal, as well as possibly reducing the amount of textile stored in households (Palm et al., 2014). By providing collection closer to real estates, or at other safe indoor facilities such as clothing stores, libraries and city halls, as stated by Göteborgsregionen, would be more accessible. This would reduce the need for transportation to a distant locations for disposal of used textiles. Availability on a national level is also one of the requirements by EPR on the new collection systems, this will thus be of further importance to the collection actors (OECD, 2016). In accordance with this, Nudie Jeans mentioned during their interview that their accessibility for customers is of great importance in order to increase their repair service operations.

In expanding the textile collection, plenty of alternatives have been discussed in the interviews. Curb-side collection is an option for increased accessibility of collection bins, however this has proven to be costly and sometimes superfluous according to interviewed municipalities. Development of curb-side collection could possibly be enabled through collaboration amongst the real estate companies and collecting NGOs, but the necessity of this depend on the demand for collection in different areas.

Furthermore, Göteborgsregionen mentions campaign-wise collection of used textiles as adequate since the households often collect an amount of used textiles before deciding to leave them at a collection point. Thereby, collection available around the clock might be excessive. Examples of successful campaigns conducted were collection events and collaborations with fashion brands, which resulted in great amounts of textiles collected. However, households need to be well-informed of when these kinds of campaigns are occurring and the information has to be available for everyone. Collection campaigns might be a compliment to the ordinary collection for selective measures as well as for increasing public awareness, and could be run by municipalities and other inter-branch organisations, such as Göteborgsregionen.

5.5 Capacities

Matching the capacities of different actors in the supply chain with estimated future volumes of used textiles, is necessary for creating a long-term sustainable textile handling system in Sweden. Today, the majority of domestic textile collection is performed by NGOs, whom export over 72% of the textiles collected (Swedish EPA, 2019a). This implies that the offset opportunities in Sweden are too few or expensive, along with the sorting process being a bottleneck further complicating closing the textile loop.

As stated by the interviewed NGOs, offset opportunities along with textile demand on the second-hand market play a vital part in determining the actors' capacities. RISE (2019a) asserts that the stakeholders

within the reuse and recycling sector generally lack profitability, aggravating the improvement potential through investments. A rapid increase in textile volumes could therefore make it difficult for the NGOs to vastly increase their capacity, since such a transition will require financial resources. Although, almost all interviewed NGOs believe they could match the capacity needed in case of a volume increase, as long as further handling options are available. How the increase is supposed to be conducted yet remains unanswered. This, along with the contrasting statement above, entails a risk of overconfidence considering upscaling of collection activities, to match sudden volumes increases.

Limitations regarding scalability of sorting derive from the current dimensions of the sorting facilities. Both interviewed sorting actors plan on expanding the sorting operations ahead, provided that the increased demand for textile sorting prevails. Further, SIPTex stated that they face similar issues compared with the NGOs regarding offset alternatives for the sorted textiles, as their business is dependent on other stakeholders purchasing their sorting service. Notable is that SIPTex's requirements for delivered volumes of textiles entails that certain types of textiles cannot be sorted at their facilities, instead requiring further handling elsewhere.

Implementation of automatic sorting processes on a large scale could possibly enable sufficient match of domestic sorting capacity, as the need of manual grading would diminish. Further, collaboration between different target groups has the potential to increase the total collection capacity, as stated by Björkåfrihet *inter alia*. Especially NGOs could benefit from extended collaboration within the target group, enabling shared use of resources to match potential larger increases of collected textile volumes. Lack of finances for investments in organisational growth has so far limited the expansion of NGO's activities, although joint efforts might help facilitate this. Offset opportunities such as second-hand reuse and recycling, set the limits for the overall collection capacity since further handling is needed for all collected textile volumes. As mentioned, a majority of collected textiles are exported which aggravates the assessment of total offset capacity. Furthermore, offset capacities are dependent on the demand for used textiles, recirculating the influential power to the consumers and manufacturers.

Large uncertainties remain regarding the actual capacities of the different actors in the supply chain of used textiles. Informational-, technological- and offset barriers along with lacking financial incentives are underlying factors to the problem. Björkåfrihet mentions the lack of investment capital as a barrier to upscaling operations, which is in line with the above. Governmental support and financial subsidises could therefore be instrumental for expanding the capacity of textile handling in Sweden. Funding for circulatory activities for used textiles could help create more effective and extensive in-house sorting processes.

Cooperation and clear communication between different target groups is of great importance when expanding the circulatory activities within the handling system. Limitations of sorting activities are for various reasons considered to be bottlenecks in the handling system of textiles, although they are dependent on the capacities of following offset opportunities. Hence, the overall capacity within the supply chain of used textiles is not principally limited by the collection capacity but rather by the succeeding sorting- and offset opportunities.

