CHALMERS
UNIVERSITY OF TECHNOLOGY

From waste to wardrobe

A comparative life cycle assessment on prolonging garment lifetime through repair and online second-hand

Master's thesis in Industrial Ecology

KLARA COLLIN ARONSSON
JOHANNA JAGEFELDT

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF ENVIRONMENTAL SYSTEMS ANALYSIS

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023
www.chalmers.se

Report No. E2023:135

REPORT NO. E2023:135

From waste to wardrobe

A comparative life cycle assessment on prolonging garment lifetime through repair and online second-hand

KLARA COLLIN ARONSSON
JOHANNA JAGEFELDT

Department of Technology Management and Economics
Division of Environmental Systems Analysis
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023

From waste to wardrobe
A comparative life cycle assessment on prolonging garment lifetime through repair and online second-hand
KLARA COLLIN ARONSSON
JOHANNA JAGEFELDT

Supervisor: Adeline Jerome, Environmental Systems Analysis
Examiner: Maria Ljunggren, Environmental Systems Analysis

Report no. E2023:135
Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Gothenburg, Sweden 2023

From waste to wardrobe
A comparative life cycle assessment on prolonging garment lifetime through repair and online second-hand

KLARA COLLIN ARONSSON
JOHANNA JAGEFELDT

Department of Technology Management and Economics
Chalmers University of Technology

Abstract

The clothing industry, encompassing all its activities from production to end-of-life, is a major contributor to environmental damage. The global production and consumption of clothes have roughly doubled in the past 15 years and fast fashion, with short garment lifecycles, intensifies the resource demand and the ensuing emissions. As a response, a shift from the traditional linear model of take-make-dispose to circularity can be seen through clothing companies working with circular business models (CBMs) or implementing circular strategies. Understanding the environmental impact of these circular initiatives is crucial for reducing the overall environmental footprint of clothing.

The aim of the thesis was to assess the environmental impact of prolonging a pair of pant's lifetime through two CBMs based on circular strategies or business models represented on the Swedish market and comparing it to the linear model. This was done by a mapping of Swedish clothing companies to select two either circular strategies or CBMS to serve as the foundation for the proposed models. Two general CBMs, one based on repair and one on an online second-hand (OSH) platform, were created, derived from information from interviews and literature. The environmental impact of the models was evaluated by conducting a life cycle assessment, and a sensitivity analysis was performed to assess the robustness of the results.

The study found that companies are embracing circularity, either through CBMs or by implementing circular strategies such as physical and online second-hand, repair, exchange, and rental services. It was also shown that by extending a pair of pants' lifetime through CBMs based on repair or OSH, the environmental impact per garment lifetime is reduced compared to the linear model. It was found that repair resulted in the lowest impact due to the significant increase in the number of enabled uses and the relatively small impact from the repairing process, despite a large impact from additional consumer car transports. OSH was also found to be preferable to the linear model. The additional processes required by OSH, i.e. truck transports and sorting and managing of the pants had a relatively low environmental impact and the CBM enabled more uses of the pants than the linear model achieved. However, OSH enabled fewer uses compared to repair, which made it fall between the linear model and repair in terms of overall impact. Lastly, it was also found that the potential of both repair and OSH is mainly dependent on consumers' transportation modes and distances, and the actual number of achieved uses.

The study shows the importance for consumers to fully utilize purchased garments and to consider repairing them instead of buying new ones when they are worn out. When considering selling or donating their clothes, the study also shows the importance of only doing so if the garments are undamaged and of good quality to avoid additional transportation and waste creation that could ensue if the receiving company should deem the clothes unfit for resale. This, as general consumer behavior, would result in an overall reduction in the demand for the production of new clothing. Furthermore, the study shows that the consumers' choice of transportation mode and ability to combine errands is of big importance to the overall efficiency and impact of the CBM.

Keywords: Circular economy, circular business model, circular strategies repair, second-hand, environmental impact, textile industry, fast fashion, clothing.

Acknowledgments

First and foremost, we want to thank our examiner Maria Ljunggren and our supervisor Adeline Jerome for guiding us through this journey and for insightful discussions and feedback. Maria, thank you for your generous engagement since day one, and your guidance within the debated world of circularity definitions. Adeline, thank you for your expertise on life cycle assessment, your fast replies to desperate emails, and for saving us from being lost in the OpenLCA universe.

Furthermore, we would like to express our gratitude to Senior Researcher Mathias Janssen. Thank you for taking your time and helping us with the OpenLCA software, the very non-userfriendly but, without a doubt, invaluable tool for our study.

We would like to extend our appreciation to the companies who generously provided us with access to their practices and experiences. A great thank you to Kevin Gelsi at Nudie Jeans & Co for taking your time and providing us with an important understanding of how an acknowledged brand can perform a repair service. We would also like to express our gratitude to Sofie on Repamera, who helped us fill out the gaps in our understanding of consumer behavior and the patterns of garment reparation.

Finally, we would like to express our heartfelt appreciation to our friends and family for cheering us on throughout this journey and for their support when days were long, and the software was not cooperating. Completing this thesis would not have been possible without your help.

Klara Collin Aronsson & Johanna Jagefeldt, Gothenburg, September 2023

List of Acronyms

Below is the list of acronyms that have been used throughout this report listed in alphabetical order:

AD	Abiotic resource depletion potential
AP	Acidification potential
BAU	Business as usual
BM	Business model
CBM	Circular business model
CE	Circular economy
CT	Consumer transportation
DT	Distribution retail
EP	Eutrophication potential
EwS	Europe without Switzerland
Eq	Equivalents
FAEP	Freshwater aquatic ecotoxicity potential
f.u.	Functional unit
GHG	Greenhouse gases
GLO	Global
GWP	Global warming potential
HTP	Human toxicity potential
kWh	kilowatt-hour
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
MJ	Megajoule
ODP	Ozone depletion potential
OSH	Online second-hand
SE	Sweden
S&M	Sorting & management
RoW	Rest of the world

Contents

List of Figures

List of Tables

1
Introduction

With a market value of three trillion dollars in 2020, clothing is one of the biggest industries in the world. Clothes make up one of the most common ways of self-expression and with a growing global population and improved living standards, there has been an increase in both production and consumption. Over the past fifteen years, the worldwide production of clothing has essentially doubled (Ellen MacArthur Foundation, 2017; Shirvanimoghaddam et al., 2020). With this growth, it is essential to address the significant environmental impact it brings.

Every year, Swedes buy approximately 14kg of textiles, which in addition to clothing also can include other textile-based goods like home textiles, per person. About half of this, 7.5kg, is thrown in household waste (Elander et al., 2019), resulting in almost 80 000 tonnes of clothing being incinerated annually, whereof half is estimated to be fully functional (Naturvårdsverket, n.d.-a). Over the past two decades, the average clothing consumption has increased by almost 30% in Sweden, although a reduction in clothing expenses has been seen during the same period (Elander et al., 2019). These changes are much rooted in the emergence of fast fashion, meaning faster releases of new styles, a higher number of collections per year, and, more often than not, lower prices (Ellen MacArthur Foundation, 2017).

Clothing is resource-intensive and polluting. In terms of causing environmental damage, textiles are ranked as the most harmful area of consumption in the EU, after housing, transportation, and food (Norden, 2015). Producing textiles requires substantial energy input, and the utilization of non-renewable resources leads to significant emissions of greenhouse gases (GHG) (Niinimäki et al., 2020). Annually, textile production consumes roughly 93 billion cubic meters globally, affecting water-scarce areas. It deploys a wide range of chemicals for dying and finishing treatments, alongside significant quantities of fertilizers and pesticides in cotton cultivation. These substances are frequently discharged into the environment, resulting in pollution of water, soil, and air. With limited textile recycling options and a global recycling rate of just one percent for discarded textiles, there is a constant need for new raw materials. In addition to the production processes, the industry involves various activities that also add to its overall environmental impact. These activities include long-distance shipping, managing warehouses and stores, laundering, and the disposal of discarded items (Ellen MacArthur Foundation, 2017).

The traditional model for the clothing industry has, until recent years, solely been linear, meaning the life cycle phases of take-make-dispose. On a global scale, clothes tend to undergo a relatively low number of uses, and over the past 15 years, the achieved number of uses has decreased by 36%. This short lifetime of clothes intensifies their environmental impact (Ellen MacArthur Foundation, 2017). Although fast fashion still holds a firm grip over society, a shift is emerging. Younger generations are increasingly showing interest in sustainable fashion (GFA, 2022). This shift aligns with the introduction of a more circular approach (Saccani et al., 2023). The concept of circular economy (CE) is multifaceted, with over 200 definitions circulating. However, its general goal is to create an economic system that reduces waste, promotes resource efficiency, and minimizes environmental impact. This moves away from the linear model and instead focuses on slowing down and closing the loops.

There are different approaches for companies to transition toward a circular economy. One is a circular business model (CBM), a concept that lacks a universally recognized definition but refers to when a company's fundamental business model (BM) revolves around circular principles. An example of this could be a clothing rental company, which embodies circularity by extending the useful lifespan of garments. As explained by Nußholz (2017), the term CBM is pre-eminent in promoting the shift towards circular economy (CE). This study will base the concept on the definition proposed in the review (p. 12):

A circular business model is how a company creates, captures, and delivers value with the value creation logic designed to improve resource efficiency through contributing to extending the useful life of products and parts (e.g., through long-life design, repair, and remanufacturing) and closing material loops.

Circular strategies provide an additional way for companies to integrate circularity into their operations. As with CE and CBMs, circular strategies encompass a range of definitions. Within the scope of this study, circular strategies will denote specific actions that companies can adopt while adhering to a linear BM. For example, a company might incorporate a rental service into its existing framework of clothing production and sales (Nußholz, 2017). Considering fast fashion and the short-lived nature of clothing, services based on prolonging the lifetime of clothing are of interest when looking at ways to decrease the industry's environmental impact. Through services that enable this extension, a higher number of uses for clothing can be achieved, subsequently leading to a lower demand for new production.

Numerous clothing companies in Sweden have embraced the circular movement, either by adopting CBMS or implementing circular strategies. However, the actual environmental impact of these initiatives is not always fully understood (Europaparlementet, 2023). Circular strategies and CBMs should not be automatically assumed to possess environmental benefits solely due to their circular nature. For instance, practices like rental services may require additional actions such as transportation or electricity consumption, generating their own environmental impact that could outweigh the benefits. Hence, a crucial need for understanding which actions hold potential environmental benefits and under what circumstances arises. To accurately assess their environmental impact, it is essential to evaluate the whole life cycle of the clothing (Nußholz, 2017).

1.1 Aim

The aim of this project is to assess the environmental impact of prolonging a garment's lifetime under two CBMs derived from either circular strategies or CBMs represented on the Swedish market and compare it to the linear model of take-make-dispose. In extension, this study can serve as support for consumers to understand the implementation of different CBMs.

1.1.1 Research questions

To fulfill the aim of this thesis the following research questions have been formulated

- What are current circular strategies and CBMs based on prolonging garment lifetime practiced by recognized Swedish clothing companies?
- What is the environmental impact of a garment produced and used under two CBMs, based on practiced circular strategies or CBMs, and how does it compare to the linear model?
- What factors contribute to the potential of these two CBMs to have a lower environmental impact than the linear model?

1.2 Delimitations

The study is done on nationally established clothing companies in Sweden. Small, local businesses such as tailors, second-hand stores, and flea markets are therefore excluded. The two studied CBMs will be modeled based on practical examples found among the mapped Swedish companies. However, since the information from companies will be complemented with assumptions based on statistics, the result will be general and differ from specific cases. The study will focus on a specific garment as a representative case study for garments in general, and this garment will remain constant across the three models (the two CBMs and the linear model) for the purpose of comparison. As a result, due to variations between garments, the results cannot represent all garments but can still indicate general patterns within the processes of clothing production and consumption.

The textile industry has a history of global controversy, utilizing low-cost labor resulting in poor working conditions (Guarnieri and Trojan, 2019). While this aspect is important to evaluate when determining the sustainability of an industry, it is outside the scope of this study. Economic factors are another important aspect of sustainability, but this is also excluded from the study.

2

Background

2.1 Circular economy

To create a more sustainable clothing industry, in terms of lowering its environmental impact, a transition from linearity towards CE is needed. As mentioned in the introduction, CE has no universally accepted definition and is currently described by more than 200 definitions, all sharing the common objective of promoting sustainable development (Kirchherr et al., 2023). It can shortly be described as an economic system characterized by closed-loop resource management, fuller use of products as well as minimized waste and damage to the environment. By for example keeping clothing in the loop through reuse and recycling, instead of disposing of it, CE decouples economic growth from environmental damage (Saccani et al., 2023).

There are numerous recommended approaches for transitioning towards a CE, often presented with the "Rs framework". Ranging from three to nine Rs, they all refer to different strategies that can be implemented in order to promote sustainable development. However, the core of the framework can be presented with the 4Rs of reduce, reuse, recycle, and recover (Kirchherr et al., 2017), as seen in Figure 2.1.

The 4Rs Framework			
Reduce	**Reuse**	**Recycle**	**Recover**
Example: Reduce losses and input materia in production	***Example:*** Extend technical lifetime	***Example:*** Return materials to use	***Example:*** Recover energy from end of life management

Figure 2.1: *An overview of the 4Rs framework*

Reduce aims at reducing resources used and waste created by, for instance, efficient design or processes. Reuse aims at extending the usage of already existing products through, for instance, repair, second-hand, renting, or sharing. Recycle aims at recovering material while recover aims at recovering energy, and instead of wasting it, inserting it into production (Kirchherr et al., 2017). There are other ways to prioritize measures, including the EU waste hierarchy, as shown in Figure 2.2.

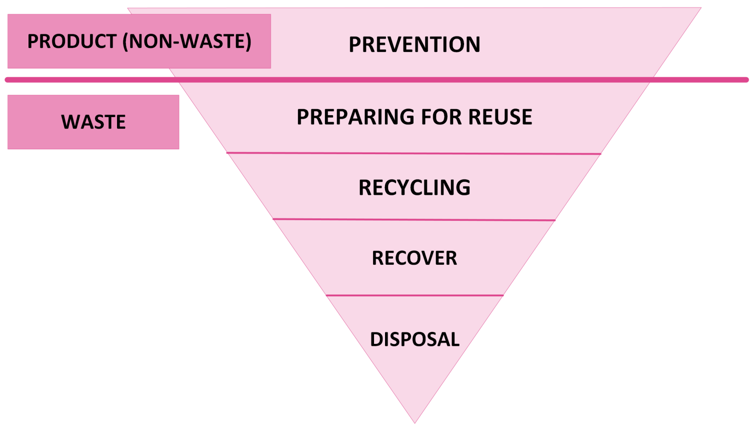

Figure 2.2: *The waste hierarchy (European Commission, 2023)*

However, the application of the waste hierarchy, along with the strategies outlined in the R-framework is debated due to their generalized nature. They tend to miss real-world factors, such as combining different measures and losses in remanufacturing, repair, and recycling processes that are usually detected when practicing life-cycle thinking. Consequently, the actual benefits of these measures may be smaller than expected, and rankings may change under unfavorable conditions. While the waste hierarchy's environmental suitability can be demonstrated for certain materials, its applicability to all materials and products with diverse components may be questionable (Böckin et al., 2020).

Companies can embrace different approaches to transition towards a circular economy. As previously presented in Chapter 1, circular strategies will in this study refer to specific circular actions that companies adhering to a linear BM can undertake. Furthermore, the concept of a CBM will be based on the definition by Nußholz (2017), summarized as how a company creates value with a value-creation logic designed to improve resource efficiency.

2.2 Textile flows in Sweden

To understand the need and potential for CE, circular strategies, and CBMs, an evaluation of the current textile flows in Sweden will be presented. On average, Swedes purchase 14kg each of clothes and home textiles yearly, excluding private import of clothing from other countries. Of this, 7.5kg becomes waste while 3.5kg is either donated or collected. The remaining three kilograms are kept in households or traded (Elander et al., 2019). This results in approximately 80.000 tonnes of textile being discarded annually, only to get incinerated and used for energy production (Naturvårdsverket, n.d.-b). Approximately half of the discarded textiles are in good condition and fully usable. Although the remaining half may not be entirely intact, some could undergo repair, repurposing, or material recycling if collected (Naturvårdsverket, n.d.-a). In addition, there is an overproduction of clothing and 30% of produced clothing is incinerated before reaching the consumer (Rauturier, 2022). This illustrates the linear nature of clothing production and consumption in Sweden, along with the short lifecycles of garments. High consumption of new clothing, low consumption of second-hand clothing, and large amounts of clothing being incinerated indicate the need for CBMs and circular strategies to be adopted, and their potential in decreasing the need for new production and the excessive disposal of clothing in good condition.

The donated textiles in Sweden only partly stay within the country. Less than one percent is recycled nationally, with most of that turned into industrial single-use equipment (Naturvårdsverket, n.d.-b). The majority of textile that stays in Sweden goes to second-hand, but since Swedes on average only buy 0.8kg of second-hand clothing per year, there is an excess of clothes in the second-hand market (Elander et al., 2019). About 70% of what is collected is exported for international second-hand or material recycling internationally, of which 20% is recycled and turned into, i.e., composite material and isolation (Naturvårdsverket, n.d.-a). Based on these numbers, an overview of Sweden's textile flows was constructed by the authors, as depicted in Figure 2.3, with stock shown as the annual addition.

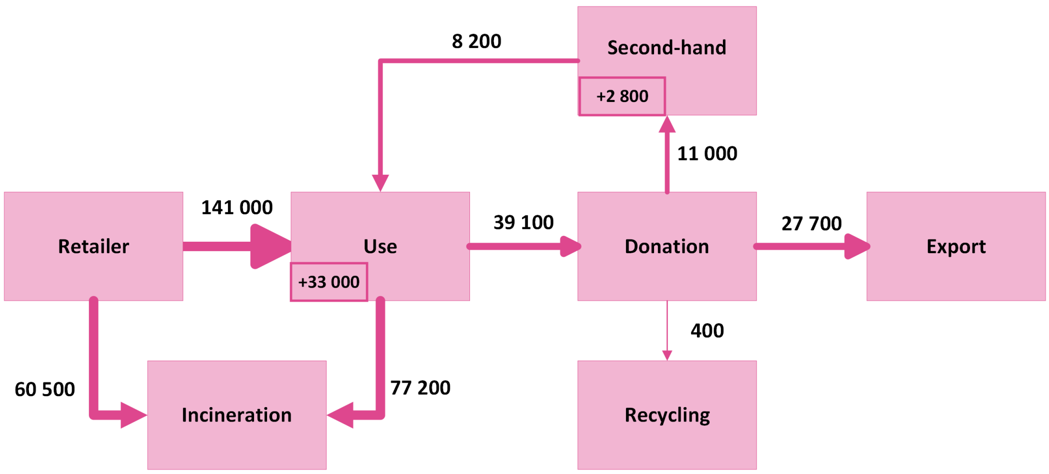

Figure 2.3: *The textile flow of private consumption in Sweden for 2019 in tons*

In Sweden, there is no national system for, nor requirements on, collecting textiles and donated clothing is currently managed by charity organizations and private companies (Norden, 2015). Several companies have also started using return possibilities in stores, where consumers can return their unwanted or worn-out clothes to be recycled or "re-loved" by someone else, as a way to promote the company's circular image & some companies offer a voucher with this system. However, this has been seen as an incentive for consumers to buy more and, can therefore fuel a higher production instead (Ellen MacArthur Foundation, 2021). The actual destinations of the returned clothes can also diverge from the claims made by companies. A substantial quantity, predominantly from Europe but also other regions, finds its way to developing nations, where it is dumped. The condition of these clothes differs, and while some can be used or sold again, most end up openly burned or left in giant piles spreading over large areas and into waters (Lindberg and Wennman, 2023).

2.3 Circular economy applied to the textile industry

Ending a product's life cycle and discarding the produced material is inevitable. However, the life cycles of clothes are extremely short. In Sweden, textile waste is taken care of through municipal incineration with heat and power recovery since this is the major waste management for household waste (Avfall Sverige, 2022). While incineration might be a preferable option to sending clothing to landfills, it means that the resources and environmental impact invested in the garment are lost. Moreover, incinerating clothing does not eradicate the material and often causes the release of harmful substances into the environment (Ellen MacArthur Foundation, 2017).

To reduce the environmental impact of garments and transition to a CE, the literature suggests different courses of action. Production stands for roughly 80% of the climate impact, providing a lot of possibilities for improvement (Roos et al., 2019). While improving production processes presents environmental benefits, keeping already existing garments in the loop is also important (MFA, 2018). Sandin et al., (2019), showed that by doubling the lifetime of a garment, the environmental impact could be reduced by as much as 49%. Strategies based on reuse aim to prolong the products' lifetime, which has big potential for products where the production has a high impact compared to the use phase (Nußholz, 2017). Suggested design methods for prolonging a garment's lifetime are for example higher quality, and enabling repair and recycling (Saccani et al., 2023). If clothes are designed to last longer, increasing the actual number of uses is also needed to lower the environmental impact. Böckin et al., (2020), show that renting clothes as a circular strategy can increase the environmental benefit as well as the economic profit for the company.

Considering the abundance of second-hand clothes in Sweden today, it is clear that solely sorting and collecting more textiles is not enough to extend the lifespan of clothing (Naturvårdsverket, n.d.-a). This is where circular strategies and CBMs based on prolonging garment lifetime create possibilities for decreasing the environmental impact of clothing before they become waste (Saccani et al., 2023). In addition to CBMs and circular strategies, logistics for collection and reuse, better technology for sorting and recycling textiles, as well as legislation that enforces circularity are needed (IVA, 2023). While CBMs and circular strategies are being adopted by many Swedish clothing companies, their actual environmental gain or loss of them is not yet well understood. Claims that circular options are good for the environment are made, but the actual benefits are not presented.

2.4 Policy initiatives

In 2025 a new EU directive will demand countries to collect textiles separately and prepare them for recycling under the EU Waste Framework Directive (Norden, 2015). This aims at enhancing industrial competitiveness and innovation in the textile sector, as well as promoting the EU market for sustainable and circular textiles, and is part of the 2020 EU Circular Economy Action Plan. Its visions are described by the European Commission as

(Norden, 2023, p. 12);

By 2030 textile products placed on the EU market are long-lived and recyclable, to a great extent made of recycled fibers, free of hazardous substances, and produced in respect of social rights and the environment. Consumers benefit longer from high-quality, affordable textiles, fast fashion is out of fashion, and economically profitable re-use and repair services are widely available. In a competitive, resilient, and innovative textiles sector, producers take responsibility for their products along the value chain, including when they become waste. The circular textiles ecosystem is thriving, driven by sufficient capacities for innovative fiber-to-fiber recycling, while the incineration and landfilling of textiles are reduced to the minimum.

In other words, large amounts of textiles will be collected and made available for recycling. However, the current recycling options are limited, as only one company worldwide, Swedish Renewcell, has the ability to recycle textiles on a larger scale (KTH, 2023). Renewcell recycles textiles made of 95% cotton, with an annual capacity of 60 000 tons (Renewcell, 2023). This is not yet near meeting the existing demand and does not cover all clothing types with various material compositions. The required capacity to manage the current volume of textile waste and the technology necessary to recycle mixed fibers are not yet financially viable at a commercial level. (RISE, 2018; Tänk Om, 2020).

In Sweden, voluntary commitments have been initiated a few years back to prepare for these legislative measures. The Swedish Environmental Protection Agency, Naturvårdsverket, in collaboration with the Swedish Consumer Agency and the Swedish Chemicals Agency, was assigned by the Swedish government to raise awareness among consumers about sustainable textile consumption for a period of three years. Moreover, the University of Borås has been entrusted by the government to create and lead a nationwide platform that provides businesses with resources and activities to facilitate their transition to a circular economy. Additionally, Sweden has a reduced value-added tax (VAT) rate of 12% (typically 25%) on services involving the repair of shoes, leather goods, clothing, and household linens (Skatteverket, 2023).

Companies attempting to market their transition towards circularity can be contradictory. Bold claims are meant to reassure consumers and ease their worries, but this often results in increased sales, which may raise questions about their intentions (Ellen MacArthur Foundation, 2021). A recent EU screening found that 39% of claims made by companies in the clothing, textiles, and shoe sector qualified as greenwashing. Additionally, close to 60% of these companies lacked transparency and accessible information for consumers to verify the claims (European Commission, 2021). Moreover, a large part of the returned clothing items purchased online end up being discarded due to the high cost of inspection, repackaging, and relisting for sale, making it difficult for consumers to distinguish between genuinely sustainable companies and those making false claims (Roberts et al., 2023). However, there is an ongoing development for Product Environmental Footprint (PEF) within apparel and footwear by the European Commission in their initiative on Green Claims. This is meant to enhance the dependability, comparability, and verifiability of environmental assertions regarding goods by mandating that these assertions are supported and confirmed using life cycle analysis approaches (Norden, 2023).

Given the background presented, it is clear that circular strategies and CBMs are needed and have the potential in prolonging garment lifetime and subsequently slow down clothing consumption and production. However, in order to reduce the environmental impact of clothing, there is also a need for knowledge on when and how circular initiatives are environmentally preferable and have the potential of decreasing the environmental impact compared to the current linear situation. In order to determine whether a CBM or a circular strategy is environmentally beneficial, an assessment of the whole life cycle of the products needs to be done.

3
Methodology

3.1 Mapping of Swedish circular business models and circular strategies

To understand how CBMs and circular strategies are adopted by Swedish clothing companies today, and to select which CBMs to assess with an LCA, a mapping was conducted. Swedish companies currently based on CBMs or implementing circular strategies within reuse were identified. This was done through online searches, using Swedish search words such as *"svenska klädföretag"*, *"hållbarhet"*, *"cirkulära initiativ"*, *"second-hand"*, *"lagning av kläder"* and *"klädprenumeration"* and through oral communication to find as many examples of these circular initiatives as possible.

3.1.1 Interviews

During the mapping stage, nine companies were contacted and asked to participate in semi-structured interviews or to answer questions via email. This was done to generate a better understanding of how the CBMs and circular strategies can be conducted in real life and not with the intent to collect any company data. Two interviews were conducted, one in the form of a 30-minute online meeting with general questions, and the other in the company's chat forum. The questions asked to both of these companies can be found in Appendix **D**. The interview data was compiled and shared for review and approval before being used in the report since no recording of the interviews was done. No personal data was collected during the review process, and the company could comment, modify, add, or remove information.

3.2 Life Cycle Assessment

After selecting and defining two CBMs, these were evaluated using Life Cycle Assessment (LCA). LCA is a recognized and extensively employed approach for calculating a product's environmental impact throughout its entire life cycle. This implies the steps from cradle-to-grave, including raw material acquisition, manufacturing, usage, and waste management. The procedure for performing an LCA is described in the international standards ISO 14040-14043 series (Baumann and Tillman, 2004). It can shortly be described by the four steps of goal and scope definition, inventory for a product system, evaluating associated impacts from the inventory, and continuously interpreting results in relation to the study's objectives. A schematic illustration of the steps conducted in the LCA is shown in Figure 3.1.

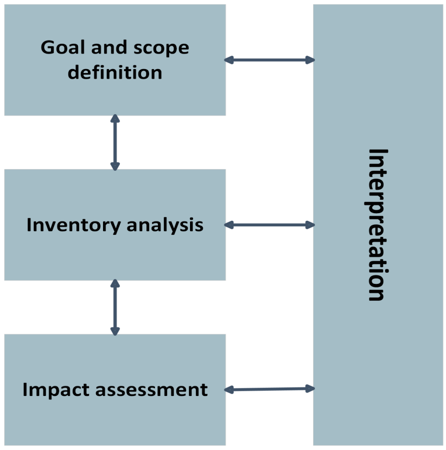

Figure 3.1: *Schematic illustration depicting the procedural steps of the LCA as boxes with arrows representing the order of conduction (Baumann and Tillman, 2004)*

Depending on available data, an LCA can be modeled with different levels of specificity. An LCA can be either case-specific or non-case-specific and this depends on the goal of the LCA as well as available data. It is rare that all required data is available, and assumptions and allocation are common practices. Allocation refers to the process of dividing the environmental impacts and resource use of a system or process consisting of various co-products and/or functions (Baumann and Tillman, 2004). Since the study focuses on the environmental impact of the whole life cycle of three different models, the two CBMs and the linear model, sharing the same product functionality, conducting an LCA for these models allows for a comparison of their environmental performance (Baumann and Tillman, 2004).

3.2.1 Sensitivity analysis

Any LCA study requires a collection of large amounts of information and data. Difficulties in obtaining appropriate data are often encountered. The instances where approximate data are used can be many. Therefore, the need for testing the robustness of the results is usually done (Baumann and Tillman, 2004). It will, in the study, be done through sensitivity analyses by changing different input parameters of the CBMs deemed relevant from the initial results. This is an important step in understanding how different factors impact the CBM's potential in being environmentally beneficial.

4

Selection and description of modeled circular business models

4.1 Mapping of companies

In total, 19 Swedish clothing companies working with either CBMs or circular strategies were found in the mapping. Among these, four distinct categories could be defined: repair, rental, second-hand, and exchange. The result from the mapping, as well as a description of the named companies' approach, is presented in Table 4.1.

The service of repair existed as a strategy at Nudie Jeans, Houdini, H&M, GANT, and Polarn O. Pyret, who offered to repair garments from their company. All were limited to physical stores except for Nudie, who also offered repair kits that could be ordered online and provided the consumer with a kit to do the repairing at home. Repair was also found as a CBM adopted by Repamera, a company that provides garment repair services through its website.

Second-hand options were widely implemented. Six were found as strategies, where Nudie Jeans, Houdini, Filippa K, Weekday, Lindex, Arket, and Polarn O. Pyret collected clothes and sold them in a dedicated second-hand section along with their regular clothing. Weekday accepted all types of clothing, whereas the others only accepted clothes made by their own company. Another seven companies were found with CBMs based on second-hand. Myrorna and Arkivet existed as physical stores, and Rerobe, Plick, Mai, Sellpy, and Vinted as online platforms. All of these second-hand companies offered a variety of clothes and brands.