5.6 Potential for circularity in the system

The reality of resource scarcity and the negative environmental impact of humanity are not sufficient enough as incentives for an industrial shift to circularity. Hence, governmental interference has been crucial when inducing action. When the United Nations implemented Agenda 2030, one of the objectives were to defend

the planet from degradation caused by unsustainable production and consumption (UN, 2015b). The Agenda influenced the European Commission to act and the potential to reach the Goals 9, 11, 12 and 13 of the Agenda are visible throughout many aspects of the study's results and analysis.

In Goal 9, the UN (2015b) presents a focus on building resilient infrastructure, promoting sustainable and inclusive industrialisation and foster innovation. Striving towards this goal, encouragement of innovative and sustainable technologies as well as new processes are essential. Co-driving logistics of the textiles has been mentioned as a future prospect by the direct reuse actors as well as a real estate company. Collecting and redistributing textiles in the same neighbourhoods could also help decrease transportation costs and emissions. An additional innovation for streamlining the collection is the automation of sorting facilities (IVL, 2020b), such as SIPTex's automated sorting technology. This is an illustrative example of how innovation is promoting efficient circular practices and enhancing capacity (Palm et al., 2014).

Goal 11 is most tightly linked to the producer responsibility, aiming to make cities and human settlements inclusive, safe, resilient and sustainable (UN, 2015b). In accordance with cities growing and urbanisation occurring, developed planning is required and with many people living in a small area, it is essential to have a well developed waste collection system (UNDP, n.d.). Placing textiles in this context, dissemination of information among consumers could play an important role in the collection system by creating awareness regarding the negative environmental impacts of textile production, as well as collection opportunities. Responsible textile handling could help reduce each person's environmental impact in the cities. Connected to the SDGs is cross-sector collaboration, which also aligns with the opinion of Batista et al. (2018a), who claimed that this is necessary in the transition to circularity. The potential producer responsibility could possibly constitute the important push needed in this direction, requiring cooperation from the actors of the supply chain. Once again this is proving the potential impact of authority interference, considering how the Swedish EPA will be a supervising force and help inspire if the EPR is implemented.

Although the policies and governmental interference are all means to a positive end, there is a question of an overlying optimistic view regarding the extent of the challenge in transforming the textile industry. Producers need to design textile goods in a way that make them easier to recycle and reuse, which will help close the material loop as required by the EPR. However, even if companies in the EU member states potentially start to design for circularity, this does not automatically mean that all producers exporting textiles to Sweden will do the same. Problems could potentially arise when Swedish actors will have to collect, sort and recycle material blends from non-member states that follow alternative laws and regulations. According to Dahlbo et al. (2017), it is still unclear whether recycled fibers could replace the virgin material. A mixture of fibers and materials in the fabrics is one big aspect which complicates the recycling process (Hasanaj & Jansson, 2018). Altogether, this is leading to uncertainties regarding the future potential of textile recycling and reuse.

Two major contributions to sustainability are responsible consumption and production, which are the main purposes of Goal 12. Waste management is here highly relevant when assessing the capacity of the textile handling system. This closely connects to the transformation towards sustainable consumption and production patterns within the textile industry, since these concepts intertwine when creating circular textile supply chain. In conclusion, an increased responsibility in this field might contribute to both governance of natural resources and more sustainable lifestyles. Connecting this to textiles, the 12th goal emphasises the

importance of information-spreading and awareness among the public, which aligns with a general perception amongst interviewees, whom expressed the importance of spreading awareness and information. For instance, a major up-rise in the second-hand consumption could be beneficial for Sweden in keeping the disposal of the textiles domestic, which in turn requires changed consumer attitudes.

Goal 12 also aims to encourage larger international companies to integrate sustainable methods and to establish sustainability statistics in their reports, enhancing transparency and keeping industries clean. By designing for reuse and recycling, materials would still have a value at the end of their user phase. Responsible production has potential of contributing to circularity, by prolonging the life-cycle of products instead of letting the NGOs and waste disposal companies pick up the slack. Circularity in the system could to a great extent be viewed as a collaborative effort, where the interviewed actors would collect, sort and redistribute the textiles in a coordinated way. The role of production could be to facilitate these efforts, by adaptation of textiles for sorting and recycling.