The four rental options were implemented as strategies at Houdini, H&M, Gina Tricot, and GANT and were limited to occasion- or outdoor wear. These were only available in selected stores apart from Houdini, who also offered this service through their website. Only one exchange option was found, existing as a CBM performed by PopSwap. Their application allowed consumers to exchange clothes with each other through a swiping and matching process. The mapping also revealed that a few companies that offered clothing subscriptions, typically on a monthly basis, had existed but ceased operations due to bankruptcy, with the most recent one at the beginning of this year (Caesar, 2023). Another company that offered private rental of designer wear went bankrupt during this study and was therefore removed from the mapping (Johansson, 2023).

Table 4.1: Summary of mapped companies based on CBMs or using circular strategies with the four categories written in abbreviations

company	Rep.	Rent.	Sec.	Exc.	Description
			Circular Strategies		
Nudie jeans	X		X		Denim wear. Repair is provided in repair shops and with repair kits that can be ordered online. Second-hand exists in physical stores (Nudie Jeans, 2023)
Houdini	X	X	X		Outdoor apparel. Rent and second-hand both online and in stores for selected items. Repair exclusive to stores (Houdini, 2023)
Filippa K			X		Designer wear. Second-hand advertised by consumers using an online platform for selling and buying (Filippa K, 2023)
Weekday			X		Fast fashion. Second-hand exclusive for selected stores (Weekday, 2023)
H&M	X	X			Fast fashion. Rent is exclusive to occasional wear provided in selected stores (H&M, 2023b). Repair provided in selected stores (H&M, 2023a).
Lindex			X		Fast fashion. Second-hand exclusive for children's wear (Lindex, 2023)
Arket			X		Fast fashion. Second-hand exclusive to one store (Arket, 2023)
Gina Tricot		X			Women's fast fashion. Rent exclusive to occasional wear provided in selected stores (Gina Tricot, 2023)
GANT	X	X			Designerwear. Repair provided in stores and rent in selected stores (GANT, 2023)
Polarn O. Pyret	X		X		Children's wear. Repair is done at cost price in store (Polarn O. Pyret, 2023a). Second-hand in both stores and online (Polarn O. Pyret, 2023b)
			Circular Business Models		
Myrorna			X		In-store second-hand with mixed fashion (Myrorna, 2023)
Arkivet			X		Second-hand designed as an ordinary store with a focus on high fashion for women (Arkivet, 2023)
Rerobe			X		Second-hand online and in one store with a focus on high fashion (Rerobe, 2023)
Plick			X		Second-hand through an application (Plick, 2023)
PopSwap				X	Exchange of men's and women's wear through an application (PopSwap, 2023)
Sellpy			X		Second-hand through a digital platform picks up clothes and advertises for the consumer (Sellpy, 2023a)
Mai			X		Second-hand with a focus on high fashion advertises on several platforms and picks up clothes when sold (Mai, 2023)
Vinted			X		Second-hand through a digital platform, customer advertises and ships when sold (Vinted, 2023)
Repamera	X				Online based company working with repairs and customization of clothes, shoes, and bags (Repamera, 2023)

4.2 Selection of circular strategies or circular business models

The study aims to assess the environmental impact of prolonging a garment's lifetime through two CBMs derived from either circular strategies or CBMs represented on the

Swedish market and compare it to the linear model of take-make-dispose. Hence, both practiced strategies and CBMs could be selected as the base for the two CBMs to be assessed in the LCA. In total, nine of the 19 companies were contacted for interviews to receive a better understanding of how the circular services were performed. Nudie Jeans and Repamera responded, both of them working with repair services.

Although all CBMs and circular strategies that were found would be of interest to study, a selection to focus on two was made. A choice was made to focus on CBMs that could be more widely implemented and accessible to a broader range of people. Since all rental services found were limited to occasion wear, which the general population does not frequently use, these were excluded. Whereas the exchange option covered a variety of clothing, only one was found, and the choice fell on second-hand and repair due to their wider implementation. Additionally, repair and second-hand are well-established concepts, with practices like tailors and second-hand stores that have been around for a long time. Conducting an LCA requires large amounts of data. In this case, more information was accessible concerning repair and second-hand due to their well-established existence in various industries and a higher number of existing implementations. Additionally, information was available on the corresponding companies' websites, and from previous contact with Nudie Jeans and Repamera. Consequently, the decision was taken to proceed with repair and second-hand. Looking at a physical second-hand store would have been interesting since it is a common concept. However, online platforms such as Sellpy have grown and become a common practice for many people in recent years. Therefore the choice was made to continue with online second-hands (OSH). Similarly, although Repamera performs repair as an online CBM, previous contact with Nudie Jeans led to the choice to study a physical repair CBM.

4.3 Description of circular business models

In order to develop models representing a garment going through an OSH or repair CBM, as well as a linear model, information was needed. Given the non-site-specific nature of the study, the CBM models aim to represent how CBMs based on either OSH or repair could be carried out and their corresponding outlines. Information on how repair could be conducted and consumer patterns regarding, e.g., what part of a pair of pants usually breaks, what fabric is used for mending it, and how many times consumers usually repair their pants was received from the interviews with Nudie and Repamera. Interview questions and answers can be found in Appendix **D**. The interviews were complemented using literature to provide data for the LCA, and information related to OSH was conducted from OSH platform websites since no information was received from the contact with the companies.

The majority of the information on how repair can be carried out was found through Nudie Jeans and therefore the choice was made to study a pair of pants to resemble their process. To enable comparison, the studied pants remained constant between the three models. The weight was decided by using the average weight of 10 of the author's own pants and subsequently set to 300g. In order to study a commonly used material for clothing, the pants were set to be made of 100% cotton. The choice to use a single material was also made to facilitate the interpretation of the results and enable tracking the results across different processes of the pant's lifecycle. Furthermore, regardless of which model, the pants go through the same processes from the cultivation of cotton until retail. Therefore, these pre-consumer processes are designed the same across the models. As mentioned in the background, there is a constant overproduction of clothes in Sweden. This overproduction of 30% would be applied for all three models, but it was decided that this would not be considered. In the following sections, the linear model, from now on described as business-as-usual (BAU), along with the models for the selected CBMs of repair and OSH, will be described and visually explained with flowcharts.

4.3.1 Business-as-usual

The life cycle for the pants in BAU starts with cultivating and harvesting cotton fibers. This is followed by yarn production through spinning, fabric production through circular knitting, wet treatment, where the fabric is bleached, and confectioning, where the fabric is cut, sowed, and turned into pants. All production steps are assumed to occur in India, which is the largest cotton producer in the world, and where several Swedish clothing companies have parts of their production (SwedWatch, 2008). A more detailed description of the production steps, assumptions, and data modeling can be found in Appendix **B**.

After the pants have been manufactured, they are shipped from India to a city port in Sweden and transported by truck to a warehouse on the outskirts of that city. In the warehouse, they are sorted and further distributed to a physical store located centrally in the city. The consumer travels to the store and brings them home in a paper bag provided by the retailer. At home, the pants are worn, washed, dried, and ironed until the consumer does not want to keep them anymore. This leads to the pants being disposed of in the household waste, which is assumed to be incinerated with heat and power recovery, representing Swedish end-of-life practices (Avfall Sverige, 2022). Figure 4.1 provides an overview of the described steps and depicts the entire cradle-to-grave flowchart. The energy and water used in the processes are shown as arrows entering the system. The emissions and waste produced by each activity are shown as arrows leaving the system. Transportation between processes is shown with black arrows, and processes that do not require transportation are shown in color in the flowchart, as can be seen for washing.

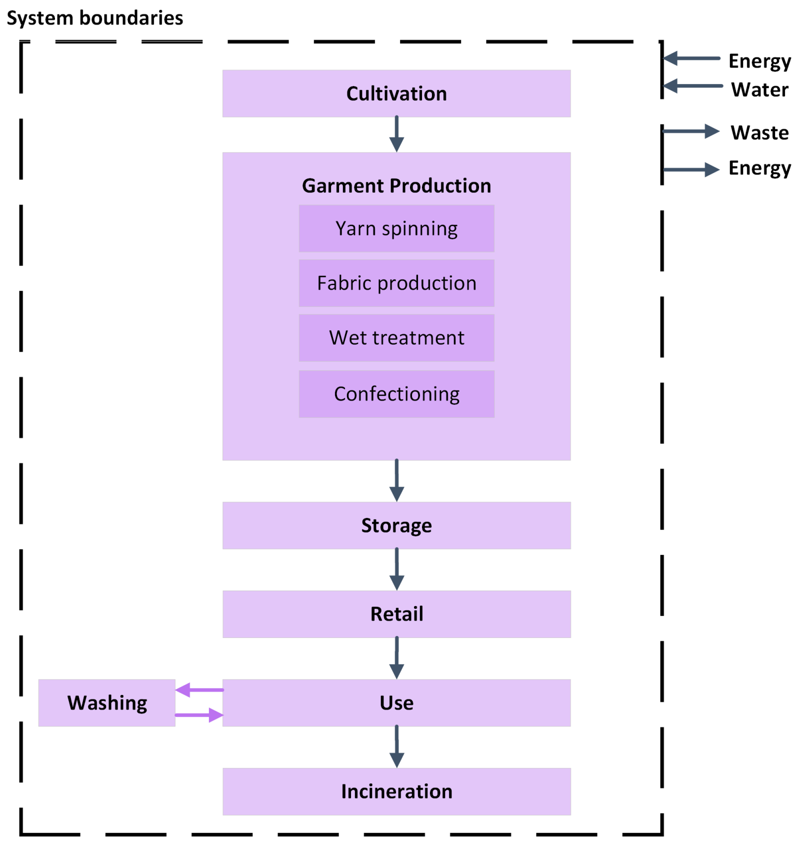

Figure 4.1: *Cradle-to-grave flowchart for business-as-usual*

4.3.2 Repair

In the repair model, the pants go through the same processes as described above for BAU up until the consumer purchases them. Instead of the consumer throwing the pants in the household waste when not wanting to keep them anymore, the pants are used until they are worn out. Then, they are taken, by the consumer, to a repair shop located centrally in the city. After being repaired, they are picked up by the consumer and brought home in a new paper bag, provided by the repair shop. Then, they are used again until a new repair is needed, depicted by the double arrows in Figure 4.2. This is repeated until they are deemed not worth repairing anymore by the consumer, and instead are thrown as household waste and sent to incineration. Based on information from Repamera and Nudie Jeans, this was assumed to happen after three repairs. In order to mend the pants in the repair process, new fabric is needed. At Nudie Jeans, both waste fabric from the confectioning process and fabric from collected old pants were used. It is possible that newly produced fabric could be used but due to a lack of data, it was assumed that all needed fabric was leftovers from confectioning transported together with new pants in order to reach the repair shop. An average amount of material was assumed to be needed for each repair.

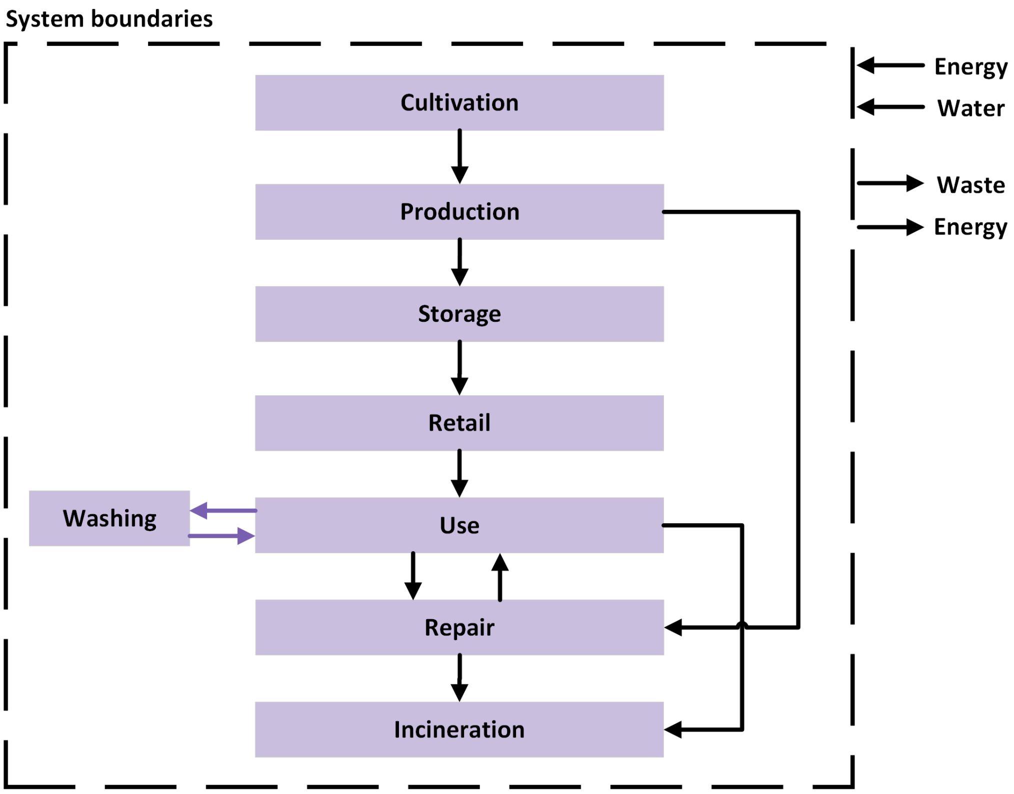

Figure 4.2: *Flowchart for the circular business model repair*

4.3.3 Online second-hand

The OSH model also resembles BAU until the consumer does no longer want to keep the pants. This is assumed to occur when the pants are still in good condition. The consumer decides to sell the pants, and, to do so, orders a plastic bag that is delivered home by the OSH company. The consumer puts the pants in the bag, which is then retrieved at home by the company and taken to their sorting and management (S&M) facilities. Here, the pants are inspected, sorted, photographed, and put on their website for sale. When a new consumer purchases the previously owned pants on the website, they are shipped to the new consumer's postal agent through a postal service, where the new consumer picks them up and brings them home. This loop between consumers is depicted by the arrows going back and forth between Use and S&M, seen in Figure 4.3. It is assumed that the pants are sold two times through the OSH. The first two consumers only use the pants shortly before deciding to sell them, whereas the last consumer uses them until they are worn out.

Since the pants are assumed to be in good condition both times they are sold, and therefore meet the requirements set by the OSH company, it is assumed that no pants are sorted as waste. However, due to the low consumption rates in Sweden of second-hand clothing, as described in section 2.2, not all pants are assumed to be sold and instead, unsold pants are donated. Based on the current textile flows in Sweden and information provided by Sellpy's website (Sellpy, 2023b), donated pants are assumed to be sent to charity organizations in Europe, and transported to a new consumer. This was modeled as a truck transport to Hamburg to represent the additional transportation. However, the main aspect of the modeling of the donated pants is the number of uses that are achieved through the donation. The use phase for the donated pants is modeled as the use phase for the sold pants with washing, drying, and ironing. Eventually, the pants are worn out and thrown away by both the second-hand buyer and the one who received the donated pants. In either case, it is assumed that the pants are incinerated with heat and power recovery. Some OSH stores, such as Sellpy, provide the alternative of a seller getting an item back if it is not sold or if they regret putting it up for sale, but this is not accounted for in this study.

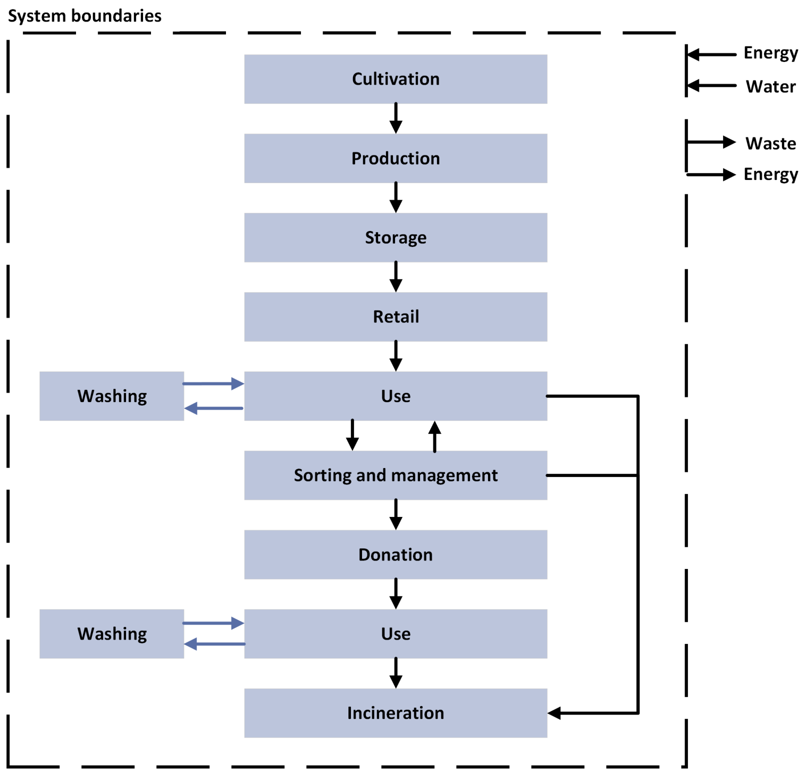

Figure 4.3: *Flowchart for the circular business model online second-hand*

4.3.4 Number of uses

The number of uses achieved is set to represent the possibilities of the models and current consumption patterns in Sweden. There is not much data available on how many times garments, and in this case pants, are used. According to the study *Environmental Assessment of Swedish Clothing* (Sandin et al., 2019), the average number of uses of jeans purchased and used per year in Sweden is 240. Another study, made on 1500 women, showed that garments are used on average seven to ten times before being discarded (Morgan and Birtwistle, 2009). The studied pants were assumed to be less used than jeans, considered more of an everyday garment, and more used than the average of all garments, which could be everything between evening wear and tops. Additionally, the studied pants weigh 300g instead of a general pair of jeans, estimated to weigh 477g (Sandin et al., 2019). The thinner fabric was assumed to be worn faster than the thicker fabric of jeans. Therefore, it was assumed that one pair of pants was used 200 times before being discarded in BAU. To represent the current consumption, where a large share of clothes is thrown as household waste despite being in good condition, the maximum usage of one pair of pants was set to 300 uses, meaning that after 300 uses, they would tear. This also means that in BAU, the pants are discarded before they are fully used and worn out. Since the environmental impact from different fates of the pants will be compared, the precise number of uses assumed is not as important as the number of achieved uses in relation to each other.

For the repair model, it was assumed that one pair of pants is fully used until they are worn out after 300 uses, and then repaired. According to both Nudie Jeans and Repamera (Repamera, 2023; employee Nudie Jeans, personal communication, April 26, 2023), the number of repairs of the same garment requested by their customers is difficult to say. Still, both provided estimates of approximately four. Taking these estimates into consideration, it was decided to set the assumption of three repairs per pair of pants. After each repair process, the number of uses, until a new repair is needed, is assumed to decrease. The remaining use phases enable 150, 100, and 50 uses, respectively, presented in Table 4.2. After the third repair, it was assumed that repairing the pants was not worth it for the consumer due to the low number of additional uses it would enable

For OSH, it was assumed that the pants go through three consumers. The first one only keeps the pants for 50 uses, then decides not to keep them. This means that the pants are sold in good condition. The second consumer also keeps the pants for 50 uses, then decides to sell them, still in good condition. When the pants reach the third and last consumer they are fully used until they reach the point of being worn out. Since it was assumed that two-thirds of the pants received by the OSH company were sold, and one-third were donated, one additional half pair of pants needs to be collected in order to sell one pair of pants. This happens every time the pants change owner, resulting in 2.25 pair of pants produced in order for one pair to end up with its final consumer. However, since all pants, sold or donated, are fully used, 625 uses are achieved in total across all pants, which the total impact of the model will be distributed among. This also means that each pair of pants in the OSH model will be used 300 times.

For all three models, the use phase was modeled with washing, and it was assumed that it was done every 10th use. In the OSH model, an extra washing was added every time the pants were sold and every time they were received by a new consumer, to represent the observed behavior when selling clothes through OSH. For the repair model, it was assumed that no extra washes were needed since the pants did not change owner.

Table 4.2: Assumptions for the number of uses

	Use phase 1	**Use phase 2**	**Use phase 3**	**Use phase 4**	**Total**
BAU	200	-	-	-	200
Repair	300	150	100	50	600
OSH	50	50	200	-	300

4.3.5 Transportation

During the production phases, no transportation was assumed to happen due to one assumed location for all the processes. The first transportation is shipping from India to a port in a larger city in Sweden. Transportation distances for the consumer in the three models were set to represent a larger city in Sweden and that the consumer lived centrally in the city. The retailer and repair shop was located in the city center and the waste facility was in the outskirts of the city. The postal agent, where the consumer picks up their delivery in OSH was assumed to be located in the same district as where the consumer lived. The postal office, to which transports are made by the postal service, was assumed to be located in the outer parts of the city. The warehouse, from where transports are made to the retailer, as well as transports from the postal office in OSH, was assumed to be located in a nearby smaller town. The necessary distances that the consumer needs to travel were assumed by the authors and based on corresponding estimated distances in Gothenburg, as shown in Table 4.3.

Table 4.3: Transportation distance

	BAU	Repair	OSH
India to port in Sweden	14 280	14 280	14 280
Port to warehouse	70	70	70
Warehouse to retailer	70	70	70
Consumer to retailer	8.5	8.5	8.5
Consumer to waste	6	6	6
Consumer to postal agent	-	-	1
Postal agent to postal office	-	-	10
Postal office to warehouse	-	-	70

The mode of transportation in which the consumers travel to both the retailer, repair shop, and postal agent was based on the traffic situation in Gothenburg in 2019. Due to Covid-19 and the change in transportation patterns, this year represents the latest available data to represent "normal" traveling behavior in a Swedish city, as shown in Table 4.4 (Trafikkontoret, 2020). Walking or taking the bike will be assumed to lead to zero extra emissions.

Table 4.4: Modes of transportation

	Walk and bike	Public transport	Car
Base case	28%	30%	43%

5

Life Cycle Assessment

5.1 Goal and scope definition

As described in section 1.1, the goal is to assess the environmental impact of a pair of pants under the two CBMs based on repair and OSH, as represented on the Swedish market, both based on the extension of the use phase and compare it to the linear model of take-make-dispose.

5.1.1 Functional unit

The functional unit (f.u.) for this study was defined as 300 uses of a pair of pants. The reference flow is one pair of pants weighing 300g consisting of 100% cotton. This f.u. was applicable to BAU and the two CBMs, enabling comparison between the three models. The chosen f.u. included the whole use phase of the pants as described in section 4.3.4, i.e., including all uses until they are set to be worn out instead of considering individual uses.

5.1.2 Environmental Impact categories

The Sustainable Apparel Coalition (SAC), a global non-profit alliance for the clothing industry, has evaluated 16 impact categories when conducting life cycle assessments (LCAs) on clothing. They have based their evaluation on the Product Environmental Footprint (PEF) methodology to assess the relevance of different impact categories to the industry. As per their analysis, studies focused on clothing are recommended to include the seven impact categories (SAC, 2021);

- **Climate Change**, due to the emissions from production and the many transports needed throughout the whole life cycle
- **Particulate Matter**, due to the release of small substances mainly from transportation
- **Acidification**, due to the number of substances used in production
- **Eutrophication**, due to the number of substances used in production
- **Ozone Depletion**, due to the emissions from production and transportation
- **Ionizing Radiation**, due to the electricity use in production and use-phase washing
- **Photochemical Oxidation**, due to the emissions from production and transportation

Based on the described impact of processes within the clothing industry and with previous LCA studies on clothing by Sandin et al., (2019), Böckin et al., (2022), Nellström and Saric, (2019), other relevant impact categories found were;

- **Abiotic resource depletion potential**, due to the energy-requiring processes in production
- **Freshwater Aquatic Ecotoxicity Potential**, due to the number of substances used in both cultivation and production
- **Human Toxicity Potential**, due to the number of substances used in both cultivation and production
- **Land use**, due to the amounts of land needed for growing fibers like cotton
- **Water use**, due to its need in e.g., irrigation for crops and washing garments

Although it would be interesting to evaluate all the mentioned impact categories above for the repair, OSH, and BAU model, looking at too many impact categories can be inefficient and complicate conclusions (Esnouf et al., 2019). A selection was made on the availability and relevance of data to limit the number of investigated impact categories. These are presented in Table 5.1, along with the unit, characterization method, and areas of protection. Each impact category is further described in Appendix **A**. Two impact assessment methods were used to cover the chosen impact categories: CML v4.8 2016 no LT (Guinee, 2001) and ReCipe 2016 v1.03, midpoint (H) no LT (Huijbregts et al., 2016) provided by ecoinvent (Ecoinvent, 2023c) and are further described in section 5.1.2.

Table 5.1: Impact categories used in this study with respective units, method, and areas of protection

Impact category	**Unit**	**Method**	**Areas of protection (Guinee, 2001)**
Acidification Potential (AP)	Sulphur dioxide (SO_2) eq.	CML v4.8 2016 no LT	Human health, natural and man-made environment, and natural resources
Global Warming Potential (GWP)	Carbon dioxide (CO_2)-eq.	ReCipe 2016 v1.03, midpoint (H) no LT	Human health, natural and man-made environment
Freshwater Aquatic Ecotoxicity Potential (FAEP)	1,4-Dichloro-benzene (DCB) eq.	ReCipe 2016 v1.03, midpoint (H) no LT	Natural environment and natural resources
Human Toxicity Potential (HTP)	1,4-Dichloro-benzene (DCB) eq.	CML v4.8 2016 no LT	Human health
Abiotic resource depletion potential (AD)	MJ	CML v4.8 2016 no LT	Natural resources or natural resources, human health and natural environment
Eutrophication Potential (EP)	Phosphate (PO_4^{3-}) eq.	CML v4.8 2016 no LT	Natural and man-made environment and natural resources
Land use	$m^2 \times yr$ crop-eq.	ReCipe 2016 v1.03, midpoint (H) no LT	Natural resources and man-made environment
Ozone Depletion Potential (ODP)	Trichloroflouromethane (CFC-11) eq.	CML v4.8 2016 no LT	Human health, natural and man-made environment, and natural resources
Photochemical Oxidation Potential (POP)	Ethene (C_2H_4) eq.	CML v4.8 2016 no LT	Human health, natural and man-made environment, and natural resources
Water use	m^3	ReCipe 2016 v1.03, midpoint (H) no LT	Natural resources and man-made environment

The life cycle impact assessment (LCIA) methods used in ecoinvent are CML v4.8 2016 no LT, which is the latest version of the CML IA midpoint characterization approach, and ReCipe 2016 v1.03, midpoint (H) no LT, which is one of the most commonly used LCIA methods (Aitor P. Acero and Ciroth, 2016). LT stands for long-term and considers emissions that are released more than 100 years after the activities of the studied lifecycle occurred. This is usually emissions from landfills (Ecoinvent, 2023b). Since the pants are assumed to be incinerated and not in a landfill, no LT was chosen for the study.

Mid-point characterization was chosen as the best way to present results since these factors allow a decent level of aggregation which makes the results easy to interpret and communicate, keeping the results more objective. End-point characterization has the risk of simplifying results and becomes influenced by subjective judgment (Baumann and Tillman, 2004). Since the intended audience of this study is public, knowledge of the LCA methodology is limited, and a comprehensible communication of the results is necessary, which would imply the use of weighting or normalization of results. The ISO14044 standard does not recommend weighting for LCAs that are comparative in nature and intended for public disclosure, due to the same reason as for endpoint characterization. The study meets both of these criteria and as a result, the results were not weighted (Baumann and Tillman, 2004). However, they were normalized against BAU to enable a more intuitive understanding of the impact categories using the same reference value, as this is a recommended step for any LCA (Guinee, 2001).

5.1.3 Type of Life Cycle Assessment

The nature of the LCA is comparative as it sets out to compare two models representing different CBMs and a linear model. Thus, an attributional approach was chosen as more suitable than a consequential one (Baumann and Tillman, 2004). An attributional LCA aims to assess the environmental impacts of a lifecycle based on its current parameters, whereas a consequential assesses how changes in the design of the lifecycle affect the environmental impact (Finnveden and Potting, 2014). Additionally, the LCA will be a cradle-to-grave assessment, thus including the entire life cycle of the pants.

5.1.4 System boundary

As previously stated, the study conducts a cradle-to-grave LCA, starting from raw material extraction, the cradle, to waste management, the grave. The geographical boundary included the countries involved in the cradle-to-grave life cycle processes of the garment. More specifically, this means India, where production and manufacturing are assumed to happen. With the goal being based on Swedish consumers and companies operating in Sweden, all activities and transportation during storage, retail, the use phase, repair, second-hand, and waste management were assumed to only occur in Sweden. This entails that data for the energy mix used in the processes, i.e., electricity, is representative of the countries where the process takes place. Donated pants that are shipped to a new consumer might go outside the borders of Sweden but are assumed to have the same end-of-life practices as in Sweden.

This is not a site-specific study and several assumptions regarding i.e. production methods, inputs and outputs, transportation distances and modes, electricity consumption, properties of the pants, inputs for repairing, consumer patterns regarding washing, number of uses of the pants, and number of repairs had to be made. Initial assumptions are further explained in section 5.1.6 and more in detail in Appendix **B**. The time horizon for this study is seen to be over a short period of time, where the number of uses of the pants is scattered. During this period, it is assumed that there are no changes in how the pants are manufactured and disposed of. Consideration for capital goods, including maintenance and production, and personnel was excluded from the study.

5.1.5 Data Quality Requirements

According to the standards on attributional LCA, where the case is not site-specific, and the lifecycle occurs in several geographical sites, average data is recommended (Baumann and Tillman, 2004). Therefore, average data from the existing processes and material flows provided by ecoinvent in the software openLCA was used. The modeling of processes in BAU was approximated using data from Sandin et al., (2019). The most significant parts of the used data, including assumptions and allocation, are further described in section 5.2. The relevance of the chosen data was determined by considering the process information, dataset descriptions, geographical locations, and dates provided in Ecoinvent. Calculations for the total impact of the LCAs were performed in openLCA, while impact per f.u. was calculated using Excel along with creating graphs.

5.1.6 Initial Assumptions and Limitations

The study is limited to one pair of pants and does not take into account variable sizes, and it is therefore assumed that the same amount of material is needed to produce one pair of pants. It is assumed that the pants are not dyed into a specific color but only bleached and will therefore have the look of "natural" cotton. No combinations of repair and OSH were studied. For end-of-life management, it was assumed that the pants are disposed of as household waste and incinerated with heat and power recovery since there is no established way to dispose of textiles for recycling in Sweden. This also meant that no pants would end up in a landfill (Avfall Sverige, 2022).

5.2 Inventory Analysis

In this section, the data choices of the inventory analysis will be presented. Data in the form of numbers used for the calculations of environmental impact in relation to the f.u. and specific assumptions for all processes can be found in Appendix **B**. The data used in the study was approximated using data from Sandin et al., (2019), for a 100% cotton t-shirt, due to its material proportions as well as the similar complexity in design and seams. No additional features, such as buttons or zippers, were accounted for. Processes were modeled with data from the Ecoinvent 3.9.1 database (Ecoinvent, 2022)

5.2.1 Type of data

For all parts, the process data "market for" was used. Market data represent a market average with, for example, shares of types of production and/or production from different countries. Average transportation is also included when the process exists in multiple geographical locations. In cases where market activity data was not available, "production" was used instead, encompassing the processes involved in manufacturing the material, product, or service (Ecoinvent, 2023d). Geographical preferences for the production were in India (IN), and post-production was either Sweden (SE) or Europe without Switzerland (EwS). When these were unavailable, globally (GLO) or the rest of the world (RoW) was used.

5.2.2 Overview of all life-cycle phases

The contributing processes for the pair of pants, measured in kilograms (kg) throughout the three models, are shown in Table 5.2. This includes estimated material losses during production steps, fabric additions during repairs, and the total weight required for OSH. The initial production steps are applied to all three models, and a comprehensive explanation of these steps, along with assumptions and modeling details, can be found in Appendix **B**. The following subsections aim to provide the essential data required for understanding the remaining parts of the report and will start with a general description of the models followed by an explanation of the allocation methods.

For the initial purchase of the pants, the consumer brings them home in a paper bag. This bag is modeled using the dataset "market for paper sack" (RoW) (Ecoinvent, 2023e) and was assumed to weigh 39g. For the repairing of the pants, the required additional fabric was modeled as collected waste fabric from the production, that was transported to the retailer. It was assumed that 10g of fabric was required for each repair and 10g of fabric from the pants itself was removed during the repair process. Consequently, the overall weight of the pants remained constant at 300g, with a total fabric requirement of 30g to facilitate three separate repairs. This fabric was modeled to be disposed of and incinerated. For OSH, the plastic bag is modeled with "market for packaging film, low-density polyethylene" (GLO) (Ecoinvent, 2019) and was assumed to weigh 15g. No additional impacts, such as electricity use for sorting, photographing, and adding the pants on the website, were modeled for OSH.

Table 5.2: Contributing processes for the pair of pants per kg pants

Process	Pants [kg]
Production phase	
Yarn spinning	3.64E-01
Fabric production	3.53E-01
Wet treatment	3.53E-01
Confectioning	3.00E-01
Distribution and retail	
Distribution and storage	3.00E-01
Retail	3.00E-01
Use phase	
Use of pants	3.00E-01
Extending use	
Repair of pants	3.10E-01
Sorting and managing OSH	4.50E-01

5.2.3 Allocation

There are several similar processes with multi-functionality, and the same allocation methods were used as in the study by Sandin et al., (2019). For instance, transportation involves the distribution of multiple products in a single vehicle, electricity includes use for whole warehouses and stores, washing includes more than one garment at a time in the machine, and incineration serves as a disposal method and generates heat and power. The allocation of impacts for these processes was conducted based on mass because the impacts of these processes are expected to be proportional to the mass of the materials involved. For transportation, different EURO sets are used, which represent a standard for vehicle emissions set by the European Union (Ecoinvent, 2023f). It defines the maximum limits for pollutants emitted by vehicles, with the latest being EURO6.

5.2.3.1 Transportation

Transportation of the pants from India to Sweden was modeled with the dataset "market for transport, freight, sea, container ship" (GLO) (Ecoinvent, 2023f). This includes delivering the service of transportation of one metric ton across a distance of one kilometer (km). The ship operates with heavy fuel oil with a load capacity of 43,000 tonnes, and it is estimated to transport an average of 7,200 million tonnes*km per year for 25 years.

For consumer transportation, the dataset "market for transport passenger car" (RoW) (Ecoinvent, 2023f) published for the time period 2012-2023 was used. This market process takes into account internal combustion engines from different car classes (EURO3, EURO4, and EURO5). The vehicle is an average of the different car sizes (small, medium, and large) and fuel types (petrol, diesel, and natural gas) for each EURO category. It also takes a medium-sized electric car into account, however, the share between ICE and EV was not provided in ecoinvent. The weight of the pants was allocated to a trip with a total distance from home to store and back set to 17 km/kg clothing, meaning that one kilogram of garments is bought each trip, i.e., 2-3 garments. This entails that for the allocation, the distance for the pants of 0.3kg becomes 5.1km in total since the unit of a passenger car in ecoinvent is set in km.

For transportation using a tram, the dataset ”market for transport tram” (GLO) was used (Ecoinvent, 2023f). There is a slight difference from the car as the dataset is delivering the service of transportation of one passenger across one km, meaning that the unit is set as person*km, and the total distance is, therefore, 17km. The tram operates with electricity, with an average load of 52.8 passengers per vehicle.

Freight of the pants via truck transportation is allocated in a similar way using the unit kg*km, to calculate the impact for the pair of pants based on different average loadings depending on truck size assumed by ecoinvent. The truck sizes used in the study for transportation are the datasets ”market for transport, freight, lorry 16-32 metric tons, EURO6” (RoW) (Ecoinvent, 2023f), where the pants are assumed to be transported in a larger truck, for example, from production to warehouse. Data for this transportation is calculated for a vehicle operating on diesel with an average load factor of 5.79 tonnes, including an empty return trip. Secondly, ”market for transport, freight, lorry 3.5-7.5 metric tons, EURO6” (EwS) (Ecoinvent, 2023f), is a smaller truck size and is used, for example, when the pants are transported from warehouse to the retailer. Data for this transportation is calculated for a vehicle operating on diesel with an average load factor of 0.98 tonnes, including an empty return trip. Lastly, ”market for transport, freight, light commercial vehicle” (EwS) (Ecoinvent, 2023f) is the smallest truck used in the study, for example, when the pants are transported in a plastic bag from the consumer to S&M. Data for transportation is calculated for a vehicle operating on diesel or petrol. No average load was provided for this dataset in ecoinvent.

5.2.3.2 Electricity

Electricity is consumed in many of the processes of the pants’ lifecycle. In all of the production processes, which were assumed to occur in India, electricity was modeled using the dataset ”market for electricity, medium voltage (IN, Western grid)” (Ecoinvent, 2023a). This includes electricity generated by hard coal, oil, and lignite. For the warehouse, where the pants are stored, the washing by the consumer, and the sowing during a repair, the electricity consumption was allocated using mass to represent the need for each pair correctly. All of these were modeled using the dataset ”electricity, low voltage, residual mix” (SE) (Ecoinvent, 2023a), which includes electricity generated within Sweden, imported electricity, grid losses, and emissions related to the building of grids and transformers. For the retailer and S&M, the electricity need was assumed as 1.94kWh/pants. For washing, it was assumed 0.225 kilowatt-hours (kWh)/pants. Besides being washed, it was assumed that the pants were dried with heat using 0.67kWh/pants after 30% of the washes and ironed using 0.027kWh/pants after 15% of the washes (Sandin et al., 2019).

5.2.3.3 Washing in use phase

For washing, detergent production was modeled separately, as seen in Appendix **B**. The inputs, therefore, consisted of detergent, electricity, and ”market for tap water” (EwS) (Ecoinvent, 2023h). To allocate the impacts to one pair of pants per washing, 0.0158kg detergent, electricity as described above, and 6.2 liters of tap water, were assumed (Sandin et al., 2019).

5.2.3.4 Incineration

Since the pants are made of cotton, they, along with the paper bag, were modeled as waste paperboard for incineration using the dataset "treatment of waste paperboard, municipal incineration" (RoW) (Ecoinvent, 2023g). The plastic bag was modeled using the dataset "treatment of waste polyethylene terephthalate, municipal incineration" (RoW). Datasets for RoW were used since no options were available for Sweden for these specific materials. Expansion with substitution was also applied, meaning that the heat and power generated from incineration would replace the national annual market mixes of heat and power generation. These datasets were therefore used as negative inputs. They consisted of "electricity, low voltage, residual mix" (SE) (Ecoinvent, 2023a) for power which for paperboard waste generates 0.55 kWh/kg, and "heat, district or industrial heat from municipal waste incineration to generic market for heat district or industrial, other than natural gas" (SE) (Ecoinvent, 2023h) for heat which generates 3.98MJ/kg. Since the weight of the plastic bag was small compared to the pants and the paper bag combined, all recovered heat and power were modeled with the same amount as for the waste paperboard.

5.3 Impact assessment

The following section will provide the results from the LCA, presented for each impact category separately. As some of the impact categories are influenced by the same processes causing their result to follow the same pattern, these five will be presented in the report while the complete set of results is presented in Appendix **B**:

- Acidification
- Global warming, where the same pattern is seen for ozone depletion, photochemical oxidation, and abiotic resource depletion
- Freshwater ecotoxicity
- Human toxicity
- Land use, where the same pattern is seen for water use and eutrophication

All impacts are presented per f.u. of 300 uses of pants. Impact values are rounded to two decimals, and all percentages are rounded to the nearest whole value. Values for all impact categories are presented in a table and graph in Appendix **B**.

In all diagrams illustrating the contributions for each impact category, the following definitions apply:

- **Production** encompasses all garment production steps, from cultivation to the confectioning process.
- **Distribution & retail (D&R)** includes the transportation of the garment from India to Sweden, as well as the transportation within Sweden from the port to the warehouse and from the warehouse to the retailer, all of which are carried out by the retailer. Additionally,

this category accounts for the impacts associated with electricity usage in the warehouse and retailer.

- **Use** consists of the impacts from washing, drying, and ironing, including electricity consumption, detergent production, water usage, water treatment, and the treatment of the paper bag used to carry the pants home from the store.
- **Repair** focuses on the impacts associated with repairing the pants by the retailer. It includes electricity consumption, and treating waste fabric.
- **Sorting & management (S&M)** addresses the impacts related to the sorting and management of the garment. It includes the electricity consumption in the warehouse, the transportation of the plastic bag to the consumer and back (including the pants), and the treatment of the plastic bag.
- **Consumer transportation (CT)** consists of all transportation activities conducted by the consumer, including transportation to and from the retail store, repair shop, and postal agent.

Since the pre-consumer processes are almost identical for the three models, their contribution to the result is mainly affected by the number of uses and therefore follows the same pattern across the impact categories, as can be seen in Figure 5.1. The impact of production for repair and OSH remains one-third and two-thirds of BAU within each impact category since the same processes with the same impacts are attributed to 600 and 300 uses for repair and OSH, respectively, compared to 200 uses for BAU. The same pattern can be seen for distribution and retail. However, the contribution from these pre-consumer processes and the following processes differ with each impact category, as will be presented in the following section.

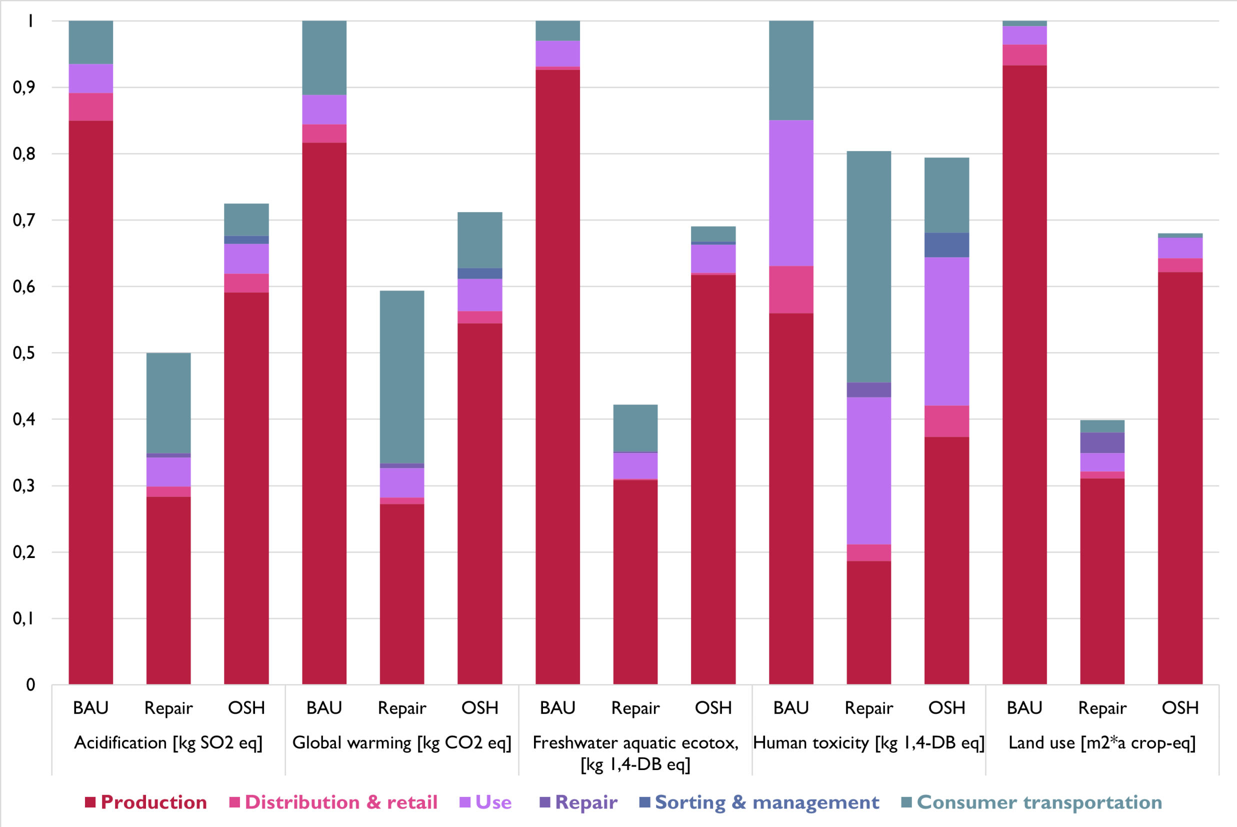

Figure 5.1: *Results for impact categories per f.u. normalized to business-as-usual*

5.3.1 Acidification

The total impact on acidification for BAU is 6.40×10^{-2} kg SO_2-eq. 85% originates from production, specifically cotton cultivation, electricity use, and wet treatment. Cotton cultivation involves the usage of fertilizers, causing emissions of ammonia and nitrogen oxides, contributing to one-third of the production's impact. Electricity generated by oil and lignite, parts of India's energy mix, causes emissions of sulfur dioxide and nitrogen oxides. During wet treatment, sulfuric acid is emitted during bleaching. Additionally, producing fluorescent whitening and heat causes emissions of sulfur dioxide and nitrogen oxides. D&R accounts for 4%, mainly due to the shipping transportation emitting sulfur dioxide and nitrogen oxides. Use makes up 5%, with the main contributors being electricity and detergent for washing. Nuclear and oil-generated electricity, parts of Sweden's electricity mix, and the production of copper for electricity networks cause sulfur dioxide emissions. Detergent production emits sulfur trioxide, sulfur dioxide, nitrogen oxides, and ammonia. CT accounts for 6%, mainly from car transportation emitting nitrogen oxide, ammonia, and sulfur oxide.

For repair, the total impact is 50% lower than for BAU, meaning 3.20×10^{-2} kg SO_2-eq. Production and D&R account for 56% and 3%, respectively. Similar to use in BAU, use in repair accounts for 9%. The additional repairing process contributes only 1%. CT, which in the repair model means additional transportation back and forth to the repair location 8.5km away, accounts for 30% of the total impact.

The total impact of OSH is 72 % of BAU, which is 4.48×10^{-2} kg SO_2-eq. The production makes up 84%, and D&R is 4%. Use, which for OSH means additional washes requiring electricity and detergent, accounts for 6% and is slightly more than for BAU and repair. S&M makes up 2%, primarily due to electricity consumption. CT, which for OSH means additional transportation back and forth to the postal office 1 km away, accounts for 7%.

5.3.2 Global warming

The total impact on global warming for BAU is 12.67kg CO_2-eq. Production accounts for 82%, of which half is due to fiber production, where electricity and cotton cultivation are major contributors. Electricity generated by hard coal, oil, and lignite emits CO_2 and dinitrogen monoxide (N_2O), and during cotton cultivation, N_2O and CO_2 are emitted due to irrigation, tillage, and usage of fertilizers. The wet treatment causes CO_2 emissions from heat production and methane and CO_2 emissions when producing fluorescent whitening. D&R makes up 3%, mainly due to electricity generated by oil, the production of paper bags, and ship transportation. Use accounts for 4% due to electricity for washing and detergent production emitting CO_2. CT accounts for 11%, primarily caused by N_2O_2, methane, and CO_2 emissions from car transportation.

For repair, the total impact is 59% of BAU, meaning 7.52kg CO_2-eq. Production and D&R account for 46%, and 2%, respectively. Use contributes as much as BAU, which makes up 8%. The additional repair process contributes 1%, primarily due to the production of paper bags. CT accounts for 44%.

The total impact of OSH is 72% of BAU, being 9.02kg CO_2-eq. 77% stems from production and 3% from D&R. Use accounts for 7%, slightly more than for BAU and repair. S&M contributes 2%, mainly due to electricity use and production, as well as the incineration of plastic bags since this emits CO_2. CT is responsible for 12% and is lower than both BAU and repair. The much shorter CT in OSH compared to repair and the higher number of uses compared to BAU makes the total impact per f.u. lower.

5.3.3 Freshwater aquatic ecotoxicity

For BAU, the total impact on freshwater aquatic ecotoxicity is 16.59×10^{-2} kg 1.4-DB eq. 93% originates from production, primarily from seed cotton production due to runoff from fertilizers and pesticides, erosion due to plowing, and water withdrawal for irrigation. D&R accounts for less than 1%. Use contributes to 4%, mainly due to the production of coconut oil for detergent, which emits metals into the soil. CT contributes 3% due to the production of petroleum for car transportation.

For repair, the total impact is 42% of BAU, corresponding to 6.99×10^{-2} kg 1.4-DB eq. Of this, production is 73%, and distribution and retail are less than 1%. Use contributes 9% and repair with less than 1% due to electricity. 17% originates from transportation.

The impact from OSH is 69% of BAU, with a total of 11.46×10^{-2} kg 1.4-DB eq. Out of this, production accounts for 89%, distribution, and retail for less than 1%, and use 6%. S&M contributes 1% due to electricity and emissions from incinerating plastic bags and transportation for 3%.

5.3.4 Human toxicity

BAU has a total impact of 8.57kg 1.4-DB eq for human toxicity. Production contributes 56% due to fiber production, electricity use, wet treatment, and cardboard box production. During cotton seed production, lead and chromium are emitted into the soil. Mining and production of copper required for electric networks cause arsenic, nickel, and cadmium emissions. Production of fluorescent whitening for wet treatment requires open burning of waste outputs, which emits PAH and benzene. Heat production emits hydrogen peroxide, and cardboard production for packaging emits PAH. The impact from production differs from the result for the other impact categories where production makes out the majority of the total impact. D&R contributes 7%, mainly due to the production of paper bags and emissions during transportation. Use accounts for 22% due to the production of detergent and coconut oil, which requires wood preservation that emits i.e. pyrene and fluorine, and the use of electricity which requires smelting of copper that emits i.e. sulfur dioxide and lead. 15% stems from CT, which is a significant amount compared to the other impact categories. This is mainly due to the production of cars and internal combustion engines. This requires smelting of copper concentrate which emits arsenic ions, nickel, cadmium, and copper ions, benzene chlorination which emits benzene and ferrochromium production that emits chromium.

Repair's impact on human toxicity is 80% of BAU, in total 6.89kg 1.4-DB eq. Of this, production only accounts for 23%, D&R for 3%, and use 28%. The repairing contributes 3%, mainly due to the production of paper bags. CT contributes 43%. Human toxicity is the only impact category where repair exceeds OSH, and CT is the main contributor to this impact.

OSH's total impact on human toxicity is 6.81kg 1.4-DB-eq., 79% of BAU, slightly lower than for repair. Production accounts for 47%, D&R 6%, and use 28%, which is equal to both BAU and repair. 4% stems from S&M, primarily due to electricity use, and 14% originate from CT.

5.3.5 Land use

BAU has an impact of 3.92m$^2\times$yr annual crop-eq. on land use. 94% of this originates from production, where almost all of it is due to cotton cultivation and its occupation of land and irrigation requiring water withdrawal. D&R accounts for 3%, mainly due to the occupation of land for pine forestry for the production of paper bags. Use contributes 3%, mainly from coconut oil production for detergent, which requires forestry occupying land. CT accounts for less than 1% due to land occupation of road networks.

For repair, the total impact is 1.56m$^2\times$yr annual crop-eq., which is 41% of BAU. 76% originates from production, 3% from D&R, and 7% from use. Repair accounts for 8% due to the additional paper bag and CT for 6%.

The total impact of OSH is 2.67$m^2 \times$yr annual crop-eq., 68% of BAU. Production accounts for 91%, D&R 3%, and use 5%. S&M has close to 0% impact. Finally, CT accounts for 1%.

5.4 Sensitivity analysis

In order to further explore the robustness of the LCA result and the impact of different assumptions made for the models, a sensitivity analysis was done. The initial results indicated that CT and the actual number of uses of the pants played a significant role in the outcome of the different models. The ratio for CT between cars and trams, the distances for transportation, and the number of uses were therefore analyzed and are further described in the following sections.

5.4.1 Transportation mode

For all models, transportation done by the consumer is inevitable for the initial purchase of the pants. For repair, additional trips are made back and forth to the repair shop, for each repair. For OSH, additional trips are back and forth to the postal agent. In order to see the potential impact when changing the ratio, a sensitivity analysis was done with all CT made by car, as presented in Table 5.3.

Table 5.3: Percentages for transportation mode

	BAU	**100% car**
Walk and bike	28%	0%
Public transportation	30%	0%
Car	43%	100%

5.4.2 Transportation distance

To evaluate the impact of distances on CT, an analysis was done for suburban consumers. The distances to the store, repair shop, and waste treatment were set to 20km and 3km to the postal agent. For OSH, an addition to the analysis was created, assuming a centrally located consumer in another city. The distances between the first warehouse and the store, as well as between the postal agent and the sorting and management warehouse, were modeled as 430km and 500km, instead of 70km. The other distances remained the same as the original model and are described in Table 5.4. Distance from consumer to the retailer, waste, and postal agent was assumed to be the same for the persons living centrally in both of the larger cities, assuming the same store exists in both places. All distances are assumptions made using google maps with Gothenburg as a reference, Kullavik as the suburb, and Stockholm as another city.

Table 5.4: Distances from different cities

	Main city [km]	Suburb [km]	Another city [km]
Consumer to retailer	8.5	20	8.5
Consumer to waste	6	30	6
Consumer to postal agent	1	3	1
Postal agent to postal office	10	20	10
Postal office to warehouse	70	70	500
warehouse to retailer	70	70	430

5.4.3 Number of uses after repair

For the repair model, each pair of pants was assumed to be repaired three times with full usage. For the sensitivity analysis, the pants were assumed to be repaired once, and then only used 50 times out of the 150 times enabled in use phase 2. This was interesting in order to assess the environmental impact of repairing a pair of pants and the relation between the number of uses and the total impact that results in 350 uses instead of 600. The changes are shown in Table 5.5 with the respective new amount of total uses gained and the washing needed, compared to the base case, which refers to the original modeling of repair.

Table 5.5: Number of repairs made for each pant

	Base case	One repair
Repairs	3	1
Total uses	600	350
Washes needed	60	35

5.4.4 Ratio of sold pants in online second-hand

For the OSH model, it was assumed that two-thirds of the collected pants were sold and one-third were donated. In order to explore the effect of different ratios between sold and unsold pants, three parts for this sensitivity analysis were created for OSH. In the first one, 20% were sold and 80% donated, in the second, 20% sold and 80% incinerated. This was based on the flows of donated clothes in Sweden as described in section 2.2. In the third one, 100% of the clothes were sold, based on how the company Vinted, which was found in the mapping, performed their CBM of OSH. It entails that all clothes are sold and shipped by the consumers themselves, resulting in no S&M process, nor transportation of plastic bags. The new assumptions can be seen in Table 5.6 where base case refers to the original modeling of OSH.

Table 5.6: Ratio of sold pants in OSH

	Base case	80% donated	80% incinerated	User-user
Sold	70%	20%	20%	100%
Donated	30%	80%	-	-
Incinerated	-	-	80%	-

5.4.5 Full usage for business-as-usual

The last interesting aspect to look at regarding consumer behavior is what would happen if everyone used the pants until they were worn out before discarding them. It was initially assumed that the pants were only used 200 times in BAU. In other words, the pants are discarded before being worn out. Therefore BAU with full usage of the pants was tested in this sensitivity analysis as seen in Table 5.7.

Table 5.7: Assumptions for number of uses

	Use phase 1	Use phase 2	Use phase 3	Use phase 4	Total
BAU	200	-	-	-	200
BAU full use	300	-	-	-	300
Repair	300	150	100	50	600
OSH	50	50	200	-	300

5.5 Result of sensitivity analysis

5.5.1 Transportation mode

Since all models include CT, the impact from transportation increases for all three models when 100% of CTs are made by car, as seen in Figure 5.2. However, for land use, the difference is small for all models since most of the impact for this impact category originates from production. Overall, due to the bigger amount of CT in repair, its impact increases the most, making it worse than OSH on global warming and both OSH and BAU for human toxicity when all CTs are made by car. If all CT instead were done through walking och biking, it would have no impact. This would be visually represented by the impact of CT being removed from the staples seen in Figure 5.2. In this case, the impact of repair would be much lower for all impact categories, with OSH still in second place and BAU last. This shows a sensitivity for the ratio of transportation modes for repair, especially for global warming and human toxicity. For OSH and BAU, this ratio makes a smaller difference but is still significant in acidification, global warming, and human toxicity.

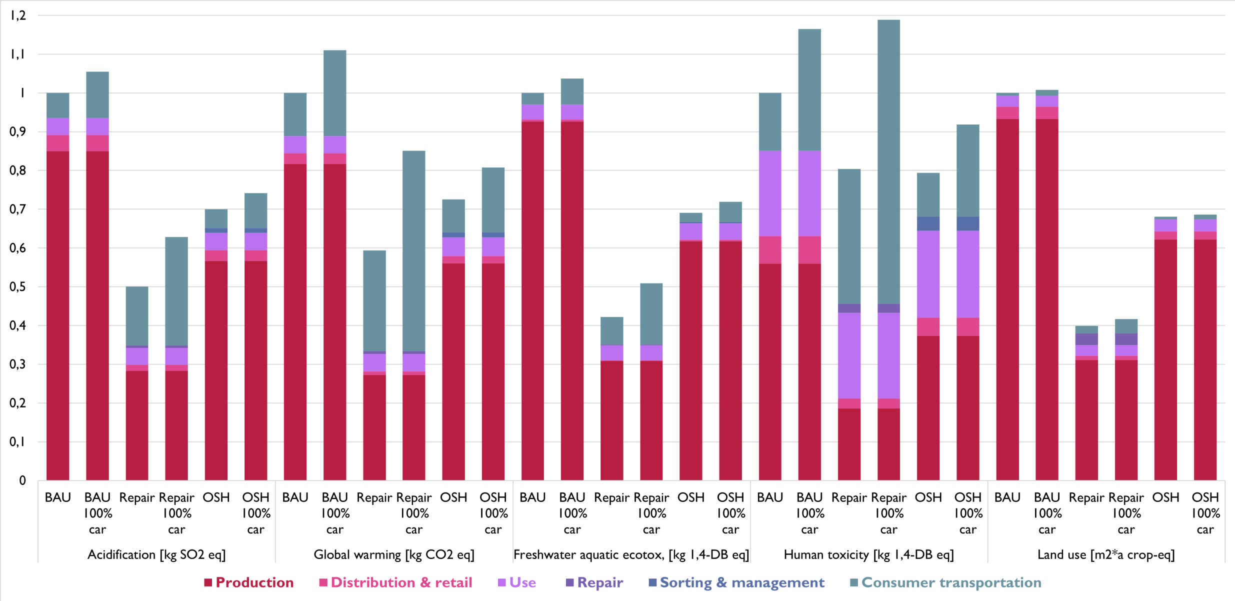

Figure 5.2: *Results for impact categories per f.u. for sensitivity analysis of ways of transportation normalized to business-as-usual*

5.5.2 Transportation distance

When changing the distances for transportation, a similar pattern to the result of transportation mode can be seen. For land use, not much is changed for either model or distance and for freshwater aquatic ecotoxicity, the difference is small for all except repair, where transportation contributes more in the base case. For consumers living in the suburb, the impact for repair increases significantly on acidification, global warming, and human toxicity, making it surpass base case OSH on acidification, suburb OSH for global warming, and exceeding both OSH and BAU on human toxicity. Both OSH and BAU are also sensitive to the increased distance in these impact categories, and the difference is not as big as for repair. When changing the consumer's location to another city for OSH, the total impact is smaller for all impact categories compared to when the consumer lives in the suburb of the original city and is almost similar to the base case. The small increases in the S&M show that truck transportation does not have as big of an impact as consumer car transportation to and from the store or repair location. This result shows that the repair remains preferable to OSH for some impact categories, but not for all when the consumer lives in the suburb. Comparing OSH for a consumer living in another city with repair for a consumer living in the suburb, OSH is instead preferable.