Goal 13 primarily emphasises climate action. According to Sandin and Peters (2018), the increase in reuse and recycling of textiles could be potential reduction of virgin fibre production and thereby, lowering the overall environmental impact of the textile industry. The mixture of fibers and materials in textiles are also important aspects, which complicate the recycling processes today and by diminishing these more preferable conditions for recycling can be obtained. Brands as for instance Nudie Jeans, who actively works towards a closed-loop system, could potentially set an example for a transformed textile industry.

The fundamental building blocks of the linear economy have always been connected to economic growth (Sauvé et al., 2016), for a circular economy to become as established there has to be economic profit to be made in the process (Dervojeda et al., 2014). The shift could be made easier if economic growth did not have to be sacrificed for the benefit of the environment. A positive aspect is the increasing amount of direct reuse platforms (SMED, 2019), which was also expressed by the interviewees. Digital platforms are blossoming and purchasing vintage garments and home textiles becomes easier when the goods are photographed and displayed online (SMED, 2019). The second-hand stores on online platforms have the potential to become more established and a force to be reckoned with. Conclusively, there is great potential for extended circularity within the supply chain of used textiles, where platforms like online reuse facilitate sustainable choices. Innovation and development of new technologies will further play a vital part in enhancing circularity within the system.

5.7 Summarised answers to research questions

The discussion above aims to highlight important areas within the Swedish supply chain of used textiles, in order to answer the research questions of the thesis summarised below.

Which activities and actors are involved in the supply chain of used textiles and how will the actors' roles develop ahead?

As outlined in the section *Activities and actors in the system*, the current supply chain of used textiles lacks organised standardisation and consequently textile collection and sorting practices differ greatly throughout Sweden. The NGOs are the main collectors of used textiles, and to the extent that municipalities, waste disposal companies and real estate companies perform separate collection, this is generally conducted in collaboration with the NGOs. The sorting procedure is identified as a bottleneck in the system since it today is performed manually, therefore being a resource-intensive activity. Innovative automated sorting facilities are in a state of development, currently with relatively low overall impact on the system, although being a potential enabler for improved efficiency of the process. Currently, the manual sorting performed by NGOs is raising domestic handling costs, leading to export and suggesting that a alteration of NGOs role as textile sorters would be beneficial for the entire industry.

The amount of used textiles distributed through direct reuse platforms are increasing, and enables reuse from consumer-to-consumer, removing intermediary steps. Due to its convenience and profitability for the consumer, direct reuse could be considered a successful circular business model and possibly also contribute to a decrease in newly produced textile consumption.

Implementation of the EPR would relocate the responsibility for used textiles from municipalities to producers, moreover introduce requirements for separate collection. Instructions from the government regarding the design of the collection system are currently unclear, causing uncertainties for all actors involved in the supply chain. The distribution of roles is yet to be traced out, although it is possible that the NGOs could continue to act as collection providers in a new system.

What volumes of used textiles are currently being collected in Sweden and what are the expected changes in quantity and quality?

The summarised volumes of used textiles currently collected by the interviewed target groups, stated in the section *Future volumes*, amounted to 26,600 tonnes. However, only a selection of collecting actors in Sweden were included giving that the number cannot be considered representative for the entire Swedish collection. The latest number published on collected textiles volumes through NGOs was 38,300 in 2016, which was reported in a survey by SMED (2018a). The different number of interviewed actors in the two studies explains the divergence in total volumes collected, leading to that no certain conclusion can be drawn in how the volumes have changed. Although, a general perception discovered empirically was that the actors expect volumes to increase as a consequence of the EPR. The Swedish EPA estimates that the volumes will be doubled, suggesting a future number of 80,000 tonnes.

The NGOs have experienced a decreasing quality of the textiles collected, resulting in a smaller amount saleable in second-hand stores along with decreased offset opportunities. Fast-fashion and linear consumption are possible causes for the declining quality, and implementing the EPR might counteract this trend, if

applied according to the waste hierarchy. Producers will have to ensure textile quality, which can enable a sustainable afterlife for the all goods, for instance through cleaner material composition and elevated fiber quality. This is claimed to be necessary change, in order to increase reuse and recycling activities.

Another factor that might contribute to the decreased quality of the textiles collected through NGOs, is that quality pieces can now be sold on direct reuse platforms, whom are experiencing an increase of textile volumes distributed. However, this is not negatively affecting Swedish circularity, but can rather be described as a relocation of textile reuse activities.

What are the barriers, enablers and future prospects in the current system?

As stated in the sections *Barriers*, *Enablers* and *Potential for circularity in the system*, the transformation of the supply chain of used textiles is complex and involves a vast amount of stakeholders. When discussing the barriers of textile circularity, a prominent challenge is the creation of economic value. Profitability in used textile handling is restricted by the resource-intensive character of associated operations which in turn is limiting scalability. Additionally, the aforementioned problem of decreasing textile quality together with a lack of successful circular business models result in low incentives for investment and supply chain development. Another theme discovered in the interviews was deficient information flows, leading to problems with transparency and traceability in the supply chain and towards the consumers. Accurate and accessible information could in general improve coordination and facilitate circular practises. The main barrier identified is the lack of offset opportunities for used textiles within Sweden. Circular offset alternatives, as recycling and reuse, are either yet to be widely established or experiencing an insufficient demand. Hence, used textiles are currently mostly exported for off-shore reuse, energy recovery or incineration. The problem is further aggravated by a decreasing export market.

In enabling the development of circularity, increased dissemination of information was identified as an important factor. Informing consumers of circular practices, mainly regarding reuse and separate collection could decrease the amount of textiles in the household waste and change attitudes. Among the actors of the supply chain, information could enhance traceability which in turn could improve the processes both inter- and intra-organisationally. Dissemination of information could further be enabled through collaborations between actors in the supply chain, simplifying development of reversed information flows as well as innovative solutions for extended collection. Another enabler discovered is the impact of laws and regulations, such as the EPR, which can work as an incentive for transformation. Extended collection points, could by increasing the availability for circular disposal of textiles be a important component in the transition.

As aforementioned, EPR might lead to increased volumes of textiles collected placing a demand for improvement of the restricting activities of sorting and offset. Additionally, the quality of newly produced textiles will have to be enhanced in order to extend the recycling and reuse opportunities. The supporting technologies in the supply chain of used textiles need innovations, thereby requiring investments. Relatively new flows, canalised through online platforms are showing potential to grow in importance for the reuse industry. Thus, the potential future implementation of the EPR will determine the design of the supply chain of used textiles.

How does the capacity of the different actors in the supply chain match the estimated future volumes of used textiles from Swedish households?

As stated in the section *Capacities*, the majority of the actors claim to be able to upscale collection operations, given that there are sufficient opportunities for used textile offset. However, there is a risk for overconfidence among the actors regarding textile handling capacity, considering the current mismatch between used textile supply and the possibilities to handle collected volumes. Upscaling downstream operations is further limited by poor profitability, hence the willingness to invest is low. If the EPR is implemented, the volumes of used textiles are as aforementioned expected to increase, which might make it difficult for the actors to match the capacity needed in the activities regarded as system bottlenecks. Lastly, the potential increase in the flow of textiles distributed through online platforms has in practice unlimited capacity to expand, and the development in this sector is dependent on the user demand for the goods offered.

6 Conclusion

Before the Swedish textile industry can be viewed as fully circular, considerable measures need to be taken. Transforming the textile industry will involve a multitude of stakeholders, ranging from producer throughout the entire post-consumer phase. The supply chain activities that have been studied are mainly the collection, sorting, transportation as well as different offset alternatives such as e-commerce and export. Additionally, the roles of actors within various target group are examined and contextualised within the system of used textiles. A share of the interviewees primarily work with information and policy regarding improvement of waste management, therefore they have a coordinating function.

The study confirms the general picture of NGOs presently conducting a majority of textile collection in Sweden. Waste disposal companies and municipalities mainly rely on the services of NGOs as collection providers through their containers, although some waste disposal companies collect themselves. The collection containers are distributed nation wide at different locations in Swedish society, often at recycling centers or stations. Other collection options are discovered to be curb-side collection points, in-store collection and collection by occasional initiatives. Transport is generally conducted by third party intermediaries, however, some NGOs takes care of transportation logistics intra-organisationally. In current practice, sorting of used textiles is conducted manually in-store or at sorting facilities owned by either NGOs or external partners. Regardless, this study focuses more on the opportunities of automated sorting technologies provided by SIPTex and Wargön Innovation. The most common offset for used textiles in Sweden is export principally within Europe, whilst the main fraction of textiles kept nationally goes to re-use on the second-hand market. Recycling and re-manufacturing practices are uncommon for the lion's share, consequently a large amount of unusable textiles mainly end up being energy recovered or incinerated. Furthermore, a rising trend is that of direct reuse through online platforms enabling consumer-to-consumer re-selling of textiles. Transport within this segment is handled by the consumers themselves or external forwarding agents.