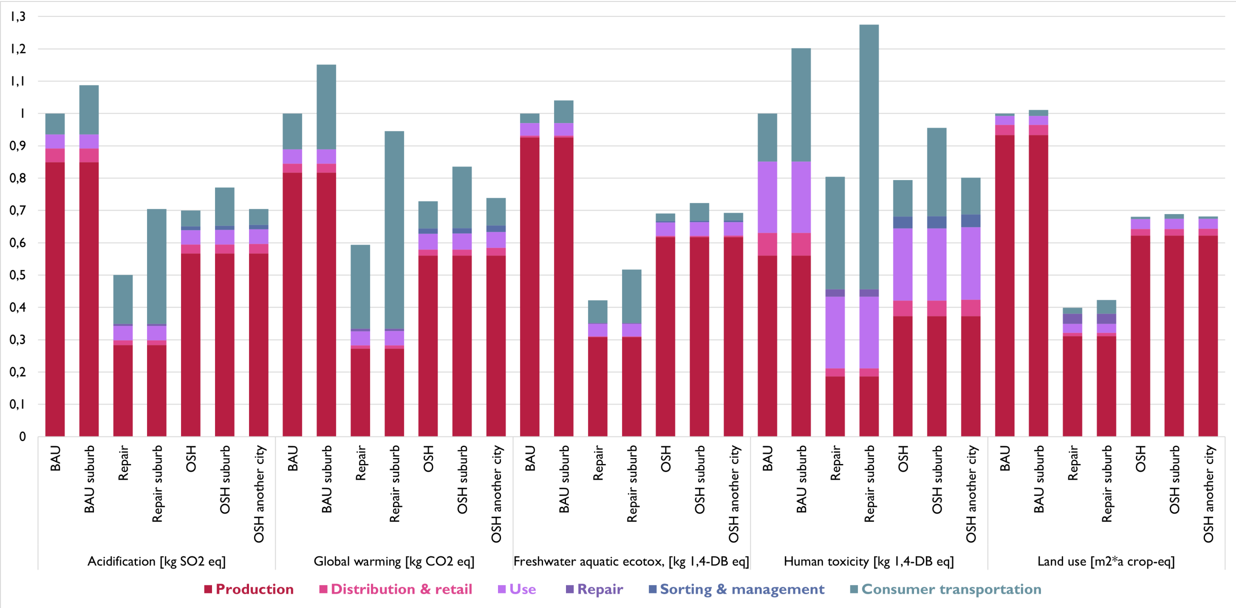

Figure 5.3: *Results for impact categories per f.u. for sensitivity analysis of transportation distance normalized to business-as-usual*

5.5.3 Number of uses after repair

When repairing the pants and then only using them 50 times, the impact of repair is increased. Due to the smaller number of uses, the production and D&R account for a bigger impact and share, causing a bigger total impact despite the decrease in use. For acidification, freshwater aquatic ecotoxicity, and land use, repair's impact is almost as high as base case OSH. For global warming, it is worse than OSH. For human toxicity, where the repair base case is originally higher, the impact remains higher than OSH. For all impact categories, repair remains better than BAU. The importance of the number of uses achieved of the pants, when additional actions are taken, is clear for repair in order to be favorable compared to base case OSH.

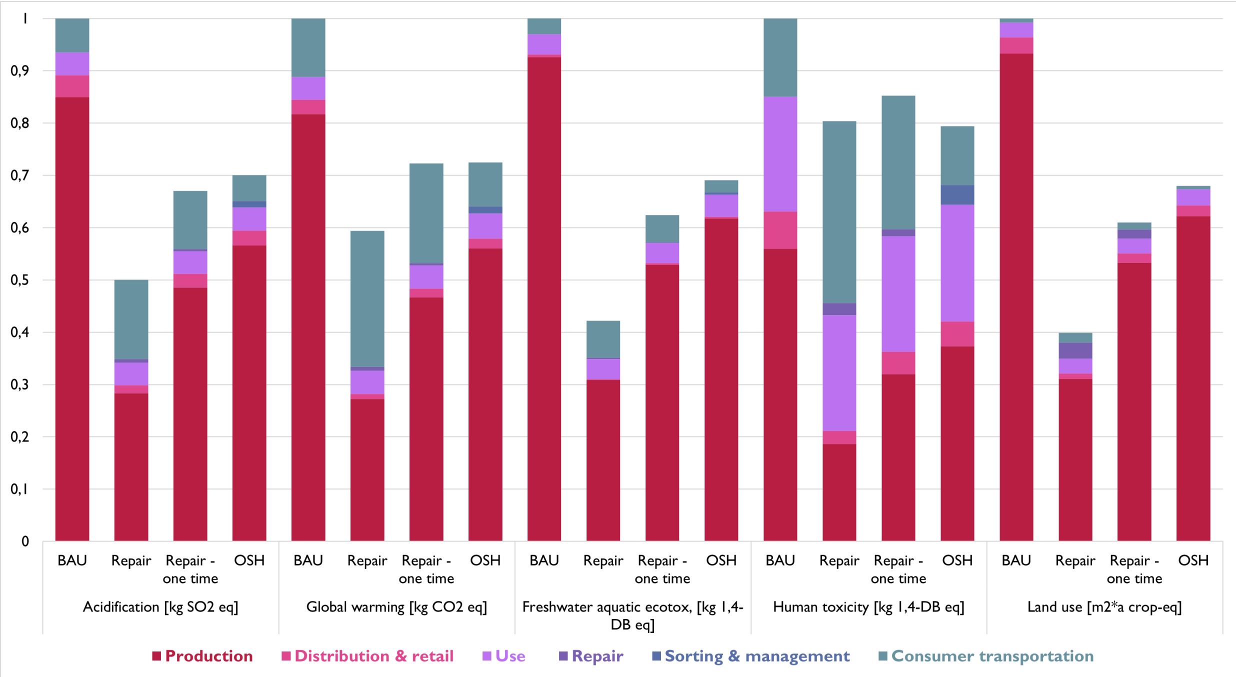

Figure 5.4: *Results for impact categories per f.u. for sensitivity analysis of the number of uses after repair normalized to business-as-usual*

5.5.4 Ratio of sold pants in online second-hand

Compared to previous sensitivity analyses, the ratio between sold, donated, and incinerated pants result in significantly different results. When comparing the base case OSH where 70% of the received pants are sold and the remaining 30% is donated with 20% sold and 80% donated, the difference is minimal. The number of uses is the same, but the additional transportation to Germany of donated pants contributes less than the fewer CT back and forth to postal services required. Additionally, the donated pants are not assumed to be washed when received, nor ironed or dried after washing, causing a smaller use of electricity. This makes the impact of use and transportation a little higher, especially for global warming and human toxicity, which are mostly affected by these differences.

When 20% of the pants are sold, and the remaining 80% is incinerated instead of donated, the number of uses decreases significantly. Whereas the studied pant is still used 300 times, the incinerated unsold pants are only used 50 times each in their first use phase. With this decrease in the number of uses for all pants required to be produced in order for one pair of pants to reach full use, the total impact per f.u. for OSH is almost three times as big as BAU. The result of changing the ratio of sold, donated, and incinerated pants shows that OSH is still preferable to BAU when a larger ratio is donated. Despite the 80/20 being the worst-case, it still shows that an increased ratio of incinerated clothes decreases the benefits of OSH significantly.

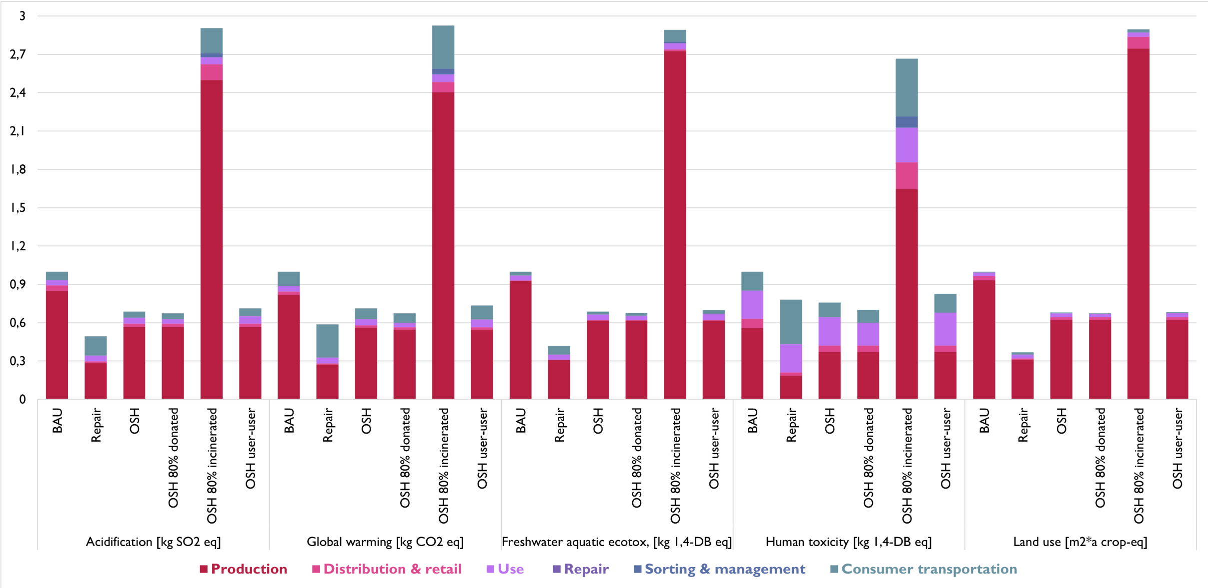

Figure 5.5: *Results for impact categories per f.u. for sensitivity analysis of the ratio of sold pants in OSH normalized to business-as-usual*

5.5.5 Full usage of business-as-usual

The final sensitivity analysis was done on the impact of the actual usage of the pants. If a total usage of 300 uses is modeled for BAU, instead of 200, the impact per f.u. is decreased for all impact categories, which can be seen in Figure 5.6. BAU results in lower impacts than OSH for all impact categories, and for human toxicity, it is even lower than repair. Since the same number of uses as in OSH is reached, without additional actions of transportation, plastic bags, and S&M, the total impact is lower. Despite repair having twice as many uses, it is worse in terms of human toxicity due to the model's additional car transportation. It is clear that the result of BAU, as well as OSH and repair, is dependent on the number of uses modeled.

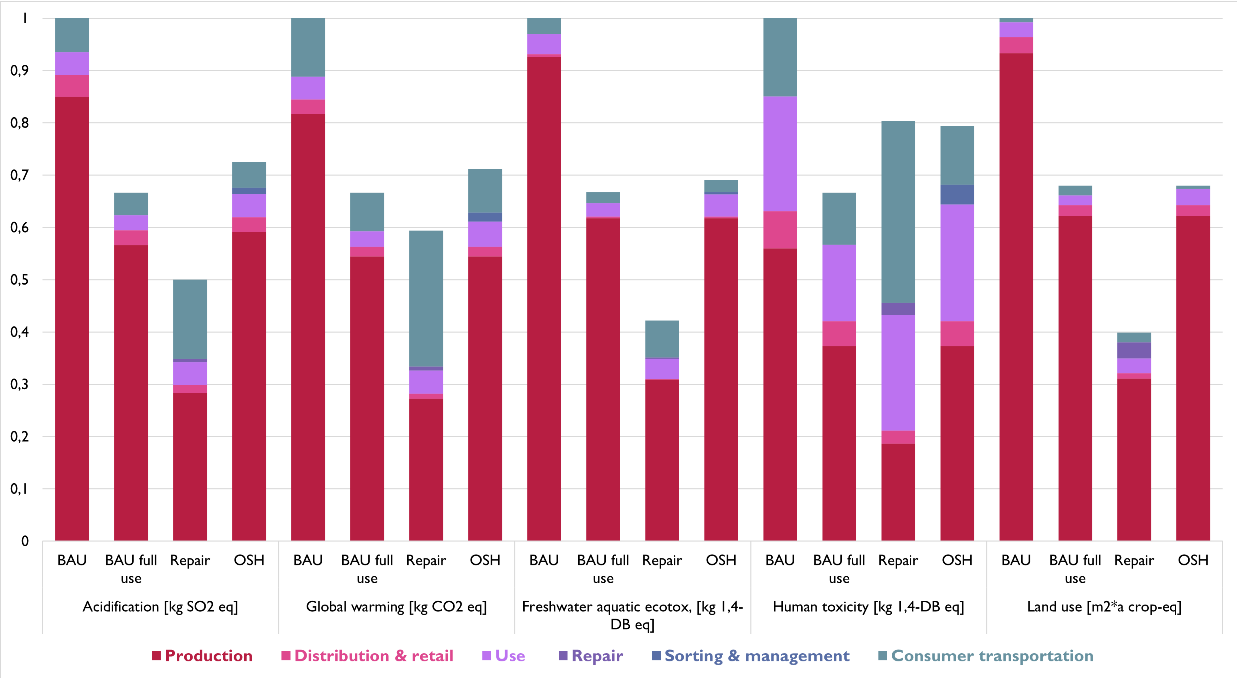

Figure 5.6: *Results for impact categories per f.u. for sensitivity analysis of full usage for business-as-usual normalized to current business-as-usual*

6
Discussion

6.1 Current circular practices in Sweden

When conducting the mapping, it was noted that many companies claim to work with sustainability or circularity in different ways, but not all of these were included in the mapping. For instance, many companies, including some in the mapping, collect discarded garments from consumers in return for a voucher at their store. While the collected textile could possibly be recycled if it meets the requirements of the current methods, this service may become an incentive for consumers to buy more and, can therefore fuel a higher production instead. Recycling of collected clothing would be interesting to assess in order to determine its environmental impact, both compared to other strategies and/or CBMs, as well as a complement, for instance, if an OSH platform would send unsold clothing to recycling.

At the beginning of the mapping, several companies that operated based on the CBM of offering clothing rental services through subscription plans were found. However, it was noticed that some had already gone bankrupt, with the rest going bankrupt during the mapping. This was interpreted as an indication of interest in providing that service, but that it currently lacks economic viability. The mapping has certain limitations. For instance, the mapping was only conducted through online searching which limits the found companies to those who have marketed the initiatives on their websites, and there are likely more companies based on CBMs or implementing circular strategies than those identified in the study. The companies who answered questions, however, gave good support for understanding how a repair service can be performed. Still, it could have been beneficial if more companies were contacted and if more would have been able to take part in interviews. This could have provided more knowledge on how OSH companies manage clothing and what their processes look like, how much of the clothing put up for sale that are sold, and what happens to what is not sold.

6.2 Environmental impacts of the circular business models

By prolonging a pair of pants' lifetime through repair and OSH, more uses are enabled from the same amount of production. This results in a lower impact from pre-consumer processes (production and D&R) per f.u. for the repair and OSH models, compared to BAU. As previously stated, the resulting impact of the pre-consumer processes of OSH and repair are one-third and two-thirds compared to BAU, since the models enable 600 and 300 uses, respectively, compared to BAU which enables 200 uses, as can be seen in Figure

5.1. However, in order to prolong the pant's lifetime through repair and OSH, additional actions such as transportation, repair, and production of packaging are required, which contribute to the total environmental impact of the CBMs.

The impact of use is mainly dependent on washing. Since the washing is proportional to the number of uses for all models, except for OSH, where a few additional washes are made, the impact of use remains similar independent of the model. This shows that washing has little to no impact on the results when comparing the models to one another. Despite this, washing consumes water, electricity, and detergent and still has an impact, even if it is small in comparison.

The repair process does not contribute significantly to any impact category. However, land use and human toxicity are somewhat affected, mainly due to the production of paper bags. Electricity and fabric needed for repair do not have a significant impact. Similarly, the impact of S&M is relatively small across all impact categories. It does, however, impact human toxicity to some extent, mainly due to additional truck transportation. In comparison to the OSH's total impact, S&M does not contribute significantly.

The biggest difference between the models and impact categories is the impact of CT. Whereas CT accounts for a big share of all models' impact, it is most prominent for repair. Despite the higher number of uses, the impact is still significant, especially for acidification, global warming, and human toxicity. The impact of repair on human toxicity is slightly higher than on global warming since the impacts are derived from different processes. For global warming, it is the exhausts from driving the car that mainly cause the impact. For human toxicity, it is emissions from the production of the car that mainly causes the impact. The additional CTs in OSH are relatively small, and combined with the increased number of uses, the impact is lower than for BAU. In repair, on the other hand, the additional CTs are of larger magnitude due to the longer distances, which result in a much bigger impact despite the even higher number of uses.

Despite the big impact of CT, repair has a significantly lower impact in all impact categories except human toxicity compared to both BAU and OSH. Apart from CT, the additional actions needed to perform repair and enable more uses are comparably small and do not significantly increase the result of repair. However, the big impact of CT is the drawback of repair. Despite the decreased impact for most impact categories, it comes with the cost of an increased impact on human toxicity. It is also clear that the possible benefits of repair are dependent on the modeling of CT.

Based on the result, the required actions needed to perform OSH are also relatively small, and the increased number of uses results in a considerably lower impact than BAU. However, the impact of enabling more uses through OSH is smaller than through repair, but since OSH only enables half the number of uses compared to repair, the resulting impact is higher. If the additional actions required for repair were as small as for OSH, the results of repair would be half the size for OSH, since it enables twice the number of uses. This is clearly not the case, as shown in Figure 5.1. Looking at the results of the LCA made on stated assumptions, both OSH and repair seem preferable compared to BAU, and repair seem the more beneficial choice for all impact categories but human toxicity.

6.3 Contributing factors to the potential of the circular business models

Repair and OSH both result in a lower environmental impact than BAU. However, the result shows a difference in which processes of the CBMs contribute to the total environmental impact. Whereas the decreased impact of OSH, derived from the increased number of uses, only is complemented with a small impact from S&M and use, the impact of CT decreases. The even bigger decreased impact of repair, derived from an even higher number of uses, is complemented by a small impact from repair but a major impact of CT.

The sensitivity analyses showed that transportation mode, transportation distance as well as number of uses all play a significant role in the potential of the CBMS. When increasing the ratio of car transportation to 100% of CTs, repair still remains the CBM with the lowest impact for acidification, freshwater aquatic ecotoxicity, and land use. However, its impact exceeds significantly and is even higher than OSH and BAU for global warming and human toxicity. When 100% of CT is made by car, the impact of tram transportation is eliminated, and the impact is only derived from the processes required for CT. This causes the impact of CT on global warming to increase roughly by 100%, and 110% on human toxicity. As previously shown, the impact on global warming and human toxicity of CT is derived from different processes, causing the initial impact of CT bigger on human toxicity than global warming. This causes the impact on human toxicity to increase more when 100% of CT is made by car and the total impact of repair to surpass BAU. While the impact of CT on global warming also increases significantly, the total impact still remains lower than BAU. While the impact of OSH also is increased for all impact categories when 100% of CT is made by car, this increase is not as big and OSH remains significantly lower compared to BAU for all impact categories. However, 100% car transportation is the worst-case and not likely to be representative. Nevertheless, it shows the CBM's environmental benefits' dependency on the transportation mode.

Similar to the result for transportation mode, the sensitivity analysis on transportation distance shows the role that CT plays in the environmental impact of the models, especially repair. For consumers living in the suburb, the impact of BAU and OSH is increased, but not significantly, and OSH remains preferable to BAU. For repair, similar results to 100% car transportation are shown, and the CBMs lose their benefits for three out of four impact categories. When the consumer lives in another city, requiring much longer truck transportation but shorter car transportation, the impact is much smaller than when the consumer lives in the suburb and only slightly higher than the original model. This shows that the increased truck transportation did not have a significant impact on the potential of the CBMs, which confirms what was previously shown for car transportation. However, this is based on the assumption of an average truckload, which might not always be the case. A low truckload would cause the truck transports to have a much higher impact on the result.

The other factor that significantly contributes to the potential of the CBMs is the number of uses. If a consumer repairs a pair of pants followed by only using them one-third of the enabled uses, the benefits decrease. The sensitivity analysis shows that the impact of repair, when performed this way, is more similar to OSH and even higher for the two impact categories. The benefits in terms of less impact from pre-consumer processes are partly lost. In this case, it is still preferable compared to BAU and OSH, but it shows the impact that number of uses has on the potential of repair.

Changing the ratio of sold, donated, and incinerated pants were shown only to have a significant impact when the pant's actual number of uses was affected. In terms of environmental impact, the difference between 30/70, 20/80, and 100/0 ratios of sold vs. donated pants was minimal since the same number of uses was achieved. On the other hand, when 20% of the pants were sold and 80% were incinerated instead of used, the impact for OSH was four times higher than BAU. Although this is a worst-case, it still implies the role this factor plays for the potential of OSH. The 20/80 ratio is representative of the statistics for which donated clothes are sold in Sweden. However, the fates of the unsold and sold pants, and therefore the number of uses achieved in reality are not known. This also implies the importance of consumers considering the state of the pants before deciding to try selling them through OSH. Companies who work with OSH platforms usually have requirements on clothing that are important to follow in order for the pants to be put up for sale. If a consumer possesses clothing that is in bad shape, that will not be sold and used further, the consumer should throw them in the household waste. Worn-out clothing will be incinerated either way, but by throwing them at home unnecessary transportation and management will be avoided.

The sensitivity analysis where full usage was achieved for BAU resulted in it being preferable to OSH, but far from as beneficial as repair for all impact categories. The additional processes needed to perform OSH have a relatively small impact, but OSH does not enable more uses than BAU when full usage is achieved. This makes the environmental impact of BAU with full usage lower than OSH. Once again, this shows the importance of the number of uses achieved for the potential of any model.

In the graphs it can be seen that the increase for OSH when 100% of CT is done by car is relatively small, indicating that a few more use phases could probably take place before the total impact becomes bigger than BAU due to the added transportation. For repair, however, the impact of transportation significantly increases when 100% of CT is done by car. An additional repair would also increase the impact due to transportation. This limits the number of repairs that can be done before the repair's impact is bigger than BAU unless transportation is done in another way. From the sensitivity analysis it was shown that when everyone walked or biked, repair would by far be the best option since a high number of uses is enabled while no impact from transportation is added.

Further analysis was done on what the impact would be if the pants are only repaired one time and then used 50 times. This option was still preferable compared to BAU and OSH for four out of five impact categories. On the other hand, if the pants would be repaired and then not used at all, the total impact would probably have been higher than OSH even if the first use phase enabled full usage. This indicates the importance of using the pants as much as possible to reduce the impact of the production per f.u.. Similar results were also shown for BAU when a full number of uses was achieved before the pants are discarded, as it had a lower total impact than OSH, but higher than repair.

In summary, OSH prolongs the pants' lifetime by enabling more uses than BAU when the pants are not fully used by the initial consumer. Repair on the other hand prolongs the pants' lifetime by creating more uses when the pants have reached full usage and are worn out. As seen in the study, prolonging the pant's lifetime through OSH is preferable to incinerate them and purchase a new pair. If purchased pants would be used by the initial consumer until they are worn out, this would have a lower environmental impact than achieving full usage through OSH, which has also been shown in the study. However, with the textile flows in Sweden today, it is clear that all purchased clothes are not fully used and therefore OSH is a good option for prolonging pants' lifetime, for unused pants in good condition, to keep the environmental impact down. As has also been shown in the study, repairing torn pants instead of purchasing new ones is environmentally preferable. The environmental gains are even bigger if the necessary transportation can be done through walking, biking, or public transport since CT causes the main environmental impact by prolonging the pant's lifetime through repair. Prolonging the pants' lifetime through both repair and OSH is a good option, but is suitable for different circumstances. Both options cause a lower environmental impact than BAU but in the end, the potential of them are dependent on CT, the condition of the pants received by the OSH company and the achieved number of uses.

6.4 Comparing results to other research

Other previous studies are case-specific or focus on the environmental focus on the environmental impact of the linear model. This study has instead been non-case-specific and focused on general CBMs, their environmental impact compared to BAU, and what factors affect their potential to be preferable to BAU. Sandin et al., (2019), focus on the environmental impact of six different garments with different material compositions and purposes. The study showed that production holds the biggest impact and highlights the importance of consumer transportation back and forth to the store and is according to Sandin et al., (2019) one of the first studies to have that focus on consumer transportation. The study supports what was found in this thesis, namely that the extended use phase of garments and low-impacting consumer transportation is important in order to reduce environmental impact.

In the company-specific study by Böckin et al., (2020), the circular strategy of renting was evaluated by looking at both economic and environmental aspects compared to the company's linear BM. The study showed that production was the main contributor to the linear model's environmental impact, and when using the rental model for clothes, CT and washing were the main contributors among the additional processes needed to perform the rental service. This aligns with the results in this study, showing the big impact that CT plays in all models. Both studies' sensitivity analyses indicated that these factors are highly variable and dependent on consumer behavior, making the BM become either environmentally beneficial or have a higher overall environmental impact than the linear model in the worst cases.

6.5 Uncertainties and limitations

In S&M, electricity use for the warehouse was accounted for. In contrast, for the repair shop, the electricity use needed for a repair in the repair shop was realized only to have been modeled for the actual sewing and not the shop's electricity use when the pants were there. This difference in the modeling approach may have slightly impacted the results. Still, due to the low amount of electricity needed for the repair shop, it was considered insignificant compared to the impacts from other parts of the life cycle. The assumption that the retailer provides a new paper bag after each repair had a rather significant impact on land use and human toxicity and would probably vary in real-life situations.

One important uncertainty observed in the study was the resulting impact on human toxicity, which differed noticable compared to the other impact categories. While the majority of the impact across all other impact categories originated from the production, the impact on human toxicity did not and was instead associated with both CT and production, at a similar magnitude. Due to this, the impact on human toxicity for repair and OSH became signifant and much higher compared to the other impact categories and the total impact of repair even exceeded OSH. This did not follow the previous pattern when comparing the three models. Car transports were expected to have a signifant impact on human toxicity, but not to exceed the impact of production. This raised concerns that the modeling of CT could be faulty, and that some aspects might have been overlooked during the LCA, causing the impact on human toxicity to not be correct. Upon closer examination, it became evident that the primary driver of human toxicity from car transports was related to the production of the vehicles themselves. In contrast, within the production phase, the primary contributor to human toxicity was the manufacturing processes of the involved substances used and not the emissions of these substances, which was expected. This was the case despite that emissions into the air and water for all produciton phases was modelled. Furthermore, the LCA did not account for the use and production of machinery and factory infrastructure, not more than the electricity and heat used. These uncertainty may have had implications for the study's results and the conclusions made from it, especially since the impact human toxicity did not follow the expected pattern and seemed as a major drawback for repair.

The fabric for repair is modeled as leftover fabric from confectioning, meaning that new fabric does not need to be produced. The transportation required for the additional fabric to reach the repair shop is insignificant in comparison, due to its low weight. The fabric used for each repair is modeled as 10% of the pant's total weight, which means that leftover fabric corresponding to 30% of the pants' weight will be required to repair the pants three times. If the fabric used for repairing instead would be newly produced fabric, 30% more fabric would need to be produced, and the impact from production would therefore be 30% higher. However, looking at the result of the study for the total impact, this would hardly affect the comparison. The total impact of repair would remain smaller than both BAU and OSH for all impact categories except human toxicity where it originally already was bigger, even when the impact from production is increased by 30%.

Regarding water consumption, it is crucial to remember that the study is made on pants made of 100% cotton. Cotton cultivation requires huge amounts of water, making water consumption during the wash seem negligible. If, for instance, pants made of another material that does not require as much water for production were analyzed, the water consumption during use could be more interesting, with a possible higher impact of the additional washes in OSH. Additionally, more frequent washing could accelerate the pants' tearing and shortens their lifetime. A limitation of the study regarding the washing is that the emissions from the detergent production into the water were not modeled. This impacts the result of the models, especially on ecotoxicity, but considering the big impact of production it is not sure this would be noticeable. Moreover, since the washing is modeled the same per f.u. in repair and BAU and only with a small difference in OSH, this would probably not have an impact on the comparison of the models.

The sold and donated items ratio did not matter since it was modeled that the pants would be fully used either way. However, all donated clothes might not be fully used and instead incinerated, which would affect the result as seen from the ratio between sold and incinerated pants. Another possibility would be that they end up somewhere else in the world, adding to the large landfills of clothes. There are several OSH available on the market. Some of them offer sellers the opportunity of reclaiming unsold garments as well as returning a purchase, which was not taken into consideration in the modeling. If unsold clothing is returned to the seller, additional transportation and management are required, increasing the impact, especially if the garment is not used further.

Another uncertainty of the study regarding OSH is the required truck transportation and the lack of sensitivity analysis on this aspect. It was seen from the result and sensitivity analysis that these transportations do not have as big an impact on the result as the car transportations. Truck transportation is always assumed to have an average load, which might not be the case for every trip. Trucks loaded below average would cause the transportation in OSH to impact the results more, especially when the pants are transported a long distance, such as between the warehouse and another city. If, for instance, the truck is only loaded half of what was assumed, twice the impact of the transportation would be allocated to the pants. As seen in the study, the impact from the process of S&M, which includes the truck transports, is comparably small for all impact categories, even when the consumer lives in a suburb or another city. A doubling of the impact from truck transportation would not increase the total impact of OSH significantly, but it would cause OSH to have a higher impact on human toxicity compared to repair. This would mean that repair would have the lowest impact on all impact categories, which was not the initial result. Moreover, if trucks were loaded even less efficiently, for instance, carrying 1kg of pants as assumed for CT, the environmental impact of OSH would considerably increase. This could potentially lead to OSH's environmental impact surpassing that of BAU, although a thorough assessment would be necessary to determine this.

One significant limitation of this study is that it focuses exclusively on cotton pants, which restricts the generalizability of the conclusions to other materials or types of clothing. The potential variations in environmental impact and performance of CBMs modeled with different materials and garment types have not been explored in this study. For instance, if the study instead would have focused on polyester pants, a fossil-based material, the result would look different. Using a fossil resource instead of renewable cotton would require the extraction of oil instead of water-consuming cotton cultivation, and incinerating polyester instead of cotton would intensify the emissions. This would affect the impact of i.e. global warming and abiotic resource depletion. In addition, other types of garments and materials than cotton pants could require other production methods, which could, for instance, could affect electricity consumption and bleaching and dying practices. This could both increase and decrease the impact of the different processes. However, based on the result of the study, this would probably not change the result of the comparison of the three models since the impact of production affects all three.