The governmental proposal of EPR will according to the estimations by the Swedish EPA increase the volumes of collected textiles notably, from 38,300 tonnes to 80,000 tonnes. Consequently, there is a new awareness among the target groups regarding the need for expanded collection capacity. The general perception is that collection could be elevated, given a capacity match further down the supply chain of used textiles. Sorting and offset activities are pointed-out as bottlenecks in the handling system, thereby viewed as major improvement areas when enhancing circularity in the textile industry. Current manual sorting of textiles lacks scalability and in order to obtain large-scale profitability within the industry, innovative technologies for automated sorting need to be implemented. In turn, improved sorting enables extended reuse as well as textile-to-textile recycling, since these offset alternatives require refined fractions with textiles of uniform composition and quality. Material composition and fiber purity are identified as vital parts in shaping a circular textile industry, as these determine at which level of the waste hierarchy the textiles can be handled. Alluding to this, collecting actors report decrease of textile quality which narrows the demand for reuse on the second-hand market.

Similarly, current offset practices are mostly unsustainable due to a decreasing export market, following sufficiency in domestic textile second-hand supply of importing nations. Furthermore, incineration and energy recovery are in a sustainability context deemed undesirable, especially considering the immense pollution connected to virgin textile production. Capitalising on used textiles by preserving the value through

redistribution or upcycling are in a circular industry more profitable, in comparison to disposal of textiles as waste. Despite this, shortcomings within recycling practices leads to excessive application of downcycling and deficient fiber-to-fiber recycling, a method that could help retain the material value. Improvements in material design, sorting- and recycling technologies are essential components when creating profitability within circular textile offsetting. Additionally, an increase of domestic reuse is desirable and necessary in order to close the Swedish textile loop, limiting the flow of material resources abroad in line with the proposition of EPR.

The general lack of incentives for developing system improvements in the field of used textiles has been identified as an overlying barrier. Economic interests set the framework for the development of the overall textile industry, requiring implementation of successful circular business models and regulation policies for financial relief of the actors. Transparency issues are found to be a consistent limitation to increased collaboration along with augmented consumer knowledge. Informational flows between different stakeholders in the supply chain of used textiles are insufficient or non-existing, therefore aggravating internal coordination as well as credible market communication. Along with the aforementioned technological barriers, practical difficulties connected to design and management of collection containers restrict textile circulation. Absence of standardisation and poor resistance to external stress from rain, damage by damp or vandalism constrain efficient textile collection in the current system.

Opportunities of improved practices can be achieved through dissemination of information, contributing to greater transparency in the supply chain of used textiles. Traceability throughout the dispersed operations in the textile industry can increase control of the system and enable advancement of circular activities. Another aspect is the communication towards households regarding how and where to separately dispose of used textiles. Transparency together with increased consumer knowledge could create engagement and better awareness on the issue of textile consumption. To further reach the households, sustainable disposal of textiles can be facilitated by improved availability of textile collection points. Convenient collection opportunities could prevent storage of used textiles that have potential to be reused or in other ways circulated. Potentially, the rise of online redistribution through e-commerce platforms could play an important part in enabling accessible re-use.

Furthermore, this study identifies collaboration as the most significant enabler of circular SCM, characterising the outcome of empirical data as well as the literature review. Coordination of the activities between the actors is crucial since achieving circular supply chains is an effort of interdependence. The results of this study shows that upstream practices, such as product design, lay the foundation for possible improvements of the downstream textile handling, facilitated by knowledge and information sharing. As stated by Magnus Nilsson (personal communication, March 25, 2021) "synergies amongst the academy, policy makers and the industry enable sustainable solutions", summarising the possible impacts of successful collaboration.

In conclusion, the system's potential for circularity will be determined by the stakeholders' power of action. The capacity of textile circulation in Sweden is mainly limited by the mismatch between the evident opportunity to increase collection, and the profoundly larger challenge of creating scalable sorting and offset practices. There is a great need for innovation, improved process design along with widespread dissemination of information. This requires explicit structures of incentives providing value for consumers, stakeholders as well society equally. Societal trends and consumer attitudes associated with a linear take-make-dispose

economy have to be altered in order to drive the transition.

Implementing circularity in the Swedish supply chain of used textiles places demand for a collaborative effort from all involved stakeholders, including the interviewed target groups. Circular economy consists of a loop where producers, consumers, collectors and waste management are integrated through streamlined operations. The concept involves material design, governmental interference and changed consumer behaviour, all vital parts of changing the way textiles are consumed. Hence, even if the actors were to become circular on their own, a holistic perspective on transformation would generate substantial shared value for the entire textile industry.

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Appendices

A Appendix A

Interview questions template. See attached document, *Appendix A: Interview template*.

B Appendix B

Summary of the results from the interviewed actors. See attached Excel-file, *Appendix B: Results table*.

C Appendix C

Explanation of the handled volumes presented. See attached Excel-file, *Appendix C: Handled volumes*.



CHALMERS