6.6 Methodology and data

Creating and defining CBMs increases the risk of simplifications that could impact the results. The same could be argued for the LCA, which is a method that requires a significant amount of data and assumptions when no case-specific data is used, and no existing data for a pair of 100% cotton pants were found. Many aspects are, however, covered through the use of sensitivity analysis. Since the data for the production processes is approximated from a t-shirt made of 100% cotton, it can differ from what the data would be for a pair of pants. No additional features on the pants, such as buttons or zippers, were accounted for. This would most certainly lead to a higher impact on the production. For example, abiotic resource depletion would become more interesting with the addition of other materials.

If more or fewer uses had been assumed, the total impact from each model would change accordingly. However, the relative impact would not change unless the number of uses in the models was defined in another way. This was also seen from the sensitive analysis of repairing only one time and full use of BAU.

None of the pants were assumed to be of bad quality, but if a torn pair are sent to OSH, they will probably be collected and sorted into waste. If the consumer sorts them out at home, the pants will meet the same fate and be incinerated. The only difference will be that the pants will travel to a postal agent, postcentral, and to the warehouse. Despite the relatively small impact, transporting, managing, and storing a garment that will be incinerated is unnecessary.

Locating the post-production phases in Sweden is more likely to decrease the total impact than if another country was studied. This is primarily attributed to electricity generation and waste management practices. The recovery from incineration of heat and power back into the system results in negative values in an LCA that contribute to reducing the overall environmental impact. This is not always standard practice in other countries, and using landfills as waste management could then be an addition to consider. Moving the whole production would have the same effect since there is also less required transportation. Still, since cotton can't be grown in Sweden, this would be an alternative for another material or moving parts of the production from India to Sweden.

Overproduction of clothes that are not sold and instead incinerated before reaching consumers was not accounted for in any of the models. If it was, this would increase the environmental impact of the pants further. Since the CBMs enable an increased number of uses through repair and OSH, the relative result for the models would remain, but the initial environmental impact from the production would increase and shares of this would be added to the impact of the CBMs. The study focused on physical stores and individuals residing in a city, with warehouses outside the city. Individuals living outside of the city were accounted for in the sensitivity analysis; however, warehouses situated in other countries were not. This geographical restriction may affect the generalizability of the findings to a broader context.

7
Conclusions

7.1 Research questions

In conclusion, it was seen that many companies are embracing circularity. Circular strategies of second-hand, repair, and rental were observed. CBMs were mostly seen as physical and online second hands, but a few examples of exchanging, repairing, and renting were also seen. Second-hand initiatives have gained popularity, particularly online, while repair services, although less common as a CBM, are also prevalent. Renting clothes on subscription has been done by many companies in the last years, but no company has yet seemed succeeded in making it profitable.

Selected from the mapping and further described were two CBMs of repair and OSH. By prolonging the lifetime of a pair of pants by increasing its uses and doing this through either of the CBMs, it was shown that the total impact can be reduced despite additional activities and their impact. The major impact of performing repair is due to the consumer transportation when bringing the pants back and forth to the store, and for OSH, it is the transportation of the pants from the seller to the new consumer. The additional washes, the fabric, and electricity needed for repairs, as well as the resources needed for sorting and managing the pants, did not have a significant impact. By enabling more uses than both OSH and the linear model, the repair is preferable in terms of all environmental impact categories except human toxicity with the assumptions modeled. OSH was still preferable to the linear model but not as good as repair despite the large share of car transportation in repair.

Due to the significant impact of transportation for both repair and OSH, the ratio between transportation modes and distance, play a key role when determining whether the CBMs have a lower impact than the linear model. However, the most crucial factor for either model is the number of uses. Repair enables more uses than the initial pair of pants would withstand, and OSH enables more uses compared to what the initial consumer would achieve. Hence, both CBMs are a good option as long as the transportation is done efficiently. By extending the pair of pants' lifetime through repair and OSH, the environmental impact per functional unit is reduced, despite additional actions and associated impacts. While OSH is preferable compared to the linear model, repair has the overall lowest impact. In summary, the potential of the CBMs is mainly dependent on the actual number of achieved uses, especially for repair, and the amount of car transports.

While this study specifically examines cotton pants, its findings offer insights that can potentially be applied to other garments. Despite variations in materials, production methods, and types of clothing the comparison of circular business models with the conventional linear model remains informative, highlighting the crucial environmental impact of the production phase and the potential of services of repair and OSH.

7.2 Recommendations for future research

A few aspects were identified that would be relevant in future studies on the subject. First, it would be valuable to investigate additional CBMs observed on the market and also assess the potential impact of combining these to enhance the number of garment uses and overall sustainability outcomes. Secondly, it would be interesting to explore the environmental impact of companies that implement circular strategies that are not based on prolonging the use phase, i.e. collecting clothes for recycling. Thirdly, it would also be of interest to extend the analysis beyond cotton, as it only represents one commonly used material for clothing, to explore the environmental impact and possible change in the number of uses of garments made from different materials. This comparative analysis would provide valuable insights into the environmental implications of various materials and their suitability for circular strategies and CBMs in the clothing industry. Addionally, related to the uncertainties regarding the modeling of, and the resulting impact on human toxicity, it is recommended that further investigation is conducted to determine whether the deviation from the expected pattern stems from data gaps or other factors within the LCA.

Performing additional sensitivity analyses would further help the understanding, specifically, new fabric production for the repair shop and changes in truckload for when the pants are transported in OSH. In addition, future research should explore the distances that consumers have to their postal agent, especially those living outside of the city where public transportation might be limited, to see the effects of consumer transportation fully. To conduct these sensitivity analyses effectively, it is crucial to investigate consumer behavior extensively, providing a solid understanding of the actions taken by a wide range of consumers and what incentivizes both consumers and companies to choose a circular option. Including the economic aspect is interesting since this has a big impact on the market, and as seen in the mapping, a few CBMs in Sweden have ended due to this.

7.3 Implications

This study shows that both consumers and companies have a role to play in reducing the environmental impact of clothing by achieving a garment's full potential lifetime. Consumers have the power to make conscious choices to maximize the possible number of uses of purchased clothes, and companies have the opportunity to guide and inform consumers about sustainable practices. By repairing clothes instead of buying new ones, the overall environmental impact of a garment can be reduced. If feasible, opting for sustainable transportation alternatives such as biking, walking, or using public transportation methods like trams is recommended. Companies can advocate for this and actively implement sustainable transportation methods within their operations. When a garment only takes up space in the closet but is still of good quality, consumers should use the opportunity to sell it second-hand or donate it. This is not recommended when a garment is no longer functional, to avoid additional transportation and the risk of it being incinerated without recovery or ending up in a landfill in another country. Here lies a big opportunity for companies working with OSH to set policies and inform their consumers about them. Through long-lasting design in terms of both quality and appearance, companies can also encourage consumers to cherish and keep their clothing longer.

References

Aitor P. Acero, C. R., & Ciroth, A. (2016). Lcia methods. impact assessment methods in life cycle assessment and their impact categories. *Greendelta*.

Arket. (2023). *Rearket*. Retrieved April 25, 2023, from https://www.arket.com/sv_se/rearket.html

Arkivet. (2023). *Om arkivet*. Retrieved April 25, 2023, from https://arkivet.com/sida/om-arkivet/

Avfall Sverige. (2022). *2021 swedish waste management*. https://www.avfallsverige.se/media/wwbd2za0/svensk_avfallshantering_2021_web.pdf

Baumann, H., & Tillman, A.-M. (2004). *The hitchhiker's guide to lca : An orientation in life cycle assessment methodology and application*. Studentlitteratur.

Böckin, D., Willskytt, S., André, H., Tillman, A., Ljunggren, M., & Söderman, M. (2020). How product characteristics can guide measures for resource efficiency — a synthesis of assessment studies. resources, conservation and recycling, 154c. https://doi.org/10.1016/j.resconrec.2019.104582

Böckin, D., Goffetti, G., Baumann, H., Tillman, A.-M., & Zobel, T. ((2022)). Environmental assessment of two business models - a life cycle comparison between a sales and a rental business model in the apparel sector in sweden.

Caesar, J. (2023). *Hajpad modeidé höll inte – ansöker om konkurs*. Retrieved March 5, 2023, from https://www.di.se/digital/hajpad-modeide-holl-inte-ansoker-om-konkurs/

Ecoinvent. (2019). *Market for packaging film, low density polyethylene*. https://ecoquery.ecoinvent.org/3.6/apos/dataset/773/impact_assessment

Ecoinvent. (2022). Ecoinvent version 3.9.1 [Accessed June 2023]. https://ecoinvent.org

Ecoinvent. (2023a). *Electricity*. https://ecoinvent.org/the-ecoinvent-database/sectors/electricity/

Ecoinvent. (2023b). *Faqs, what does lt and w/o lt mean?* https://ecoinvent.org/offerings/faqs/#1629117724603-64a1e105-dae4

Ecoinvent. (2023c). *Impact assessment*. Retrieved August 4, 2023, from https://ecoinvent.org/the-ecoinvent-database/impact-assessment/#1661935753091-c04f8181-42cf

Ecoinvent. (2023d). *Market activities*. https://ecoinvent.org/the-ecoinvent-database/market-activities/

Ecoinvent. (2023e). *Pulp & paper*. https://ecoinvent.org/the-ecoinvent-database/sectors/pulp-paper/

Ecoinvent. (2023f). *Transport*. https://ecoinvent.org/the-ecoinvent-database/sectors/transport/

Ecoinvent. (2023g). *Waste management & recycling*. https://ecoinvent.org/the-ecoinvent-database/sectors/waste-management/

Ecoinvent. (2023h). *Water supply.* https://ecoinvent.org/the-ecoinvent-database/sectors/water-supply/

Elander, M., Miliute-Plepiene, J., & Guban, P. (2019). Återanvändning av textil via utvalda online marknadsplatser och appar. https://www.naturvardsverket.se/4a4364/globalassets/amnen/kretslopp-avlopp-avfall/avfallsslag/textil/ateranvandning-av-textil.pdf

Ellen MacArthur Foundation. (2017). A new textiles economy: Redesigning fashion's future. https://ellenmacarthurfoundation.org/a-new-textiles-economy

Ellen MacArthur Foundation. (2021). *Circular business models in the fashion industry - new study identifies usd 700 billion opportunity.* Retrieved March 1, 2023, from https://ellenmacarthurfoundation.org/news/circular-business-models-in-the-fashion-industry

Esnouf, A., Heijungs, R., Coste, G., Latrille, É., Steyer, J.-P., & Hélias, A. (2019). A tool to guide the selection of impact categories for lca studies by using the representativeness index. *Science of the Total Environment*, *658*. https://reader.elsevier.com/reader/sd/pii/S0048969718350575

Europaparlementet. (2023). *Textilproduktionens och textilavfallets inverkan på miljön.* Retrieved June 15, 2023, from https://www.europarl.europa.eu/news/sv/headlines/society/20201208STO93327/textilproduktionens-och-textilavfallets-inverkan-pa-miljon

European Commission. (2021). Screening of websites for 'greenwashing': Half of green claims lack evidence. https://ec.europa.eu/commission/presscorner/detail/en/ip_21_269

European Commission. (2023). *Waste prevention and management.* Retrieved June 2, 2023, from https://ec.europa.eu/environment/green-growth/waste-prevention-and-management/index_en.htm

Filippa K. (2023). *Preowned.* Retrieved April 25, 2023, from https://www.filippa-k.com/se/en/preowned.html

Finnveden, G., & Potting, J. (2014). Life cycle assessment. In P. Wexler (Ed.), *Encyclopedia of toxicology (third edition)* (Third Edition, pp. 74–77). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-386454-3.00627-8

GANT. (2023). *Hållbarhet på gant.* Retrieved April 25, 2023, from https://www.gant.se/hallbarhet/7rules

GFA. (2022). *The gfa monitor 2022.* Retrieved January 28, 2023, from https://globalfashionagenda.org/resource/the-gfa-monitor/

Gina Tricot. (2023). *Exclusive party pieces, the celebration.* Retrieved April 25, 2023, from https://www.ginatricot.com/se/hallbarhet/conscious-campaigns/rent

Guarnieri, P., & Trojan, F. (2019). Decision making on supplier selection based on social, ethical, and environmental criteria: A study in the textile industry. *Resources, Conservation and Recycling*, *141*, 347–361. https://doi.org/10.1016/j.resconrec.2018.10.023.

Guinee, J. (2001). Handbook on life cycle assessment. an operational guide to the iso standards. *The International Journal of Life Cycle Assessment*, *7*. https://doi.org/10.1007/BF02978897

H&M. (2023a). *Repair services.* Retrieved April 25, 2023, from https://www2.hm.com/sv_se/hallbarhet-pa-hm/take-care/repair-services.html

H&M. (2023b). *Välkommen till h&m rental*. Retrieved April 25, 2023, from https://www2.hm.com/sv_se/dam/hallbarhet/9035-rental22.html

Houdini. (2023). *Upptäck*. Retrieved April 25, 2023, from https://houdinisportswear.com/sv-se/explore

Huijbregts, M. A. J., Steinmann, Z. J. N., Elshout, P. M. F., Stam, G., Verones, F., Vieira, M., Zijp, M., Hollander, A., & van Zelm, R. (2016). Recipe 2016, a harmonized life cycle impact assessment method at midpoint and endpoint level, report i: Characterization. *National Institute for Public Health and the Environment*. https://www.rivm.nl/bibliotheek/rapporten/2016-0104.pdf

Huijbregts, M. A. J., Steinmann, Z. J. N., Elshout, P. M. F., Stam, G., Verones, F., Vieira, M., Zijp, M., Hollander, A., & van Zelm, R. (2017). Recipe2016: A harmonised life cycle impact assessment method at midpoint and endpoint level. *The International Journal of Life Cycle Assessment*, *22*, 138–147. https://doi.org/10.1007/s11367-016-1246-y

IVA. (2023). *Resurseffektivitet och cirkulär ekonomi*. Retrieved January 30, 2023, from https://www.iva.se/projekt/resurseffektivitet-och-cirkular-ekonomi/

Johansson, M. (2023). *Ännu ett uthyrningsföretag ger upp – gemme collective i konkurs*. Retrieved March 5, 2023, from https://www.dagenshandel.se/article/view/901012/annu_ett_uthyrningsforetag_ger_upp_gemme_collective_i_konkurs

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221–232. https://doi.org/https://doi.org/10.1016/j.resconrec.2017.09.005

Kirchherr, J., Yang, N.-H. N., Schulze-Spüntrup, F., Heerink, M. J., & Hartley, K. (2023). Conceptualizing the circular economy (revisited): An analysis of 221 definitions. *Resources, Conservation and Recycling*, *194*, 107001. https://doi.org/https://doi.org/10.1016/j.resconrec.2023.107001

KTH. (2023). *Renewcell förändrar klädindustrin*. Retrieved June 2, 2023, from https://www.kth.se/om/innovation/alumner/renewcell-forandrar-kladindustrin-1.975859

Lindberg, S., & Wennman, M. (2023). Här är snabbmodets "ground zero". *Aftonbladet*. Retrieved June 19, 2023, from https://www.aftonbladet.se/nyheter/a/bgW3ld/har-ar-snabbmodets-ground-zero

Lindex. (2023). *Secondhand*. Retrieved April 25, 2023, from https://www.lindex.com/se/secondhand

Mai. (2023). *Få dina kläder sålda*. Retrieved April 25, 2023, from https://www.maiapp.se/?utm_source=google&utm_medium=cpc&utm_campaign=19553440781&utm_content=144394771359&utm_term=mai%5C%20second%5C%20hand&gad

MFA. (2018). *Ny forskning utmanar gränserna för "fast "och "slow" fashion*. Retrieved January 30, 2023, from http://mistrafuturefashion.com/sv/ny-forskning-utmanar-granserna-fast-och-slow-fashion/

Morgan, L., & Birtwistle, G. (2009). An investigation of young fashion consumers' disposal habits. *International Journal of Consumer Studies*, *33*, 190–198. https://doi.org/10.1111/j.1470-6431.2009.00756.x

Myrorna. (2023). *Hållbarhet*. Retrieved April 25, 2023, from https://www.myrorna.se/om myrorna/hallbarhet/

Naturvårdsverket. (n.d.-a). *Så påverkar konsumtionen i sverige*. Retrieved January 31, 2023, from https://www.naturvardsverket.se/amnesomraden/textil/dagens-textila-floden-ar-en-global-miljoutmaning/sa-paverkar-konsumtionen-i-sverige/

Naturvårdsverket. (n.d.-b). *Textilavfall*. Retrieved January 30, 2023, from https://www.naturvardsverket.se/amnesomraden/avfall/avfallslag/textilavfall

Nellström, M., & Saric, M. ((2019)). A comparative life cycle assessment of nudie jeans' repair and reuse concept.

Niinimäki, K., Peters, G., Dahlbo, H., Perry, P., Rissanen, T., & Gwilt, A. (2020). The environmental price of fast fashion. https://doi.org/10.1038/s43017-020-0039-9

Norden. (2015). Well dressed in a clean environment: Nordic action plan for sustainable fashion and textiles. https://doi.org/10.6027/ANP2015-764

Norden. (2023). Mapping sustainable textile initiatives in the nordic countries. https://doi.org/10.6027/temanord2023-502

Nudie Jeans. (2023). *The sustainable product*. Retrieved April 25, 2023, from https://www.nudiejeans.com/sustainability/sustainable-products#free-repairs-for-life

Nußholz, J. (2017). Circular business models: Defining a concept and framing an emerging research field. *Sustainability*, *9*, 1810. https://doi.org/10.3390/su9101810

Plick. (2023). *Om plick*. Retrieved April 25, 2023, from https://plick.se/om-oss

Polarn O. Pyret. (2023a). *Po.p repairs*. Retrieved April 25, 2023, from https://www.polarnopyret.se/pop-cares/langt-liv/pop-repairs

Polarn O. Pyret. (2023b). *Po.p second hand*. Retrieved April 25, 2023, from https://www.polarnopyret.se/pop-cares/langt-liv/pop-second-hand?gclid

PopSwap. (2023). *Update your wardrobe without spending a dime*. Retrieved April 25, 2023, from https://www.popswap.app/

Rauturier, S. (2022). *Everything you need to know about waste in the fashion industry*. Retrieved February 6, 2023, from https://goodonyou.eco/waste-luxury-fashion

Renewcell. (2023). *Recycle textiles with us*. Retrieved June 2, 2023, from https://www.renewcell.com/en/sourcing/

Repamera. (2023). *Om oss*. Retrieved April 25, 2023, from https://repamera.se/

Rerobe. (2023). *Så här säljer du med rerobe*. Retrieved April 25, 2023, from https://rerobe.se/sv-SE/sell

RISE. (2018). *New swedish method a breakthrough in textile recycling*. Retrieved January 30, 2023, from https://www.ri.se/en/our-stories/new-swedish-method-a-breakthrough-in-textile-recycling/

Roberts, H., Milios, L., Mont, O., & Dalhammar, C. (2023). Product destruction: Exploring unsustainable production-consumption systems and appropriate policy responses. *Sustainable Production and Consumption*, *35*, 300–312. https://doi.org/10.1016/j.spc.2022.11.009

Roos, S., Sandin, G., Peters, G., Spak, B., Bour, L. S., Perzon, E., & Jönsson, C. (2019). White paper on textile recycling. http://mistrafuturefashion.com/wp-content/uploads/2019/10/S.-Roos.-White-paper-on-textile-recycling.-Mistra-Future-Fashion.pdf

SAC. (2021). Draft product environmental footprint category rules (pefcr) apparel and footwear. https://eeb.org/library/draft-product-environmental-footprint-category-rules-pefcr-apparel-and-footwear/

Saccani, N., Bressanelli, G., & Visintin, F. (2023). Circular supply chain orchestration to overcome circular economy challenges: An empirical investigation in the textile and fashion industries. https://www.sciencedirect.com/science/article/pii/S2352550922003165

Sandin, G., Roos, S., Spak, B., Zamani, B., & Peters, G. (2019). Environmental assessment of swedish clothing consumption-six garments, sustainable futures. https://doi.org/10.13140/RG.2.2.30502.27205

Sellpy. (2023a). *Så funkar det*. Retrieved April 25, 2023, from https://www.sellpy.se/howItWorks

Sellpy. (2023b). *Vad händer med varor som inte säljs?* Retrieved August 4, 2023, from https://intercom.help/sellpy/sv/articles/504009-vad-hander-med-varor-som-inte-saljs

Shirvanimoghaddam, K., Motamed, B., Ramakrishna, S., & Naebe, M. (2020). Death by waste: Fashion and textile circular economy case. https://www.sciencedirect.com/science/article/pii/S0048969720308275

Skatteverket. (2023). *Vissa reparationstjänster*. Retrieved August 4, 2023, from https://www4.skatteverket.se/rattsligvagledning/edition/2023.9/395014.html

SwedWatch. (2008). Den blinda klädimporten, miljöeffekter från produktionen av kläder som importeras till sverige. *21*.

Tänk Om. (2020). *Textilåtervinning återvinning av kläder – en inblick i din garderob*. Retrieved January 30, 2023, from https://tank-om.se/textilatervinning/

Trafikkontoret. (2020). *Trafik- och resandeutveckling 2019*. https://doi.org/Diarienummer1444/20

United Nations. (2023). *Water scarcity*. Retrieved June 1, 2023, from https://www.unwater.org/water-facts/water-scarcity

Vinted. (2023). *Så här fungerar det*. Retrieved April 25, 2023, from https://www.vinted.se/how_it_works

Weekday. (2023). *Weekday curated 2nd-hand*. Retrieved April 25, 2023, from https://www.weekday.com/en_sek/blog-article/sustainability/w/curated-second-hand.html

A

Appendix: Impact category definition

In this appendix, all the impact categories used in this study are further explained.

A1 Acidification Potential

Acidification is the result when acids are released into surface soils and waters, leading to various negative impacts on ecosystems and living organisms. The primary substances responsible for acidification are SO_2, NO_x, HCl, and NH_3, all of which generate acidifying H+ ions. This can for instance be in the form of acid rain and can cause fish mortality and forest decline, as well as the leaching of toxic metals from rocks and soils, and destruction of monuments and buildings (Baumann and Tillman, 2004).

Acidification potential (AP) is determined by a substance's ability to create H+ ions, with the ratio of the number of H+ ions produced per kilogram of substance to the number produced per kilogram of SO2 being used to define it. Therefore, AP indicates the maximum potential acidification that a substance can cause and is expressed in SO_2 equivalents (Baumann and Tillman, 2004).

A2 Global Warming Potential

Global Warming Potential is defined as the impact of anthropogenic emissions on the atmosphere's radiative forcing, which can cause harmful effects on ecosystems, human health, and material welfare. These are responsible for global warming by enabling the absorption of heat radiation in the atmosphere (Guinee, 2001). GWP measures the number of greenhouse gasses (GHGs) emitted during the life cycle which are; carbon dioxide (CO_2), methane (CH4), chlorofluorocarbons (CFCs), nitrous oxide (N_2O), and other trace gasses (Baumann and Tillman, 2004).

Because of the varying abilities to absorb infrared radiation, the GWP index was created to enable a comparison of their impact on global warming. The index is therefore based on the gasses' ability to absorb infrared radiation and expressed in CO_2-equivalents. The GWP index for one specific GHG is defined as the ratio of increased infrared radiation caused by 1 kg of that GHG compared to the increased infrared absorption caused by 1 kg of CO_2 (Baumann and Tillman, 2004).

The GWP index depends on time and therefore provides insights regarding the effect on either short-term or long-term effects depending on the chosen time horizon. Shorter time horizons often consist of 20 or 50 years, while longer time horizons are those of 50, 100, or 500 years to consider the cumulative effects of GHGs (Baumann and Tillman, 2004). In this study, a time horizon of 100 years is used in the method.

A3 Toxicity Potential

Toxicity Potentials are the different impacts caused by toxic substances such as organic solvents and heavy metals. The effects of these can for example be carcinogenic or mutagenic and are usually divided into two main categories of toxicity potentials: human and eco-toxicity. Eco-toxicity can be divided into subcategories such as Freshwater, Marinewater, and Terrestrial and only the subcategory freshwater was analyzed in this study along with human. Measuring toxicity is complicated as there is currently no coherent framework when aggregating them into toxicity potentials due to the fact that there are many chemicals that cause different impacts. To calculate toxicity, predicted environmental concentration (PEC) and predicted no-effect level (PNEC) are used as shown in the equation A1 below, this compares the effects of the studied chemical to a reference chemical. For human toxicity, the acceptable daily intake (ADI) indicator is used instead (Baumann and Tillman, 2004). For both of these the unit in this study is measured in 1,4-Dichlorobenzene (DCB) eq.

$$\frac{(PEC/PNEC)}{(PEC/PNEC)_{ref}} \tag{A1}$$

A4 Abiotic Resource Depletion Potential

Abiotic resource depletion potential, is a way of measuring how much of a resource has been taken out of the earth compared to how much is still left. Abiotic resources consist of both non-renewable and renewable non-living resources. Examples include iron ore, crude oil, and wind energy. There is a lot of debate about how to assess the impact of using up these resources, and there are many different methods for doing so. These methods can vary in how resource depletion is viewed as an environmental problem and therefore consists of different amounts of resources that are included (Baumann and Tillman, 2004). In this study, abiotic resource depletion is measured in energy in MJ (megajoule).

A5 Eutrophication Potential

Eutrophication potential (EP) is the consequence of an abundance of fertilizers ending up in soil and water, mainly caused by the substances of nitrogen (N) and phosphorus (P). The biggest sources of nitrogen leaching are agriculture, effluents from sewage works, and atmospheric emissions of NO_x. Small amounts of phosphorus comes from agriculture but it can mainly be traced back from sewage effluents. The effect of this higher level of nutrients usually leads to an increase in biological productivity which causes excessive algae blooming, using up the oxygen in the water, and can also make the water murky, which stops sunlight from getting through. This combined with the shift in nutrient levels has a direct impact on biodiversity and harms the local environment, mainly the aquatic ecosystems. The EP is therefore measured in terms of kg PO_4^{3-} equivalents (Baumann and Tillman, 2004).

A6 Land use

Land use represents the proportional loss of species caused by different land use types such as annual crops, permanent crops, mosaic agriculture, forestry, urban land, and pasture. This is a debated impact category as there are different ways to assess and base these numbers (Baumann and Tillman, 2004). Calculation of relative species loss in ReCiPe 2016 is based on field data comparing local species richness in various natural and human-modified land covers. In the case of land conversion, passive recovery towards a semi-natural, old-growth habitat occurs over time. for this impact assessment method land use is measured in $m^2 \times yr$ annual crop equivalents (Huijbregts et al., 2017).

A7 Ozone Depletion Potential

Ozone Depletion Potential (ODP), or ozone layer depletion, is the thinning of the ozone layer in the atmosphere caused due to human activities, mainly from emissions. This leads to a larger part of the harmful UV-B radiation reaching the lower parts of the atmosphere, Earth's surface, which has negative effects on the health of both humans and animals. To in extent, it can also be detrimental to terrestrial and aquatic ecosystems as well as biochemical cycles. Together with the catalyzing substances; H, OH, NO, Cl, and Br, the ozone layer is destroyed through ultraviolet (UV) radiation and visible light (Baumann and Tillman, 2004).

The ODP of a substance measures how much it contributes to this process compared to a specific substance called CFC-11 (Trichlorofluoromethane). It is determined by comparing the amount of the substance released into the atmosphere to the amount of CFC-11 released, and how much they both affect the ozone layer. This is measured while everything is in a steady state. The unit used for ODP is therefore CFC-11 (Baumann and Tillman, 2004).

A8 Photochemical Oxidation Potential

Photochemical Oxidation Potential is a way to measure the ability of an organic compound to create ozone in the troposphere. The unit is expressed in Ethene (C2H4) equivalents as a reference substance to compare against. Ozone is a harmful substance formed in the lower atmosphere (troposphere) from Volatile Organic Compounds (VOCs) and carbon monoxide (CO) when nitrogen oxides (NOx) are present. This process creates photooxidants, which can lead to summer smog, also known as Los Angeles smog or secondary air pollution. Which have negative impacts on ecosystems, crops, and human health (Baumann and

Tillman, 2004).

A9 Water use

Water use is along with land use a debated impact category on how and what to measure (Baumann and Tillman, 2004). It is often heard about in contexts where production has a high demand, especially that of cotton where the growth of cultivation is done. An important aspect of water use is the direct relation to water scarcity, due to it being a finite resource in growing demand, which is a significant issue worldwide, particularly impacting poorer societies (United Nations, 2023). Water use as an impact category in ReCiPe 2016 is a way to measure the relative amount of m^3 water consumed per m^3 of water extracted. The unit used in this method is therefore m^3 (Huijbregts et al., 2017).

B

Appendix: Life Cycle Inventory Data

This appendix includes all life cycle inventory data used, including further explanations of the processes used in garment production along with the used assumptions and characterization results for the different impact categories in order of the processes for the life cycle.

B1 Production phase

The production phase refers to all processes from cotton cultivation to the finished pants. It is assumed for all production processes that no transportation is done between the steps, nor from production facilities to waste management is modeled. The waste management of cotton fibre, yarn and fabric is modeled as waste paperboard.

The ratios between inputs and outputs in all processes remain the same for all three models, and will only be presented once to represent all. A difference can be seen in confectioning in the repair model when the waste fabric is kept to be used in the later repair process. Along with fabric, there could also be a production of features like zippers, buttons, and paper labels for garments. However, for this study, several of these will be excluded. Further, additional services like air conditioning and ventilation that require electricity are also excluded from the modeling. Only the packaging is modeled apart from the actual pants.

Yarn production

In this study, the process named yarn production covers both fiber production and yarn production, shown in Figure 4.1. The whole process of cotton cultivation is not modeled as an isolated process. Instead, as with many other inputs like car transports and electricity, the cotton needed for the yarn production is modeled as a global market input, already an existing process in OpenLCA. Cotton is cultivated in cotton plantations as a natural staple fiber, where considerable amounts of irrigated water, pesticides, and fertilizers are commonly used. Once harvested, the fibers are baled and ginned and continue to yarn production. Staple yarn production typically includes opening, carding, combing, drawing, spinning, twisting, and winding and is modeled as electricity and lubricant. (Sandin et al., 2019).

Table B1: Assumptions for yarn spinning

Inputs
The yarn production requires 4kWh of electricity per kilo of cotton fiber.
The lubricant makes up 0.16% of the total weight of the yarn.
The lubricant consists of acrylic acid, polyacrylamide, and ultrapure water.
No transportation is modeled for the cotton fibers to reach the production site.
Outputs
Approximately 11% of the original fibers are wasted during yarn production.
The lubricant is emitted into the air during the process.

Table B2: Model of Yarn spinning

Flow	Dataset	Amount	Unit
Inputs			
Fibre, cotton	Market for fibre, cotton | fibre, cotton | Cutoff, U-GLO	40.86E-02	kg
Acrylic acid	Market for acrylic acid | acrylic acid | Cutoff, U-RoW	58.18E-06	kg
Electricity, medium voltage	Market for electricity, medium voltage | electricity, medium voltage | Cutoff, U-IN-Western grid	14.55E-01	kWh
Polyacrylamide	Market for polyacrylamide | polyacrylamide | Cutoff, U-GLO	11.64E-05	kg
Water, ultra-pure	Market for water, ultrapure | water, ultrapure | Cutoff, U-RoW	40.73E-05	kg
Outputs			
Produced Cotton Yarn	(to fabric production)	36.36E-02	kg
Waste paperboard	Treatment of waste paperboard, municipal incineration | waste paperboard | Cutoff, U-RoW	44.95E-03	kg
Acrylic acid	(emissions to air)	58.18E-06	kg
Acrylamide	(emissions to air)	11.64E-05	kg
Water	(emissions to air)	40.73E-05	l

Fabric production

To produce fabric, yarn is typically woven or knitted. In this study, the yarn goes into a circular knitting machine and lubricant is assumed to be used.

Table B3: Assumptions for fabric production

Inputs
The circular knitting requires 0.21kWh of electricity for each kilo of yarn.
The lubricant consists of acrylic acid, polyacrylamide, and ultrapure water.
The lubricant makes up 8% of the total weight of the yarn.
Outputs
Approximately 1.5% of the yarn is wasted during the production of fabric, represented as waste paperboard.
The lubricant is emitted into the air during the process.

Table B4: Model of fabric production

Flow	Dataset	Amount	Unit
Inputs			
Produced Yarn	(from cotton yarn spinning)	36.36E-02	kg
Acrylic acid	Market for acrylic acid | acrylic acid | Cutoff, U-RoW	29.09E-04	kg
Electricity, medium voltage	Market for electricity, medium voltage | electricity, medium voltage | Cutoff, U-IN-Western grid	76.37E-03	kWh
Polyacrylamide	Market for polyacrylamide | polyacrylamide | Cutoff, U-GLO	58.18E-04	kg
Water, ultrapure	Market for water, ultrapure | water, ultrapure | Cutoff, U-RoW	20.36E-03	kg
Outputs			
Unbleached fabric	(to wet treatment)	35.82E-02	kg
Waste paperboard	Treatment of waste paperboard, municipal incineration | waste paperboard | Cutoff, U-RoW	54.44E-04	kg
Acrylic acid	(emissions to air)	29.09E-04	kg
Acrylamide	(emissions to air)	58.18E-04	kg
Water	(emissions to air)	20.36E-03	l

Wet treatment

A typical wet treatment process for knitted fabric often consists of the following steps: bleaching and/or dyeing, opening, drying, and fixation in stenter frames. For white and light-colored natural materials, bleaching is needed. The wet treatment modeled in this study only consists of the steps required for bleaching the cotton fabric, and drying and fixation of cellulosic in the stenter frame, meaning that no dyeing of the pants is done. The chemicals assumed to be used for this are detergent/wetting agent, lubricant, peroxide stabilizer, and softener that all consist of several inputs further explained in Table B5 below. All wet treatment processes include wastewater and air emissions treatment.

Table B5: Assumptions for wet treatment

Inputs
The wet treatment requires 0.7kWh electricity per kg fabric.
The wet treatment requires 30MJ of heat per kg of fabric.
The detergent/wetting agent consists of ethoxylated alcohol, maleic anhydride, and ultrapure water.
The lubricant consists of acrylic acid, polyacrylamide, and ultrapure water.
Peroxide stabilizer consists of acrylic acid, magnesium oxide, phosphoric acid, and ultrapure water.
Softener consists of stearic acid, ultrapure water, and diethanolamine.
The electricity use in the opening process is considered insignificant compared to the energy use in drying and therefore excluded.
Outputs
Emissions of the outputs are set to be released into both air and water.
Emissions to air are set to be for a high population density meaning that the factory is located where there is a higher population density.
Emissions to water are assumed to be released in a river nearby the production location.

Table B6: Model for wet treatment

Flow	Dataset	Amount	Unit
Inputs			
Unbleached fabric	(from fabric production)	35.28E-02	kg
Acrylic acid	Market for acrylic acid | acrylic acid | Cutoff, U-RoW	28.22E-04	kg
Acrylic acid	Market for acrylic acid | acrylic acid | Cutoff, U-RoW	70.56E-06	kg
Diethanolamine	Market for diethanolamine | diethanolamine | Cutoff, U-GLO	31.75E-05	kg
Electricity, medium voltage	Market for electricity, medium voltage | electricity, medium voltage | Cutoff, U-IN-Western grid	24.69E-02	kWh
Ethoxylated alcohol	Market for ethoxylated alcohol (AE7) | ethoxylated alcohol (AE7) | Cutoff, U-GLO	35.28E-04	kg
Fluorescent whitening agent, distyrylbiphenyl type	Market for fluorescent whitening agent, distyrylbiphenyl type | fluorescent whitening agent, distyrylbiphenyl type | Cutoff, U-GLO	21.17E-03	kg
Heat, central or small-scale, other than natural gas	Heat production, light fuel oil, at boiler 100kWh, non-modulating | heat, central or small-scale, other than natural gas | Cutoff, U-RoW	10.58E+00	MJ
Formic acid	Market for formic acid | formic acid | Cutoff, U-RoW	35.28E-04	kg

Continued on next page

Table B6 – continued from previous page

Flow	Dataset	Amount	Unit
Hydrogen peroxide, without water, in 50% solution state	Market for hydrogen peroxide, without water, in 50% solution state | hydrogen peroxide, without water, in 50% solution state | Cutoff, U-RoW	24.69E-03	kg
Magnesium oxide	Market for magneisum oxide | magnesium oxide | Cutoff, U-GLO	35.28E-07	kg
Maleic anhydride	Market for maleic anhydride | maleic anhydride | Cutoff, U-GLO	17.64E-04	kg
Phosphoric acid, industrial grade, without water, in 85% solution state	Market for phosphoric acid, industrial grade, without water, in 85% solution state | phosphoric acid, industrial grade, without water, in 85% solution state | Cutoff, U-GLO	70.56E-06	kg
Polyacrylamide	Market for polyacrylamide | polyacrylamide | Cutoff, U-GLO	56.45E-04	kg
Sodium hydroxide, without water, in 50% solution state	Market for sodium hydroxide, without water, in 50% solution state | sodium hydroxide, without water, in 50% solution state | Cutoff, U-GLO	88.20E-04	kg
Stearic acid	Market for stearic acid | stearic acid | Cutoff, U-GLO	21.17E-04	kg
Sulfuric acid	Market for sulfuric acid | sulfuric acid | Cutoff, U-RoW	70.56E-04	kg
Water (freshwater)	(resource)	21.17E+00	l
Water, ultrapure	Market for water, ultrapure | water, ultrapure | Cutoff, U-RoW	81.50E-04	l
Water, ultrapure	Market for water, ultrapure | water, ultrapure | Cutoff, U-RoW	12.35E-03	l
Water, ultrapure	Market for water, ultrapure | water, ultrapure | Cutoff, U-RoW	56.10E-05	l
Water, ultrapure	Market for water, ultrapure | water, ultrapure | Cutoff, U-RoW	19.76E-03	l
Outputs			
Bleached fabric	(to confectioning)	35.28E-02	kg
3-Methyl-1-butanol	(emission to air/high population density)	21.17E-05	kg
3-Methyl-1-butanol	(emission to water/river)	21.17E-05	kg
Acrylic acid	(emission to air/high population density)	21.17E-05	kg
Acrylic acid	(emission to water/river)	21.17E-05	kg
Acrylic acid	(emission to air/high population density)	10.58E-05	kg
Acrylic acid	(emission to water/river)	10.58E-05	kg
Alcohols, c12-14, ethoxylated	(emission to air/high population density)	74.09E-05	kg

Continued on next page

Table B6 – continued from previous page

Flow	Dataset	Amount	Unit
Alcohols, c12-14, ethoxylated	(emission to water/river)	74.09E-05	kg
Alcohols, c12-14, ethoxylated	(emission to air/high population density)	10.58E-04	kg
Alcohols, c12-14, ethoxylated	(emission to water/river)	10.58E-04	kg
Alkylbenzene (c10-c15)	(emission to air/high population density)	63.50E-04	kg
Alkylbenzene (c10-c15)	(emission to water/river)	63.50E-04	kg
COD, Chemical Oxygen Demand	(emission to water/river)	70.56E-06	kg
Dimethyl sulfate	(emission to air/high population density)	10.58E-05	kg
Dimethyl sulfate	(emission to water/river)	10.58E-05	kg
Hydrogen peroxide	(emission to air/high population density)	16.23E-02	kg
Hydrogen peroxide	(emission to water/river)	16.37E-02	kg
Magnesium	(emission to air/high population density)	52.92E-07	kg
Magnesium	(emission to water/river)	52.92E-07	kg
Phosphoric acid	(emission to air/high population density)	10.58E-05	kg
Phosphoric acid	(emission to water/river)	10.58E-05	kg
Phosphoric acid	(emission to air/high population density)	21.17E-04	kg
Phosphoric acid	(emission to water/river)	21.17E-04	kg
Sodium hydroxide	(emission to water/river)	10.58E-03	kg
Sulfuric acid	(emission to air/high population density)	21.17E-04	kg
Sulfuric acid	(emission to water/river)	21.17E-04	kg
Waste water/m3	(emission to water/river)	10.58E-04	l
Waste water/m3	(emission to water/river)	10.58E-05	l
Waste water/m3	(emission to water/river)	84.14E-05	l
Wastewater, average	Treatment of wastewater, average, wastewater treatment | wastewater, average | Cutoff, U-RoW	15.88E+00	l
Water	(emission to air/high population density)	10.58E-04	l
Water	(emission to air/high population density)	10.58E-05	l
Water	(emission to air/high population density)	84.14E-05	l
End of table			

Confectioning

Producing a garment out of fabric, known as confectioning, involves cutting, sewing, printing, and finishing and other supplementary processes, such as packaging, ironing, and washing, adding to energy and water use. Waste material generated from the cutting process is generally around 15-20% of the incoming material (Sandin et al., 2019).

Table B7: Assumptions for confectioning

Inputs
Prior to packaging, no washing or ironing was assumed to happen.
Sewing and cutting were assumed to take 30 minutes, with 0.029 kWh of electricity needed per minute.
0.07 MJ of heat is required per kilo of fabric.
1.8kg of the cardboard box was needed for packaging per kilo of finished pants. 0.0035kg of cotton fiber as sewing thread was needed per kilo of finished pants.
0.02kg of low-density polyethylene for packaging was needed per kilo of finished pants.
0.05kg of kraft paper for the template was needed per kilo of finished pants.
Outputs
In the repair model, less waste fabric goes to waste treatment since the fabric needed for repair is taken care of. This is represented by a bigger weight of the flow for finished pants.
Approximately 18% of the fabric is wasted during confectioning, represented by the waste paperboard going to the waste treatment.

Table B8: Model for confectioning of cotton

Flow	Dataset	Amount	Amount Repair	Unit
Inputs				
Bleached fabric	(from wet treatment)	35.28E-02	35.28E-02	kg
Corrugated board box	Market for corrugated board box | corrugated board box | Cutoff, U-RoW	17.64E-03	17.64E-03	kg
Electricity, medium voltage	Market for electricity, medium voltage | electricity, medium voltage | Cutoff, U-IN-Western grid	81.14E-02	81.14E-02	kWh
Fibre, cotton	Fibre production, cotton, ginning | fibre, cotton | Cutoff, U-IN	10.50E-04	10.50E-04	kg
Kraft paper	Market for kraft paper | kraft paper | Cutoff, U-RoW	15.00E-03	15.00E-03	kg
Packaging film, low density polyethylene	Market for packaging film, low density polyethylene | packaging film, low density polyethylene | Cutoff, U-GLO	60.00E-04	60.00E-04	kg
Outputs				
Finished Pants	(to distribution and storage)	30.00E-02	33.00E-02	kg
Waste paperboard	Treatment of waste paperboard, municipal incineration | waste paperboard | Cutoff, U-RoW	68.85E-03	38.85E-03	kg

B2 Distribution and retail

The transportation of the garments from the production in India to the retailer in Sweden was assumed to be carried out via ship to Sweden and truck within Sweden, based on estimated information on vehicles, and distances as presented in the assumption Table B9 below. In this study, all purchases were assumed to be made in physical stores, and not through online platforms. Since the additional waste fabric is transported in the repair model, the amount of electricity and transports are a little higher.

Distribution and storage

Table B9: Assumptions for distribution and storage

Inputs
Distance from the port in India to the port of Gothenburg was set to 14280km.
Distance from the port in Sweden to the warehouse was set to 70km.
Transport from the factory in India to a port in India was not modeled.
Electricity needed for the warehouse was assumed to be 1.94kWh per kilo of pants.
Heat recovery for municipal incineration was assumed to be 3.98 MJ per kilo of pants.
Power recovery for municipal incineration was assumed to be 0.55 kWh per kilo of pants.
Outputs
Waste paperboard represents the waste treatment of cardboard boxes that the pants are shipped in.

Table B10: Model of distribution and storage

Flow	Dataset	Amount	Amount Repair	Unit
Inputs				
Finished Pants	(from confectioning)	30.00E-02	33.00E-02	kg
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	58.20E-02	64.02E-02	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	-99.00E-02	-18.72E-02	kWh
Heat, district or industrial	heat from municipal waste incineration to generic market for heat district or industrial, other than natural gas | heat district or industrial, other than natural gas | Cutoff, U-SE	-71.64E-03	-71.64E-03	MJ
Transport, freight, lorry 16-32 metric ton, EURO6	Market for transport, freight, lorry 16-32 metric ton, EURO6 | transport, freight, lorry 16-32 metric ton, EURO6 | Cutoff, U-RoW	21.00E+00	23.10E+00	kg*km
Transport, freight, sea, container ship	Market for transport, freight sea, container ship | transport, freight sea, container ship | Cutoff, U-GLO	42.84E+02	47.12E+02	kg*km
Outputs				
Finished Pants	(to retail)	30.00E-02	33.00E-02	kg
Waste paperboard	Treatment of waste paperboard, municipal incineration | waste paperboard | Cutoff, U-RoW	18.00E-03	18.00E-03	kg

Retail

Table B11: Assumptions for retail

Inputs
The distance from the warehouse to the retailer is 70km.
Paper sack represents the paper bag every consumer receives their bought-in to bring them home.
The paper bag was assumed to weigh 39 grams.
Electricity needed for the warehouse was assumed to be 1.94kWh per kilo of pants.
Heat recovery for municipal incineration of the plastic bag was assumed to be 10.69 MJ per kilo of pants.
Power recovery for municipal incineration was assumed to be 1.54 kWh per kilo of pants.
Outputs
Waste Polyethylene represents the wasted plastic bag that the pants are transported in from the factory to the store.

Table B12: Model of retail

Flow	Dataset	Amount	Amount Repair	Unit
Inputs				
Finished Pants	(from distribution and storage)	30.00E-02	33.00E-02	kg
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	58.20E-02	64.02E-02	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	-33.00E-04	-33.00E-04	kWh
Heat, district or industrial	heat from municipal waste incineration to generic market for heat district or industrial, other than natural gas | heat district or industrial, other than natural gas | Cutoff, U-SE	-23.88E-03	-23.88E-03	MJ
Paper sack	Market for paper sack | paper sack | Cutoff, U-RoW	39.00E-03	39.00E-03	kg
Transport, freight, lorry 16-32 metric ton, EURO6	Market for transport, freight, lorry 16-32 metric ton, EURO6 | transport, freight, lorry 16-32 metric ton, EURO6 | Cutoff, U-RoW	21.00E+00	23.10E+00	kg*km
Outputs				
Finished Pants	(to use phase)	30.00E-02	33.00E-02	kg
Waste polyethylene	Treatment of waste polyethylene, municipal incineration | waste polyethylene | Cutoff, U-RoW	60.00E-04	60.00E-04	kg

B3 Use phase

This section describes the first use phase of the retailed pants, which comprises the transportation of the user to and from the store, the residential laundering, which includes washing, drying, and ironing, the transportation of waste, and the waste treatment. In order to model input of detergent, a process for detergent production was created.

Table B13: Assumptions for detergent production

Inputs
All of the inputs are substances included or needed to produce detergent, based on (MFA, 2018).
Outputs
The amount of wastewater is assumed be released into a river.

Table B14: Model of detergent production

Flow	Dataset	Amount	Unit
Inputs			
Alkyl sulphate (C12-14)	Market for alkyl sulphate (C12-14) | alkyl sulphate (C12-14) | Cutoff, U-GLO	10.38E-02	kg
Citric acid	Market for citric acid | citric acid | Cutoff, U-GLO	22.80E-03	kg
Electricity, medium voltage	Market group for electricity, medium voltage | electricity, medium voltage | Cutoff, U-EwS	25.00E-02	kWh
Enzymes	Market for enzymes | enzymes | Cutoff, U-GLO	58.00E-04	kg
Glycerine	Market for glycerine | glycerine | Cutoff, U-RoW	28.50E-03	kg
Non-ionic surfactant	Market for non-ionic surfactant | non-ionic surfactant | Cutoff, U-GLO	59.1E-03	kg
Polyethylene, high density, granulate	Market for polyethylene, high density, granulate | polyethylene, high density, granulate | Cutoff, U-GLO	46.60E-03	kg
Polyethylene, linear low density, granulate	Market for polyethylene, linear low density, granulate | polyethylene, linear low density, granulate | Cutoff, U-GLO	46.60E-03	kg
Polypropylene, granulate	Market for polypropylene, granulate | polypropylene, granulate | Cutoff, U-GLO	10.10E-03	kg
Printed paper	Market for printed paper, offset | printed paper, offset | Cutoff, U-GLO	12.60E-04	kg
Soap	Market for soap | soap | Cutoff, U-GLO	24.10E-03	kg
Sodium hydroxide, without water, in 50% solution state	Market for sodium hydroxide, without water, in 50% solution state | sodium hydroxide, without water, in 50% solution state | Cutoff, U-GLO	23.10E-03	kg
Tap water	Market for tap water | tap water | Cutoff, U-EwS	70.22E-02	kg
Outputs			
Detergent	(to use of pants)	10.00E-01	kg
Waste water	(emission to water/river)	26.60E-02	l

Table B15: Assumptions for use of pants, including washing

Inputs
The total distance back and forth to the store is 17km per kg of clothing. Since more than one item is usually bought each trip (Sandin et al., 2019), it is assumed that 1kg of products is bought each trip to the store. This means that the distance allocated for the pants of 0.3kg becomes 5.1km in total.
The mode of transportation is set to be 43% made by car, 30% by tram as public transport, and 28% by walking or taking the bike, representing Gothenburg in 2019, a city before changes in behavior patterns due to Covid-19 (Trafikkontoret, 2020).
The electricity needed for washing is 0.225 kWh per kilo of pants.
The electricity needed for drying is 0.67 kWh per kilo of pants and is done 30% of the time the pants are washed.
The electricity needed for ironing is 0.027 kWh per kilo of pants and is done for 6 minutes, 15% of the time the pants are washed.
The transport distance to the waste treatment is set to 6km, based on the distance between a central location in Gothenburg and Renovas facility in Sävenäs.
0.9kg of water per kg of pants is assumed to evaporate during washing.
Outputs
The amount of wastewater is the amount of water needed for washing
For BAU waste paperboard includes the throwing of the pants

Table B16: Model of use phase 1, including washing

Flow	Dataset	Amount BAU	Amount Repair	Amount OSH	Unit
Inputs					
Pants	(from retail)	30.00E-02	33.00E-02	30.00E-02	kg
Detergent	(from detergent production)	94.80E-03	14.22E-02	28.44E-02	kg
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	13.50E-01	20.25E-01	40.50E-01	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	12.06E-01	18.10E-01	36.18E-01	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	14.58E-02	21.87E-02	43.74E-03	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	-23.59E-02	-70.95E-03	-70.95E-03	kWh
Heat, district or industrial	heat from municipal waste incineration to generic market for heat district or industrial, other than natural gas | heat district or industrial, other than natural gas | Cutoff, U-SE	-17.07E-01	-51.34E-02	-51.34E-02	MJ
Tap water	Market for tap water | tap water | Cutoff, U-EwS	37.20E+00	55.80E+00	11.16E+00	kg
Transport, passenger car	Market for transport, passenger car | transport, passenger car | Cutoff, U-RoW	21.93E-01	21.93E-01	21.93E-01	km
Transport, tram	Market for transport, tram | transport, tram | Cutoff, U-GLO	15.30E-01	15.30E-01	15.30E-01	p*km

Continued on next page

Table B16 – continued from previous page

Flow	Dataset	Amount BAU	Amount Repair	Amount OSH	Unit
Transport, freight, lorry 16-32 metric ton, EURO6	Market for transport, freight, lorry 16-32 metric ton, EURO6 | transport, freight, lorry 16-32 metric ton, EURO6 | Cutoff, U-RoW	25.74E-01	77.40E-01	77.40E-01	kg*km
Outputs					
Waste paperboard	Treatment of waste paperboard, municipal incineration | waste paperboard | Cutoff, U-RoW	42.9E-02	12.90E-01	12.90E-01	kg
Wastewater, average	Treatment of wastewater, average, wastewater treatment | wastewater, average | Cutoff, U-EwS	31.80E+00	47.70E+00	95.40E-	l
Water	(emission to air/high population density)	54.00E-01	81.00E-01	16.20E-01	l

End of table

B4 Repair

This section presents the repair process, followed by the second, third, and final use phase for the repair model.

Table B17: Assumptions for the repair of pants

Inputs
The total amount of repairs is three and each one is modeled in the same way.
For each repair, 10g of fabric leftovers from confectioning is used.
With each repair, fabric from the pants is cut and new repair fabric is added, resulting in repair pants having the same weight as before the repair.
The electricity needed for sewing is 0.5kWh per kilo of pants.
The paper bag is assumed to weigh 39 grams.
Outputs
The waste paperboard represents the 10g leftover fabric from the repair.

Table B18: Model of repair of pants

Flow	Dataset	Amount Repair	Unit
Inputs			
Finished Pants	(from use phase)	30.00E-02	kg
Fabric for repair	(from retail)	30.00E-03	kg
Fibre, cotton	Market for fibre, cotton | fibre, cotton | Cutoff, U-GLO	30.00E-05	kg
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	15.00E-02	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	-56.70E-04	kWh
Heat, district or industrial	heat from municipal waste incineration to generic market for heat district or industrial, other than natural gas | heat district or industrial, other than natural gas | Cutoff, U-SE	-40.99E-03	MJ
Paper sack	Market for paper sack | paper sack | Cutoff, U-RoW	39.00E-03	kg
Transport, passenger car	Market for transport, passenger car | transport, passenger car | Cutoff, U-RoW	21.93E-01	km
Transport, tram	Market for transport, tram | transport, tram | Cutoff, U-GLO	15.30E-01	p*km
Transport, freight, lorry 3.5-7.5 metric ton, EURO6	Market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cutoff, U-RoW	61.80E-03	kg*km
Outputs			
Repaired Pants	(to use phase)	32.00E-02	kg
Waste paperboard	Treatment of waste paperboard, municipal incineration | waste paperboard | Cutoff, U-RoW	10.30E-03	kg

Table B19: Assumptions for use phase 2, 3 and 4

Inputs
Assumptions and input of electricity for washing, drying and ironing, heat and power recovery, detergent and water use for washing, and transports for use phase 2 and 3 have the same ratio of flows and dataset as use 1, but the different numbers of washing result in different values. These are presented in Table B20 below
In use phase 4, the pants are incinerated after the final uses, shown in B21.
Outputs

Table B20: Model of use phase 2 and 3, including washing

Flow	Dataset	Amount	Unit
Inputs			

Continued on next page

Table B20 – continued from previous page

Flow	Dataset	Amount	Unit
Pants	(from repair)	30.00E-02	kg
Detergent	(from detergent production)	71.10E-03	kg
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	10.13E-01	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	90.45E-02	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	10.94E-02	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	-21.45E-03	kWh
Heat, district or industrial	heat from municipal waste incineration to generic market for heat district or industrial, other than natural gas | heat district or industrial, other than natural gas | Cutoff, U-SE	-15.52E-02	MJ
Tap water	Market for tap water | tap water | Cutoff, U-EwS	27.90E+00	kg
Transport, passenger car	Market for transport, passenger car | transport, passenger car | Cutoff, U-RoW	21.93E-01	km
Transport, tram	Market for transport, tram | transport, tram | Cutoff, U-GLO	15.30E-01	p*km
Transport, freight, lorry 16-32 metric ton, EURO6	Market for transport, freight, lorry 16-32 metric ton, EURO6 | transport, freight, lorry 16-32 metric ton, EURO6 | Cutoff, U-RoW	23.40E-02	kg*km
Outputs			
Torn pants	(to repair)	30.00E-02	kg
Waste paperboard	Treatment of waste paperboard, municipal incineration | waste paperboard | Cutoff, U-RoW	39.00E-03	kg
Wastewater, average	Treatment of wastewater, average, wastewater treatment | wastewater, average | Cutoff, U-EwS	23.85E+00	l
Water	(emission to air/high population density)	40.50E-01	l

End of table

Table B21: Model of the use phase 4, including washing

Flow	Dataset	Amount Repair	Unit
Inputs			
Pants	(from repair)	30.00E-02	kg
Detergent	(from detergent production)	23.70E-02	kg
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	33.75E-02	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	30.15E-02	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	36.45E-03	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	-18.65E-02	kWh
Heat, district or industrial	heat from municipal waste incineration to generic market for heat district or industrial, other than natural gas | heat district or industrial, other than natural gas | Cutoff, U-SE	-13.49E-02	MJ
Tap water	Market for tap water | tap water | Cutoff, U-EwS	93.00E-01	kg
Transport, passenger car	Market for transport, passenger car | transport, passenger car | Cutoff, U-RoW	21.93E-01	km
Transport, tram	Market for transport, tram | transport, tram | Cutoff, U-GLO	15.30E-01	p*km
Transport, freight, lorry 16-32 metric ton, EURO6	Market for transport, freight, lorry 16-32 metric ton, EURO6 | transport, freight, lorry 16-32 metric ton, EURO6 | Cutoff, U-RoW	20.34E-01	kg*km
Outputs			
Waste paperboard	Treatment of waste paperboard, municipal incineration | waste paperboard | Cutoff, U-RoW	33.90E-02	kg
Wastewater, average	Treatment of wastewater, average, wastewater treatment | wastewater, average | Cutoff, U-EwS	79.50E-01	l
Water	(emission to air/high population density)	13.50E-01	l

B5 Online second-hand

This section presents the process of sorting and management along with the second and third use phase for OSH.

Table B22: Assumptions for sorting and management OSH

Inputs	
The pants go through sorting and management a total of two times. Each one is modeled in the same way, shown in the table below	
Outputs	
The waste polyethylene represents the plastic bag thrown away when the OSH company receives the clothes using sorted recycling after receiving the garments, and it is assumed to weigh 15 grams.	

Table B23: Model of sorting and management OSH

Flow	Dataset	Amount	Unit
Inputs			
Pants	(from use phase)	30.00E-02	kg
Discarded/donate Pants	(from use phase)	15.00E-02	kg
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	90.00E-02	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	30.00E-02	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	-82.50E-04	kWh
Heat, district or industrial	heat from municipal waste incineration to generic market for heat district or industrial, other than natural gas | heat district or industrial, other than natural gas | Cutoff, U-SE	-59.70E-03	MJ
Packaging film, low density polyethylene	Market for packaging film, low density polyethylene | packaging film, low density polyethylene | Cutoff, U-GLO	15.00E-03	kg
Transport, freight, light commercial vehicle	Market for transport, freight, light commercial vehicle | transport, freight, light commercial vehicle | Cutoff, U-EwS	15.00E-02	kg*km
Transport, freight, light commercial vehicle	Market for transport, freight, light commercial vehicle | transport, freight, light commercial vehicle | Cutoff, U-EwS	46.50E-01	kg*km
Transport, freight, lorry 16-32 metric ton, EURO6	Market for transport, freight, lorry 16-32 metric ton, EURO6 | transport, freight, lorry 16-32 metric ton, EURO6 | Cutoff, U-RoW	10.50E+00	kg*km
Transport, freight, lorry 16-32 metric ton, EURO6	Market for transport, freight, lorry 16-32 metric ton, EURO6 | transport, freight, lorry 16-32 metric ton, EURO6 | Cutoff, U-RoW	97.50E-01	kg*km

Continued on next page

Table B23 – continued from previous page

Flow	Dataset	Amount	Unit
Transport, freight, lorry 16-32 metric ton, EURO6	Market for transport, freight, lorry 16-32 metric ton, EURO6 | transport, freight, lorry 16-32 metric ton, EURO6 | Cutoff, U-RoW	30.23E+00	kg*km
Transport, freight, lorry 3.5-7.5 metric ton, EURO6	Market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cutoff, U-RoW	90.00E-03	kg*km
Outputs			
Finished Pants	(to use phase)	30.00E-02	kg
Discarded/donate pants	(to donation)	15.00E-02	kg
Waste polyethylene terephthalate	Treatment of waste polyethylene terephthalate, municipal incineration | waste polyethylene terephthalate | Cutoff, U-RoW	15.00E-03	kg
End of table			

Table B24: Assumptions for use phase 2 and 3

Inputs
In use phase 3, the pants are incinerated, which is therefore shown in its own table B26.
The electricity required for washing, drying, and ironing 1 kg of pants is the same as in previous use phases.
The donated pants are not assumed to be ironed or dried.

Table B25: Model of the use phase 2, including washing

Flow	Dataset	Amount Repair	Unit
Inputs			
Pants	(from sorting & management)	30.00E-02	kg
Detergent	(from detergent production)	92.43E-03	kg
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	13.16E-01	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	42.21E-02	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	51.03E-03	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	-88.00E-03	kWh
Heat, district or industrial	heat from municipal waste incineration to generic market for heat district or industrial, other than natural gas | heat district or industrial, other than natural gas | Cutoff, U-SE	-63.68E-02	MJ
Tap water	Market for tap water | tap water | Cutoff, U-EwS	36.27E+00	kg
Transport, passenger car	Market for transport, passenger car | transport, passenger car | Cutoff, U-RoW	25.80E-02	km
Transport, tram	Market for transport, tram | transport, tram | Cutoff, U-GLO	18.00E-02	p*km
Transport, freight, lorry 16-32 metric ton, EURO6	Market for transport, freight, lorry 16-32 metric ton, EURO6 | transport, freight, lorry 16-32 metric ton, EURO6 | Cutoff, U-RoW	21.70E+00	kg*km
Transport, freight, lorry 3.5-7.5 metric ton, EURO6	Market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cutoff, U-RoW	96.00E-02	kg*km
Transport, freight, light commercial vehicle	Market for transport, freight, light commercial vehicle | transport, freight, light commercial vehicle | Cutoff, U-EwS	31.00E-01	kg*km
Outputs			
Pants	(to use phase 3)	30.00E-02	kg
Waste paperboard	Treatment of waste paperboard, municipal incineration | waste paperboard | Cutoff, U-RoW	15.00E-02	kg
Wastewater, average	Treatment of wastewater, average, wastewater treatment | wastewater, average | Cutoff, U-EwS	31.01E+00	l
Water	(emission to air/high population density)	52.65E-01	l

Table B26: Model of the use phase 3, including washing

Flow	Dataset	Amount Repair	Unit
Inputs			
Pants	(from sorting & management)	33.00E-02	kg
Detergent	(from detergent production)	14.69E-02	kg
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	20.93E-01	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	12.66E-01	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	15.31E-02	kWh
Electricity, low voltage	Electricity, low voltage, residual mix | electricity, low voltage | Cutoff, U-SE	-25.30E-02	kWh
Heat, district or industrial	heat from municipal waste incineration to generic market for heat district or industrial, other than natural gas | heat district or industrial, other than natural gas | Cutoff, U-SE	-18.31E-01	MJ
Tap water	Market for tap water | tap water | Cutoff, U-EwS	57.66E+00	kg
Transport, passenger car	Market for transport, passenger car | transport, passenger car | Cutoff, U-RoW	25.80E-02	km
Transport, tram	Market for transport, tram | transport, tram | Cutoff, U-GLO	18.00E-02	p*km
Transport, freight, lorry 16-32 metric ton, EURO6	Market for transport, freight, lorry 16-32 metric ton, EURO6 | transport, freight, lorry 16-32 metric ton, EURO6 | Cutoff, U-RoW	21.70E+00	kg*km
Transport, freight, lorry 3.5-7.5 metric ton, EURO6	Market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 | transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Cutoff, U-RoW	96.00E-02	kg*km
Transport, freight, light commercial vehicle	Market for transport, freight, light commercial vehicle | transport, freight, light commercial vehicle | Cutoff, U-EwS	31.00E-01	kg*km
Outputs			
Waste paperboard	Treatment of waste paperboard, municipal incineration | waste paperboard | Cutoff, U-RoW	45.00E-02	kg
Wastewater, average	Treatment of wastewater, average, wastewater treatment | wastewater, average | Cutoff, U-EwS	53.27E+00	l
Water	(emission to air/high population density)	90.45E-01	l
Waste polyethylene terephthalate	Treatment of waste polyethylene terephthalate, municipal incineration | waste polyethylene terephthalate | Cutoff, U-RoW	10.00E-03	kg

B6 Characterisation Results

In this section, the characterization results are presented with total impact in Table B27 below and in Figure B1 after that for all cases, followed by bar charts for each impact category with an explanation of the results.

Table B27: Characterisation results for all impact categories per functional unit

	AP (kg SO_2 eq/f.u.)		
	BAU	**Repair**	**OSH**
Production	05.44E-02	01.81E-02	03.78E-02
Distribution & retail	27.00E-04	09.80E-04	18.04E-04
Use	27.75E-04	27.90E-04	28.50E-04
Repair		04.45E-04	
Sorting & management			07.78E-04
Transportation	41.40E-04	96.60E-04	31.28E-04
Total	**06.40E-02**	**03.20E-02**	**04.48E-02**
	GWP (kg CO_2 eq/f.u.)		
	BAU	**Repair**	**OSH**
Production	10.35E+00	03.45E+00	06.90E+00
Distribution & retail	34.73E-02	12.35E-02	23.15E-02
Use	55.84E-02	56.02E-02	61.22E-02
Repair		09.71E-02	
Sorting & management			21.46E-02
Transportation	01.41E+00	03.29E+00	01.06E+00
Total	**12.67E+00**	**07.52E+00**	**09.02E+00**
	FAEP (kg DCB eq/f.u.)		
	BAU	**Repair**	**OSH**
Production	15.37E-02	05.12E-02	10.25E-02
Distribution & retail	08.40E-04	03.00E-04	05.60E-04
Use	63.75E-04	63.85E-04	70.29E-04
Repair		03.75E-04	
Sorting & management			07.56E-04
Transportation	49.95E-04	01.17E-02	37.62E-04
Total	**16.59E-02**	**06.99E-02**	**11.46E-02**
	HTP (kg DCB eq/f.u.)		
	BAU	**Repair**	**OSH**
Production	04.80E+00	01.60E+00	03.20E+00
Distribution & retail	60.79E-02	21.68E-02	40.52E-02
Use	01.89E+00	01.90E+00	01.92E+00
Repair		19.57E-02	
Sorting & management			32.15E-02
Transportation	01.28E+00	02.98E+00	96.40E-02
Total	**08.57E+00**	**06.89E+00**	**06.81E+00**
	AD (MJ/f.u.)		
	BAU	**Repair**	**OSH**

Continued on next page

Production	01.13E+02	37.57E+00	75.15E+00
Distribution & retail	03.47E+00	01.24E+00	02.31E+00
Use	05.92E+00	05.96E+00	06.95E+00
Repair		01.15E+00	
Sorting & management			02.59E+00
Transportation	17.40E+00	40.60E+00	13.12E+00
Total	**01.40E+02**	**86.52E+00**	**01.00E+02**
	EP (PO_4^{3-} eq/f.u.)		
	BAU	**Repair**	**OSH**
Production	05.78E-02	01.93E-02	03.85E-02
Distribution & retail	03.45E-04	01.20E-04	02.31E-04
Use	19.91E-04	19.84E-04	21.76E-04
Repair		01.56E-04	
Sorting & management			80.00E-06
Transportation	05.74E-04	13.40E-04	04.37E-04
Total	**06.07E-02**	**02.29E-02**	**04.15E-02**
	Land use (m^2*a crop-eq/f.u.)		
	BAU	**Repair**	**OSH**
Production	03.66E+00	01.22E+00	02.44E+00
Distribution & retail	12.24E-02	04.09E-02	08.16E-02
Use	10.89E-02	10.89E-02	11.94E-02
Repair		12.22E-02	
Sorting & management			36.13E-04
Transportation	03.05E-02	07.12E-02	02.30E-02
Total	**03.92E+00**	**01.56E+00**	**02.67E+00**
	ODP (CFC-11 eq/f.u.)		
	BAU	**Repair**	**OSH**
Production	17.90E-08	05.97E-08	11.94E-08
Distribution & retail	78.69E-10	28.15E-10	52.45E-10
Use	01.91E-08	01.91E-08	01.89E-08
Repair		23.07E-10	
Sorting & management			41.44E-10
Transportation	02.34E-08	05.46E-08	01.76E-08
Total	**22.94E-08**	**13.85E-08**	**16.53E-08**
	POP (kg C_2H_4 eq/f.u.)		
	BAU	**Repair**	**OSH**
Production	23.70E-04	07.90E-04	15.82E-04
Distribution & retail	01.65E-04	60.00E-06	01.07E-04
Use	03.68E-04	03.65E-04	04.06E-04
Repair		37.83E-06	
Sorting & management			62.22E-06
Transportation	03.97E-04	09.27E-04	03.00E-04
Total	**33.00E-04**	**21.80E-04**	**24.58E-04**
	Water use (m^3 /f.u.)		
	BAU	**Repair**	**OSH**
Production	02.50E+00	83.35E-02	01.67E+00
Distribution & retail	64.80E-04	23.40E-04	43.20E-04

Continued on next page

Use	03.31E-02	03.31E-02	03.41E-02
Repair		30.80E-04	
Sorting & management			48.58E-04
Transportation	41.25E-04	96.30E-04	30.97E-04
Total	**02.54E+00**	**88.07E-02**	**01.71E+00**

End of table

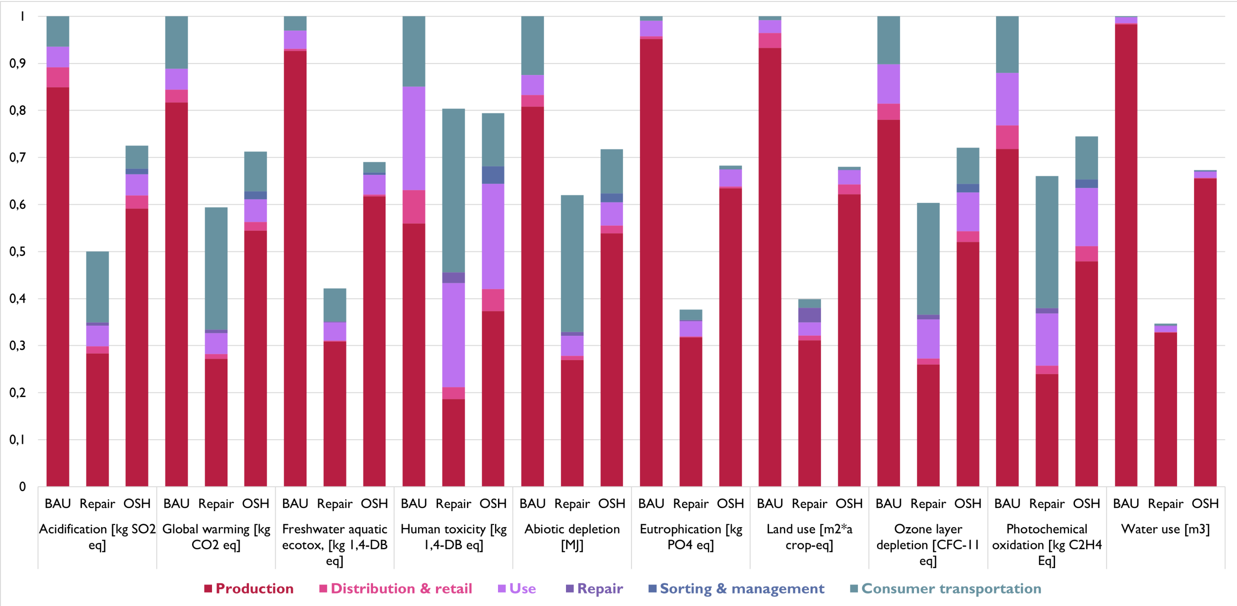

Figure B1: *Results for impact categories per f.u. normalized to business-as-usual*

C

Appendix: Sensitivity analysis

In this appendix, the characterization results following the sensitivity analysis are presented in tables and bar charts.

C1 Transportation mode

Impact for the different parts in the pants life cycle when changing the mode of transportation for all three models are shown in Table C1 below along with the total impact, followed by an illustration in Figure C1.

Table C1: Characterisation results for all impact categories per f.u. for sensitivity analysis of transportation mode

	AP (kg SO_2 eq/f.u.)					
	BAU	**BAU 100% car**	**Repair**	**Repair 100% car**	**OSH**	**OSH 100% car**
Production	05.44E-02	05.44E-02	01.81E-02	01.81E-02	03.62E-02	03.62E-02
Distribution & retail	27.00E-04	27.00E-04	09.80E-04	09.80E-04	18.04E-04	18.04E-04
Use	27.75E-04	27.75E-04	27.90E-04	27.90E-04	28.50E-04	28.50E-04
Repair			04.45E-04	04.45E-04		
Sorting & management					07.78E-04	07.78E-04
Transportation	41.40E-04	76.50E-04	96.60E-04	01.79E-02	31.28E-04	57.64E-04
Total	**06.40E-02**	**06.75E-02**	**03.20E-02**	**04.02E-02**	**04.48E-02**	**04.74E-02**
	GWP (kg CO_2 eq/f.u.)					
	BAU	**BAU 100% car**	**Repair**	**Repair 100% car**	**OSH**	**OSH 100% car**
Production	10.35E+00	10.35E+00	03.45E+00	03.45E+00	07.10E+00	07.10E+00
Distribution & retail	34.73E-02	34.73E-02	12.35E-02	12.35E-02	23.15E-02	23.15E-02
Use	55.84E-02	55.84E-02	56.02E-02	56.02E-02	61.22E-02	61.22E-02
Repair			09.71E-02	09.71E-02		
Sorting & management					17.17E-02	17.17E-02
Transportation	01.41E+00	02.80E+00	03.29E+00	06.54E+00	01.06E+00	02.11E+00
Total	12.67E+00	14.06E+00	07.52E+00	10.77E+00	09.02E+00	10.07E+00
	FAEP (kg DCB eq/f.u.)					
	BAU	**BAU 100% car**	**Repair**	**Repair 100% car**	**OSH**	**OSH 100% car**
Production	15.37E-02	15.37E-02	05.12E-02	05.12E-02	10.25E-02	10.25E-02
Distribution & retail	08.40E-04	08.40E-04	03.00E-04	03.00E-04	05.60E-04	05.60E-04
Use	63.75E-04	63.75E-04	63.85E-04	63.85E-04	70.29E-04	70.29E-04
Repair			03.75E-04	03.75E-04		
Sorting & management					07.56E-04	07.56E-04
Transportation	50.25E-04	01.12E-02	01.17E-02	02.61E-02	37.62E-04	84.44E-04
Total	16.59E-02	17.21E-02	06.99E-02	08.44E-02	11.46E-02	11.92E-02
	HTP (kg DCB eq/f.u.)					
	BAU	**BAU 100% car**	**Repair**	**Repair 100% car**	**OSH**	**OSH 100% car**
Production	04.80E+00	04.80E+00	01.60E+00	01.60E+00	03.20E+00	03.20E+00
Distribution & retail	60.79E-02	60.79E-02	21.68E-02	21.68E-02	40.52E-02	40.52E-02

Continued on next page

Use	01.89E+00	01.89E+00	01.90E+00	01.90E+00	01.92E+00	01.92E+00
Repair			19.57E-02	19.57E-02		
Sorting & management					32.15E-02	32.15E-02
Transportation	01.28E+00	02.69E+00	02.98E+00	06.28E+00	96.40E-02	02.03E+00
Total	08.57E+00	09.99E+00	06.89E+00	10.19E+00	06.81E+00	07.87E+00
AD (MJ/f.u.)						
	BAU	**BAU 100% car**	**Repair**	**Repair 100% car**	**OSH**	**OSH 100% car**
Production	01.13E+02	01.13E+02	37.57E+00	37.57E+00	75.15E+00	75.15E+00
Distribution & retail	03.47E+00	03.47E+00	01.24E+00	01.24E+00	02.31E+00	02.31E+00
Use	05.92E+00	05.92E+00	05.96E+00	05.96E+00	06.95E+00	06.95E+00
Repair			01.15E+00	01.15E+00		
Sorting & management					02.59E+00	02.59E+00
Transportation	17.40E+00	35.41E+00	40.60E+00	82.63E+00	13.12E+00	26.70E+00
Total	01.40E+02	01.58E+02	86.52E+00	01.29E+02	01.00E+02	01.14E+02
EP (PO_4^{3-} eq/f.u.)						
	BAU	**BAU 100% car**	**Repair**	**Repair 100% car**	**OSH**	**OSH 100% car**
Production	05.78E-02	05.78E-02	01.93E-02	01.93E-02	03.85E-02	03.85E-02
Distribution & retail	03.45E-04	03.45E-04	01.20E-04	01.20E-04	02.31E-04	02.31E-04
Use	19.91E-04	19.91E-04	19.84E-04	19.84E-04	21.76E-04	21.76E-04
Repair			01.56E-04	01.56E-04		
Sorting & management					80.00E-06	80.00E-06
Transportation	05.74E-04	10.95E-04	13.40E-04	25.55E-04	04.37E-04	08.25E-04
Total	06.07E-02	06.12E-02	02.29E-02	02.41E-02	04.15E-02	04.19E-02
Land use (m^2*a crop-eq/f.u.)						
	BAU	**BAU 100% car**	**Repair**	**Repair 100% car**	**OSH**	**OSH 100% car**
Production	03.66E+00	03.66E+00	01.22E+00	01.22E+00	02.44E+00	02.44E+00
Distribution & retail	12.24E-02	12.24E-02	04.09E-02	04.09E-02	08.16E-02	08.16E-02
Use	10.89E-02	10.89E-02	10.89E-02	10.89E-02	11.94E-02	11.94E-02
Repair			12.22E-02	12.22E-02		
Sorting & management					36.13E-04	36.13E-04
Transportation	03.05E-02	06.07E-02	07.12E-02	14.16E-02	02.30E-02	04.57E-02
Total	03.92E+00	03.95E+00	01.56E+00	01.63E+00	02.67E+00	02.69E+00
ODP (CFC-11 eq/f.u.)						
	BAU	**BAU 100% car**	**Repair**	**Repair 100% car**	**OSH**	**OSH 100% car**
Production	17.90E-08	17.90E-08	05.97E-08	05.97E-08	11.94E-08	11.94E-08
Distribution & retail	78.69E-10	78.69E-10	28.15E-10	28.15E-10	52.45E-10	52.45E-10
Use	01.91E-08	01.91E-08	01.91E-08	01.91E-08	01.89E-08	01.89E-08
Repair			23.07E-10	23.07E-10		
Sorting & management					41.44E-10	41.44E-10
Transportation	02.34E-08	05.12E-08	05.46E-08	11.94E-08	01.76E-08	03.86E-08
Total	22.94E-08	25.72E-08	13.85E-08	20.33E-08	16.53E-08	18.63E-08
POP (kg C_2H_4 eq/f.u.)						
	BAU	**BAU 100% car**	**Repair**	**Repair 100% car**	**OSH**	**OSH 100% car**
Production	23.70E-04	23.70E-04	07.90E-04	07.90E-04	15.82E-04	15.82E-04
Distribution & retail	01.65E-04	01.65E-04	60.00E-06	60.00E-06	01.07E-04	01.07E-04
Use	03.68E-04	03.68E-04	03.65E-04	03.65E-04	04.06E-04	04.06E-04
Repair			37.83E-06	37.83E-06		
Sorting & management					62.22E-06	62.22E-06
Transportation	03.97E-04	07.95E-04	09.27E-04	18.72E-04	03.00E-04	06.03E-04
Total	33.00E-04	37.05E-04	21.80E-04	32.10E-04	24.58E-04	27.60E-04
Water use (m^3 /f.u.)						
	BAU	**BAU 100% car**	**Repair**	**Repair 100% car**	**OSH**	**OSH 100% car**
Production	02.50E+00	02.50E+00	83.35E-02	83.35E-02	01.67E+00	01.67E+00
Distribution & retail	64.80E-04	64.80E-04	23.40E-04	23.40E-04	43.20E-04	43.20E-04
Use	03.31E-02	03.31E-02	03.31E-02	03.31E-02	03.41E-02	03.41E-02
Repair			30.80E-04	30.80E-04		
Sorting & management					48.58E-04	48.58E-04
Transportation	41.25E-04	69.30E-04	96.30E-04	01.62E-02	30.97E-04	52.27E-04
Total	02.54E+00	02.54E+00	88.07E-02	88.73E-02	01.71E+00	01.71E+00
End of table						

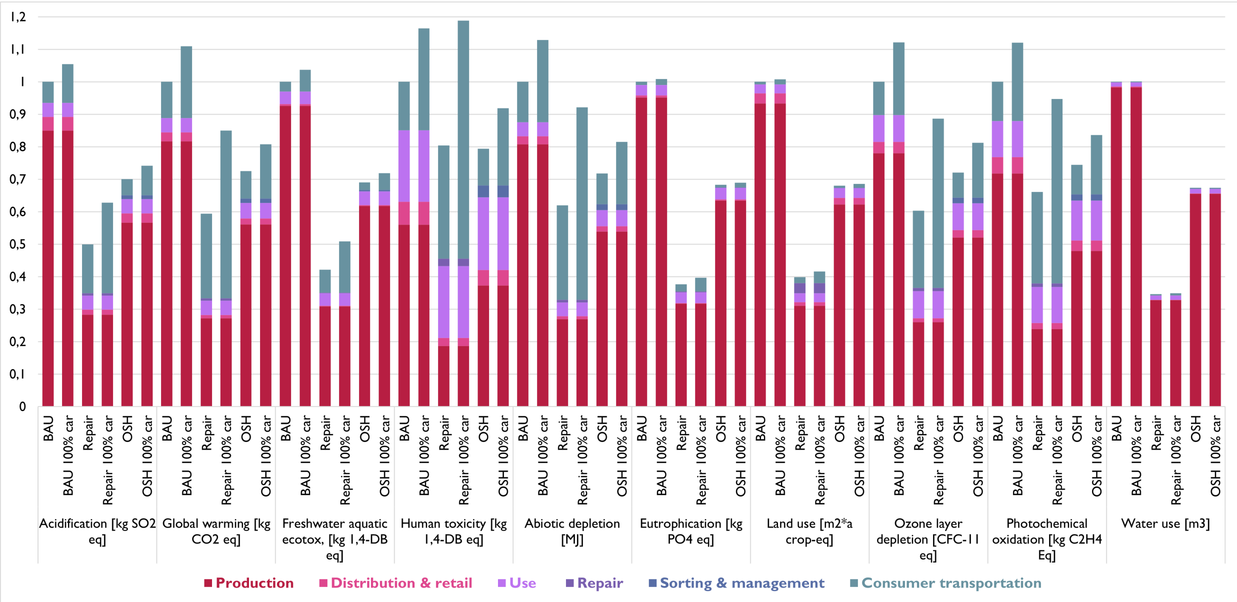

Figure C1: *Results for impact categories per f.u. for sensitivity analysis of transportation mode normalized to business-as-usual*

C2 Transportation distance

Impact for the different parts in the pants life cycle when changing the place of living for all three models are shown in Table C2 below along with the total impact, followed by an illustration in Figure C2.

Table C2: Characterisation results for all impact categories per f.u. for sensitivity analysis transportation distance

AP (kg SO_2 eq/f.u.)							
	BAU	**BAU smaller city**	**Repair**	**Repair smaller city**	**OSH**	**OSH smaller city**	**OSH other city**
Production	05.44E-02	05.44E-02	01.81E-02	01.81E-02	03.62E-02	03.62E-02	03.62E-02
Distribution & retail	27.00E-04	27.00E-04	09.80E-04	09.80E-04	18.04E-04	18.04E-04	19.33E-04
Use	27.75E-04	27.90E-04	27.90E-04	27.90E-04	28.50E-04	28.89E-04	29.08E-04
Repair			04.45E-04	04.45E-04			
Sorting & management					07.78E-04	08.04E-04	08.53E-04
Transportation	41.40E-04	97.50E-04	96.60E-04	02.28E-02	31.28E-04	75.82E-04	31.28E-04
Total	**06.40E-02**	**06.96E-02**	**03.20E-02**	**04.51E-02**	**04.48E-02**	**04.93E-02**	**04.51E-02**
GWP (kg CO_2 eq/f.u.)							
	BAU	**BAU smaller city**	**Repair**	**Repair smaller city**	**OSH**	**OSH smaller city**	**OSH other city**
Production	10.35E+00	10.35E+00	03.45E+00	03.45E+00	07.10E+00	07.10E+00	07.10E+00
Distribution & retail	34.73E-02	34.73E-02	12.35E-02	12.35E-02	23.15E-02	23.15E-02	29.56E-02
Use	55.84E-02	56.57E-02	56.02E-02	56.35E-02	61.22E-02	62.43E-02	62.70E-02
Repair			09.71E-02	09.74E-02			
Sorting & management					21.46E-02	22.08E-02	25.51E-02

Continued on next page

	BAU	BAU kullavik	Repair	Repair kullavik	OSH	OSH Kullavik	OSH Stockholm
Transportation	01.41E+00	03.32E+00	03.29E+00	07.75E+00	01.06E+00	02.40E+00	01.08E+00
Total	**12.67E+00**	**14.58E+00**	**07.52E+00**	**11.98E+00**	**09.02E+00**	**10.56E+00**	**09.16E+00**

FAEP (kg DCB eq/f.u.)

	BAU	BAU kullavik	Repair	Repair kullavik	OSH	OSH Kullavik	OSH Stock-holm
Production	15.37E-02	15.37E-02	05.12E-02	05.12E-02	10.25E-02	10.25E-02	10.25E-02
Distribution & retail	08.40E-04	08.40E-04	03.00E-04	03.00E-04	05.60E-04	05.60E-04	07.16E-04
Use	63.75E-04	64.05E-04	63.85E-04	64.10E-04	70.29E-04	70.52E-04	70.28E-04
Repair			03.75E-04	03.90E-04			
Sorting & management					07.56E-04	07.60E-04	08.93E-04
Transportation	49.95E-04	01.17E-02	01.17E-02	02.74E-02	37.62E-04	91.30E-04	38.56E-04
Total	**16.59E-02**	**17.27E-02**	**06.99E-02**	**08.57E-02**	**11.46E-02**	**12.00E-02**	**11.49E-02**

HTP (kg DCB eq/f.u.)

	BAU	BAU kullavik	Repair	Repair kullavik	OSH	OSH Kullavik	OSH Stock-holm
Production	04.80E+00	04.80E+00	01.60E+00	01.60E+00	03.20E+00	03.20E+00	03.20E+00
Distribution & retail	60.79E-02	60.79E-02	21.68E-02	21.68E-02	40.52E-02	40.52E-02	43.43E-02
Use	01.89E+00	01.89E+00	01.90E+00	01.90E+00	01.92E+00	01.92E+00	01.92E+00
Repair			19.57E-02	19.58E-02			
Sorting & management					32.15E-02	32.52E-02	34.18E-02
Transportation	01.28E+00	03.01E+00	02.98E+00	07.02E+00	96.40E-02	02.34E+00	97.00E-02
Total	**08.57E+00**	**10.31E+00**	**06.89E+00**	**10.93E+00**	**06.81E+00**	**08.19E+00**	**06.87E+00**

AD (MJ/f.u.)

	BAU	BAU kullavik	Repair	Repair kullavik	OSH	OSH Kullavik	OSH Stock-holm
Production	01.13E+02	01.13E+02	37.57E+00	37.57E+00	75.15E+00	75.15E+00	75.15E+00
Distribution & retail	03.47E+00	03.47E+00	01.24E+00	01.24E+00	02.31E+00	02.31E+00	03.17E+00
Use	05.92E+00	06.02E+00	05.96E+00	06.00E+00	06.95E+00	07.10E+00	07.09E+00
Repair			01.15E+00	01.15E+00			
Sorting & management					02.59E+00	02.68E+00	03.16E+00
Transportation	17.40E+00	40.94E+00	40.60E+00	95.54E+00	13.12E+00	31.85E+00	13.38E+00
Total	**01.40E+02**	**01.63E+02**	**86.52E+00**	**01.41E+02**	**01.00E+02**	**01.19E+02**	**01.02E+02**

EP (PO_4^{3-} eq/f.u.)

	BAU	BAU kullavik	Repair	Repair kullavik	OSH	OSH Kullavik	OSH Stock-holm
Production	05.78E-02	05.78E-02	01.93E-02	01.93E-02	03.85E-02	03.85E-02	03.85E-02
Distribution & retail	03.45E-04	03.45E-04	01.20E-04	01.20E-04	02.31E-04	02.31E-04	02.49E-04
Use	19.91E-04	19.95E-04	19.84E-04	19.80E-04	21.76E-04	21.58E-04	21.58E-04
Repair			01.56E-04	01.50E-04			
Sorting & management					80.00E-06	84.44E-06	88.89E-06
Transportation	05.74E-04	13.65E-04	13.40E-04	31.85E-04	04.37E-04	10.64E-04	04.37E-04
Total	**06.07E-02**	**06.15E-02**	**02.29E-02**	**02.47E-02**	**04.15E-02**	**04.21E-02**	**04.15E-02**

Land use (m^2*a crop-eq/f.u.)

	BAU	BAU kullavik	Repair	Repair kullavik	OSH	OSH Kullavik	OSH Stock-holm
Production	03.66E+00	03.66E+00	01.22E+00	01.22E+00	02.44E+00	02.44E+00	02.44E+00
Distribution & retail	12.24E-02	12.24E-02	04.09E-02	04.09E-02	08.16E-02	08.16E-02	08.32E-02
Use	10.89E-02	10.91E-02	10.89E-02	10.90E-02	11.94E-02	11.97E-02	11.97E-02
Repair			12.22E-02	12.23E-02			
Sorting & management					36.13E-04	37.82E-04	51.82E-04
Transportation	03.05E-02	07.18E-02	07.12E-02	16.75E-02	02.30E-02	05.58E-02	02.39E-02

Continued on next page

Total	**03.92E+00**	**03.96E+00**	**01.56E+00**	**01.66E+00**	**02.67E+00**	**02.70E+00**	**02.67E+00**
ODP (CFC-11 eq/f.u.)							
	BAU	**BAU kullavik**	**Repair**	**Repair kullavik**	**OSH**	**OSH Kullavik**	**OSH Stock-holm**
Production	17.90E-08	17.90E-08	05.97E-08	05.97E-08	11.94E-08	11.94E-08	11.94E-08
Distribution & retail	78.69E-10	78.69E-10	28.15E-10	28.15E-10	52.45E-10	52.45E-10	60.41E-10
Use	01.91E-08	01.92E-08	01.91E-08	01.92E-08	01.89E-08	01.91E-08	01.90E-08
Repair			23.07E-10	23.09E-10			
Sorting & man-agement					41.44E-10	42.54E-10	46.58E-10
Transportation	02.34E-08	05.50E-08	05.46E-08	12.84E-08	01.76E-08	04.28E-08	01.79E-08
Total	**22.94E-08**	**26.11E-08**	**13.85E-08**	**21.24E-08**	**16.53E-08**	**19.08E-08**	**16.70E-08**
POP (kg C_2H_4 eq/f.u.)							
	BAU	**BAU kullavik**	**Repair**	**Repair kullavik**	**OSH**	**OSH Kullavik**	**OSH Stock-holm**
Production	23.70E-04	23.70E-04	07.90E-04	07.90E-04	15.82E-04	15.82E-04	15.82E-04
Distribution & retail	01.65E-04	01.65E-04	60.00E-06	60.00E-06	01.07E-04	01.07E-04	01.16E-04
Use	03.68E-04	03.72E-04	03.65E-04	03.71E-04	04.06E-04	04.13E-04	04.09E-04
Repair			37.83E-06	32.26E-06			
Sorting & man-agement					62.22E-06	71.11E-06	71.11E-06
Transportation	03.97E-04	09.33E-04	09.27E-04	21.76E-04	03.00E-04	07.21E-04	03.02E-04
Total	**33.00E-04**	**38.40E-04**	**21.80E-04**	**34.30E-04**	**24.58E-04**	**28.93E-04**	**24.80E-04**
Water use (m^3 /f.u.)							
	BAU	**BAU kullavik**	**Repair**	**Repair kullavik**	**OSH**	**OSH Kullavik**	**OSH Stock-holm**
Production	02.50E+00	02.50E+00	83.26E-02	83.26E-02	01.67E+00	01.67E+00	01.67E+00
Distribution & retail	64.80E-04	64.80E-04	23.40E-04	23.40E-04	43.20E-04	43.20E-04	44.27E-04
Use	03.31E-02	03.31E-02	03.31E-02	03.31E-02	03.41E-02	03.41E-02	03.42E-02
Repair			30.80E-04	30.85E-04			
Sorting & man-agement					48.58E-04	48.71E-04	49.20E-04
Transportation	41.25E-04	96.90E-04	96.25E-04	02.26E-02	30.97E-04	75.29E-04	30.97E-04
Total	**02.54E+00**	**02.55E+00**	**88.07E-02**	**89.37E-02**	**01.71E+00**	**01.72E+00**	**01.71E+00**

End of table

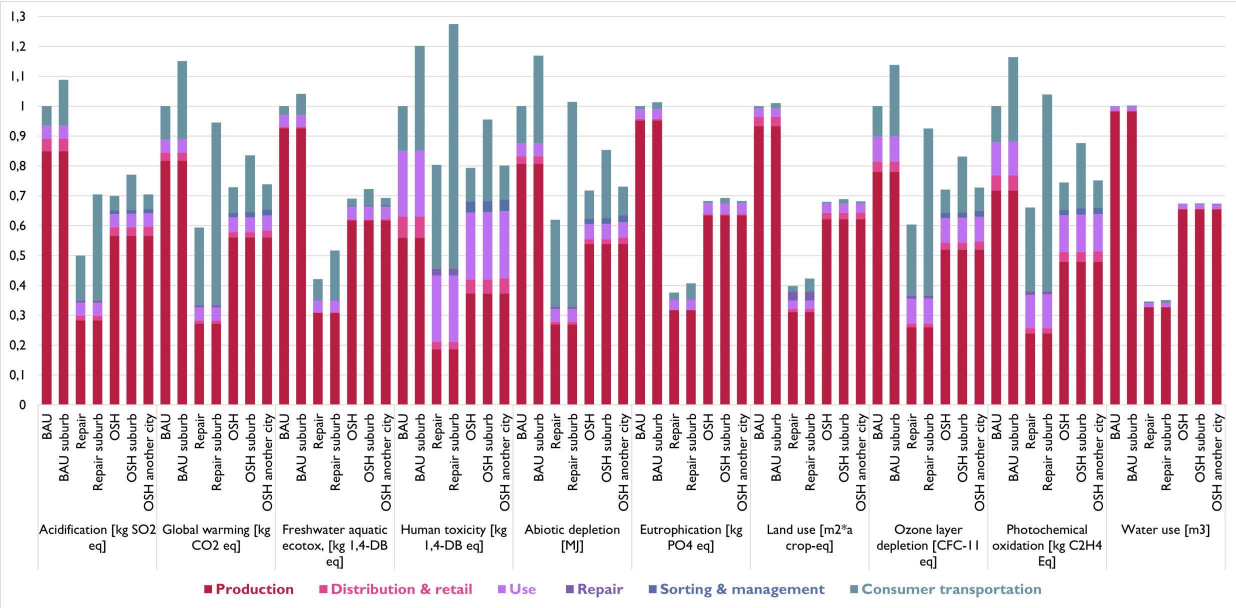

Figure C2: *Results for impact categories per f.u. for sensitivity analysis transportation distance normalized to business-as-usual*

C3 Number of uses after repair

Impact for the different parts in the pants life cycle when changing the number of uses after repair are shown in Table C3 below along with the total impact, followed by an illustration in Figure C3.

Table C3: Characterisation results for all impact categories per f.u. for sensitivity analysis of the number of uses after repair

	AP (kg SO_2 eq/f.u.)			
	BAU	**Repair**	**Repair-once**	**OSH**
Production	05.44E-02	01.81E-02	03.11E-02	03.62E-02
Distribution & retail	27.00E-04	09.80E-04	16.80E-04	18.04E-04
Use	27.75E-04	27.90E-04	27.77E-04	28.50E-04
Repair		04.45E-04	02.57E-04	
Sorting & management				07.78E-04
Transportation	41.40E-04	96.60E-04	70.97E-04	31.28E-04
Total	**06.40E-02**	**03.20E-02**	**04.69E-02**	**04.48E-02**
	GWP (kg CO_2 eq/f.u.)			
	BAU	**Repair**	**Repair-once**	**OSH**
Production	10.35E+00	03.45E+00	05.91E+00	07.10E+00
Distribution & retail	34.73E-02	12.35E-02	21.16E-02	23.15E-02
Use	55.84E-02	56.02E-02	55.87E-02	61.22E-02
Repair		09.71E-02	05.55E-02	
Sorting & management				17.17E-02
Transportation	01.41E+00	03.29E+00	02.42E+00	01.06E+00
Total	**12.67E+00**	**07.52E+00**	**10.75E+00**	**09.02E+00**
	FAEP (kg DCB eq/f.u.)			

Continued on next page

	BAU	Repair	Repair-once	OSH
Production	15.37E-02	05.12E-02	08.78E-02	10.25E-02
Distribution & retail	08.40E-04	03.00E-04	05.14E-04	05.60E-04
Use	63.75E-04	63.85E-04	63.77E-04	70.29E-04
Repair		03.75E-04	02.14E-04	
Sorting & management				07.56E-04
Transportation	50.25E-04	01.17E-02	86.40E-04	37.62E-04
Total	**16.59E-02**	**06.99E-02**	**11.06E-02**	**11.46E-02**
		HTP (kg DCB eq/f.u.)		
	BAU	**Repair**	**Repair-once**	**OSH**
Production	04.80E+00	01.60E+00	02.74E+00	03.20E+00
Distribution & retail	60.79E-02	21.68E-02	37.17E-02	40.52E-02
Use	01.89E+00	01.90E+00	01.89E+00	01.92E+00
Repair		19.57E-02	11.18E-02	
Sorting & management				32.15E-02
Transportation	01.28E+00	02.98E+00	02.19E+00	96.40E-02
Total	**08.57E+00**	**06.89E+00**	**08.92E+00**	**06.81E+00**
		AD (MJ/f.u.)		
	BAU	**Repair**	**Repair-once**	**OSH**
Production	01.13E+02	37.57E+00	64.41E+00	75.15E+00
Distribution & retail	03.47E+00	01.24E+00	02.12E+00	02.31E+00
Use	05.92E+00	05.96E+00	05.93E+00	06.95E+00
Repair		01.15E+00	65.67E-02	
Sorting & management				02.59E+00
Transportation	17.40E+00	40.60E+00	29.83E+00	13.12E+00
Total	**01.40E+02**	**86.52E+00**	**01.24E+02**	**01.00E+02**
		EP (PO_4^{3-} eq/f.u.)		
	BAU	**Repair**	**Repair-once**	**OSH**
Production	05.78E-02	01.93E-02	03.30E-02	03.85E-02
Distribution & retail	03.45E-04	01.20E-04	02.06E-04	02.31E-04
Use	19.91E-04	19.84E-04	19.84E-04	21.76E-04
Repair		01.56E-04	91.81E-06	
Sorting & management				80.00E-06
Transportation	05.74E-04	13.40E-04	09.85E-04	04.37E-04
Total	**06.07E-02**	**02.29E-02**	**03.69E-02**	**04.15E-02**
		Land use (m^2*a crop-eq/f.u.)		
	BAU	**Repair**	**Repair-once**	**OSH**
Acidification [kg SO2 eq]	Linear	Repair	Repair- one time	OSH
Production	03.66E+00	01.22E+00	02.09E+00	02.44E+00
Distribution & retail	12.24E-02	04.09E-02	07.01E-02	08.16E-02
Use	10.89E-02	10.89E-02	10.89E-02	11.94E-02
Repair		12.22E-02	06.98E-02	
Sorting & management				36.13E-04
Transportation	03.05E-02	07.12E-02	05.23E-02	02.30E-02
Total	**03.92E+00**	**01.56E+00**	**02.43E+00**	**02.67E+00**
		ODP (CFC-11 eq/f.u.)		
	BAU	**Repair**	**Repair-once**	**OSH**
Production	17.90E-08	05.97E-08	10.23E-08	11.94E-08
Distribution & retail	78.69E-10	28.15E-10	48.27E-10	52.45E-10
Use	01.91E-08	01.91E-08	01.91E-08	01.89E-08
Repair		23.07E-10	13.19E-10	
Sorting & management				41.44E-10

Continued on next page

	BAU	Repair	Repair-once	OSH
Transportation	02.34E-08	05.46E-08	04.01E-08	01.76E-08
Total	**22.94E-08**	**13.85E-08**	**19.94E-08**	**16.53E-08**
	POP (kg C_2H_4 eq/f.u.)			
	BAU	**Repair**	**Repair-once**	**OSH**
Production	23.70E-04	07.90E-04	13.54E-04	15.82E-04
Distribution & retail	01.65E-04	60.00E-06	01.03E-04	01.07E-04
Use	03.68E-04	03.65E-04	03.69E-04	04.06E-04
Repair		37.83E-06	21.62E-06	
Sorting & management				62.22E-06
Transportation	03.97E-04	09.27E-04	06.81E-04	03.00E-04
Total	**33.00E-04**	**21.80E-04**	**29.83E-04**	**24.58E-04**
	Water use (m^3 /f.u.)			
	BAU	**Repair**	**Repair-once**	**OSH**
Production	02.50E+00	83.35E-02	01.43E+00	01.67E+00
Distribution & retail	64.80E-04	23.40E-04	40.11E-04	43.20E-04
Use	03.31E-02	03.31E-02	03.31E-02	03.41E-02
Repair		30.80E-04	17.57E-04	
Sorting & management				48.58E-04
Transportation	19.65E-04	96.30E-04	70.71E-04	30.97E-04
Total	**02.54E+00**	**88.07E-02**	**01.48E+00**	**01.71E+00**
	End of table			

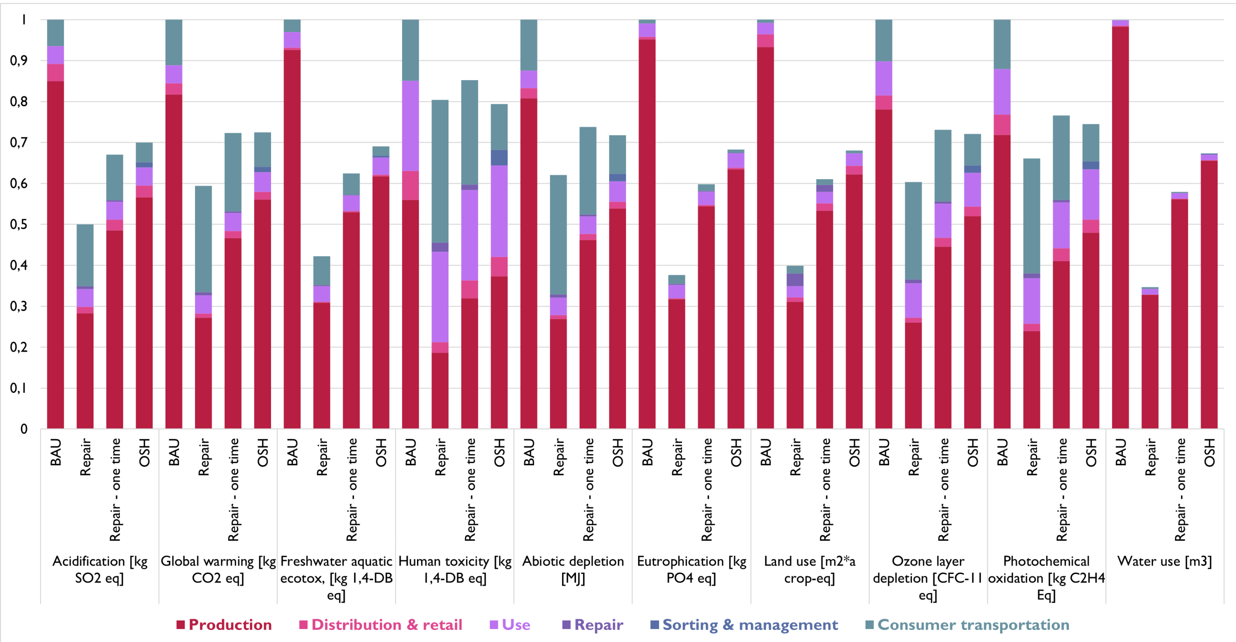

Figure C3: *Results for impact categories per f.u. for sensitivity analysis of the number of uses after repair normalized to business-as-usual*

C4 Ratio of sold pants in online second-hand

Impact for the different parts in the pants life cycle when changing the ratio of sold pants in OSH are shown in Table C4 below along with the total impact, followed by an illustration in Figure C4.

Table C4: Characterisation results for all impact categories per f.u. for sensitivity analysis of ratio of sold pants in OSH

	BAU	Repair	OSH	OSH 80% donated	OSH 80% incinerated	OSH user-user
AP (kg SO_2 eq/f.u.)						
Production	05.44E-02	01.81E-02	03.62E-02	03.62E-02	15.99E-02	03.62E-02
Distribution & retail	27.00E-04	09.80E-04	18.04E-04	18.03E-04	79.54E-04	18.00E-04
Use	27.75E-04	27.90E-04	28.50E-04	21.30E-04	35.21E-04	35.13E-04
Repair		04.45E-04				
Sorting & management			07.78E-04	07.06E-04	20.31E-04	
Transportation	41.40E-04	96.60E-04	31.28E-04	28.42E-04	01.25E-02	40.67E-04
Total	**06.40E-02**	**03.20E-02**	**04.48E-02**	**04.37E-02**	**18.59E-02**	**04.56E-02**
GWP (kg CO_2 eq/f.u.)						
	BAU	**Repair**	**OSH**	**OSH 80% donated**	**OSH 80% incinerated**	**OSH user-user**
Production	10.35E+00	03.45E+00	07.10E+00	06.90E+00	30.44E+00	06.90E+00
Distribution & retail	34.73E-02	12.35E-02	23.15E-02	23.15E-02	01.02E+00	23.15E-02
Use	55.84E-02	56.02E-02	61.22E-02	43.89E-02	74.58E-02	79.32E-02
Repair		09.71E-02				
Sorting & management			21.46E-02	18.37E-02	58.15E-02	
Transportation	01.41E+00	03.29E+00	01.06E+00	96.73E-02	04.27E+00	01.38E+00
Total	**12.67E+00**	**07.52E+00**	**09.02E+00**	**08.72E+00**	**37.06E+00**	**09.31E+00**
FAEP (kg DCB eq/f.u.)						
	BAU	**Repair**	**OSH**	**OSH 80% donated**	**OSH 80% incinerated**	**OSH user-user**
Production	15.37E-02	05.12E-02	10.25E-02	10.25E-02	45.20E-02	10.25E-02
Distribution & retail	08.40E-04	03.00E-04	05.60E-04	05.60E-04	24.69E-04	05.60E-04
Use	63.75E-04	63.85E-04	70.29E-04	58.03E-04	80.03E-04	77.89E-04
Repair		03.75E-04				
Sorting & management			07.56E-04	06.38E-04	20.84E-04	
Transportation	49.95E-04	01.17E-02	37.62E-04	34.20E-04	01.51E-02	49.01E-04
Total	**16.59E-02**	**06.99E-02**	**11.46E-02**	**11.29E-02**	**47.97E-02**	**11.57E-02**
HTP (kg DCB eq/f.u.)						
	BAU	**Repair**	**OSH**	**OSH 80% donated**	**OSH 80% incinerated**	**OSH user-user**
Production	04.80E+00	01.60E+00	03.20E+00	03.20E+00	14.12E+00	03.20E+00
Distribution & retail	60.79E-02	21.68E-02	40.52E-02	40.52E-02	01.79E+00	40.52E-02
Use	01.89E+00	01.90E+00	01.92E+00	01.52E+00	02.33E+00	02.21E+00
Repair		19.57E-02				
Sorting & management			32.15E-02	30.31E-02	75.09E-02	
Transportation	01.28E+00	02.98E+00	96.40E-02	87.66E-02	03.87E+00	01.25E+00

Continued on next page

Total	**08.57E+00**	**06.89E+00**	**06.81E+00**	**06.31E+00**	**22.85E+00**	**07.07E+00**
AD (MJ/f.u.)						
	BAU	**Repair**	**OSH**	**OSH 80% donated**	**OSH 80% inciner-ated**	**OSH user-user**
Production	01.13E+02	37.57E+00	75.15E+00	75.15E+00	03.32E+02	75.15E+00
Distribution & retail	03.47E+00	01.24E+00	02.31E+00	02.31E+00	10.20E+00	02.31E+00
Use	05.92E+00	05.96E+00	06.95E+00	04.92E+00	08.24E+00	09.11E+00
Repair		01.15E+00				
Sorting & man-agement			02.59E+00	02.14E+00	07.23E+00	
Transportation	17.40E+00	40.60E+00	13.12E+00	11.93E+00	52.63E+00	17.06E+00
Total	**01.40E+02**	**86.52E+00**	**01.00E+02**	**96.45E+00**	**04.10E+02**	**01.04E+02**
EP (PO_4^{3-} eq/f.u.)						
	BAU	**Repair**	**OSH**	**OSH 80% donated**	**OSH 80% inciner-ated**	**OSH user-user**
Production	05.78E-02	01.93E-02	03.85E-02	03.85E-02	17.01E-02	03.86E-02
Distribution & retail	03.45E-04	01.20E-04	02.31E-04	02.31E-04	10.20E-04	02.30E-04
Use	19.91E-04	19.84E-04	21.76E-04	18.45E-04	24.09E-04	22.92E-04
Repair		01.56E-04				
Sorting & man-agement			80.00E-06	69.20E-06	02.74E-04	
Transportation	05.74E-04	13.40E-04	04.37E-04	03.98E-04	17.56E-04	05.68E-04
Total	**06.07E-02**	**02.29E-02**	**04.15E-02**	**04.11E-02**	**17.55E-02**	**04.16E-02**
Land use (m^2*a crop-eq/f.u.)						
	BAU	**Repair**	**OSH**	**OSH 80% donated**	**OSH 80% inciner-ated**	**OSH user-user**
Production	03.66E+00	01.22E+00	02.44E+00	02.44E+00	10.76E+00	02.44E+00
Distribution & retail	12.24E-02	04.09E-02	08.16E-02	08.16E-02	35.99E-02	08.16E-02
Use	10.89E-02	10.89E-02	11.94E-02	10.28E-02	13.33E-02	12.70E-02
Repair		12.22E-02				
Sorting & man-agement			36.13E-04	30.53E-04	99.26E-04	
Transportation	03.05E-02	07.12E-02	02.30E-02	02.09E-02	09.23E-02	02.99E-02
Total	**03.92E+00**	**01.56E+00**	**02.67E+00**	**02.65E+00**	**11.36E+00**	**02.68E+00**
ODP (CFC-11 eq/f.u.)						
	BAU	**Repair**	**OSH**	**OSH 80% donated**	**OSH 80% inciner-ated**	**OSH user-user**
Production	17.90E-08	05.97E-08	11.94E-08	11.94E-08	52.66E-08	11.94E-08
Distribution & retail	78.69E-10	28.15E-10	52.45E-10	52.46E-10	02.31E-08	52.46E-10
Use	01.91E-08	01.91E-08	01.89E-08	01.46E-08	02.35E-08	02.28E-08
Repair		23.07E-10				
Sorting & man-agement			41.44E-10	39.15E-10	01.01E-08	
Transportation	02.34E-08	05.46E-08	01.76E-08	01.60E-08	07.07E-08	02.29E-08
Total	**22.94E-08**	**13.85E-08**	**16.53E-08**	**15.92E-08**	**65.41E-08**	**17.03E-08**

Continued on next page

POP (kg C_2H_4 eq/f.u.)						
	BAU	**Repair**	**OSH**	**OSH 80% donated**	**OSH 80% incinerated**	**OSH user-user**
Production	23.70E-04	07.90E-04	15.82E-04	15.84E-04	69.88E-04	15.80E-04
Distribution & retail	01.65E-04	60.00E-06	01.07E-04	01.04E-04	04.57E-04	01.10E-04
Use	03.68E-04	03.65E-04	04.06E-04	03.27E-04	04.67E-04	04.68E-04
Repair		37.83E-06				
Sorting & management			62.22E-06	54.00E-06	01.87E-04	
Transportation	03.97E-04	09.27E-04	03.00E-04	02.71E-04	11.97E-04	03.92E-04
Total	**33.00E-04**	**21.80E-04**	**24.58E-04**	**23.40E-04**	**92.96E-04**	**25.50E-04**

Water use (m^3 /f.u.)						
	BAU	**Repair**	**OSH**	**OSH 80% donated**	**OSH 80% incinerated**	**OSH user-user**
Production	02.50E+00	83.26E-02	01.67E+00	01.67E+00	07.35E+00	01.67E+00
Distribution & retail	64.80E-04	23.40E-04	43.20E-04	43.22E-04	79.08E-04	43.20E-04
Use	03.31E-02	03.31E-02	03.41E-02	02.76E-02	04.06E-02	03.86E-02
Repair		30.80E-04				
Sorting & management			48.58E-04	45.12E-04	01.22E-02	
Transportation	41.25E-04	96.25E-04	30.97E-04	28.20E-04	01.24E-02	40.29E-04
Total	**02.54E+00**	**88.07E-02**	**01.71E+00**	**01.70E+00**	**07.43E+00**	**01.71E+00**

End of table

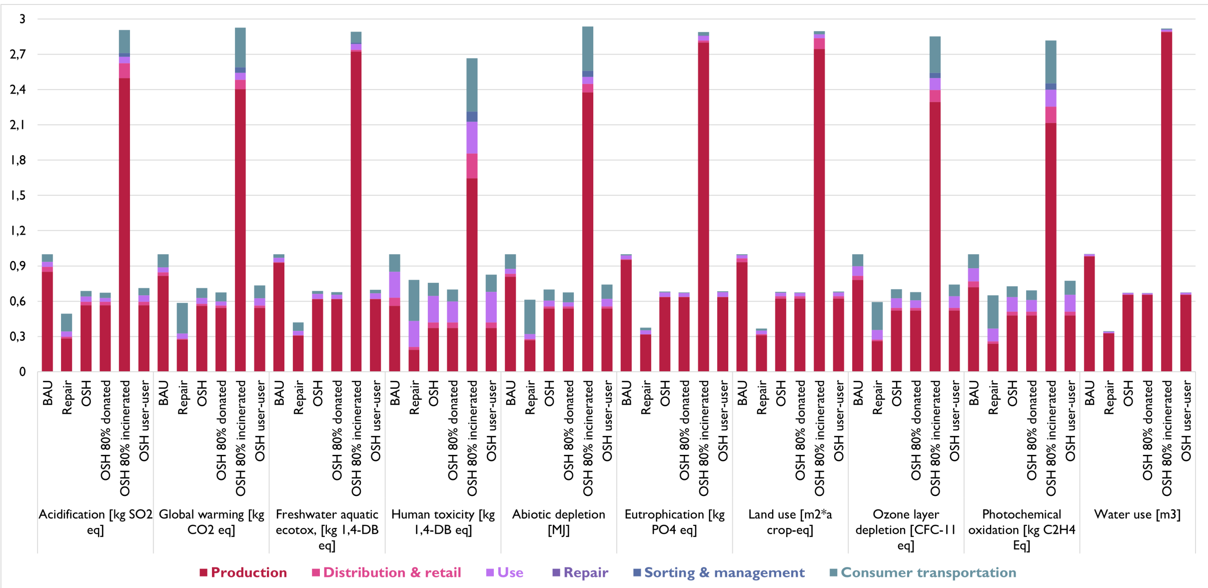

Figure C4: *Results for impact categories per f.u. for sensitivity analysis of the ratio of sold pants in OSH normalized to business-as-usual*

C5 Linear use

Impact for the different parts in the pants life cycle when changing the total uses for the linear model are shown in Table C5 below along with the total impact, followed by an illustration in Figure C5.

Table C5: Characterisation results for all impact categories per f.u. for sensitivity analysis of full usage for business-as-usual

		AP (kg SO_2 eq/f.u.)		
	BAU	**BAU full use**	**Repair**	**OSH**
Production	05.44E-02	03.62E-02	01.81E-02	03.78E-02
Distribution & retail	27.00E-04	18.00E-04	09.80E-04	18.04E-04
Use	27.75E-04	18.50E-04	27.90E-04	28.50E-04
Repair			04.45E-04	
Sorting & management				07.78E-04
Transportation	41.40E-04	27.60E-04	96.60E-04	31.28E-04
Total	**06.40E-02**	**04.27E-02**	**03.20E-02**	**04.48E-02**
		GWP (kg CO_2 eq/f.u.)		
	BAU	**BAU full use**	**Repair**	**OSH**
Production	10.35E+00	06.90E+00	03.45E+00	06.90E+00
Distribution & retail	34.73E-02	23.15E-02	12.35E-02	23.15E-02
Use	55.84E-02	37.23E-02	56.02E-02	61.22E-02
Repair			09.71E-02	
Sorting & management				21.46E-02
Transportation	01.41E+00	94.07E-02	03.29E+00	01.06E+00
Total	**12.67E+00**	**08.45E+00**	**07.52E+00**	**09.02E+00**
		FAEP (kg DCB eq/f.u.)		
	BAU	**BAU full use**	**Repair**	**OSH**
Production	15.37E-02	10.25E-02	05.12E-02	10.25E-02
Distribution & retail	08.40E-04	05.60E-04	03.00E-04	05.60E-04
Use	63.75E-04	42.50E-04	63.85E-04	70.29E-04
Repair			03.75E-04	
Sorting & management				07.56E-04
Transportation	49.95E-04	35.30E-04	01.17E-02	37.62E-04
Total	**16.59E-02**	**11.06E-02**	**06.99E-02**	**11.46E-02**
		HTP (kg DCB eq/f.u.)		
	BAU	**BAU full use**	**Repair**	**OSH**
Production	04.80E+00	03.20E+00	01.60E+00	03.20E+00
Distribution & retail	60.79E-02	40.52E-02	21.68E-02	40.52E-02
Use	01.89E+00	01.26E+00	01.90E+00	01.92E+00
Repair			19.57E-02	
Sorting & management				32.15E-02
Transportation	01.28E+00	85.25E-02	02.98E+00	96.40E-02
Total	**08.57E+00**	**05.71E+00**	**06.89E+00**	**06.81E+00**
		AD (MJ/f.u.)		
	BAU	**BAU full use**	**Repair**	**OSH**
Production	01.13E+02	75.15E+00	37.57E+00	75.15E+00
Distribution & retail	03.47E+00	02.31E+00	01.24E+00	02.31E+00
Use	05.92E+00	03.95E+00	05.96E+00	06.95E+00
Repair			01.15E+00	
Sorting & management				02.59E+00

Continued on next page

Transportation	17.40E+00	11.60E+00	40.60E+00	13.12E+00
Total	**01.40E+02**	**93.01E+00**	**86.52E+00**	**01.00E+02**
	EP (PO_4^{3-} eq/f.u.)			
	BAU	**BAU full use**	**Repair**	**OSH**
Production	05.78E-02	03.86E-02	01.93E-02	03.85E-02
Distribution & retail	03.45E-04	02.30E-04	01.20E-04	02.31E-04
Use	19.91E-04	13.27E-04	19.84E-04	21.76E-04
Repair			01.56E-04	
Sorting & management				80.00E-06
Transportation	05.74E-04	09.07E-04	13.40E-04	04.37E-04
Total	**06.07E-02**	**04.05E-02**	**02.29E-02**	**04.15E-02**
	Land use (m^2*a crop-eq/f.u.)			
	BAU	**BAU full use**	**Repair**	**OSH**
Production	03.66E+00	02.44E+00	01.22E+00	02.44E+00
Distribution & retail	12.24E-02	08.16E-02	04.09E-02	08.16E-02
Use	10.89E-02	07.26E-02	10.89E-02	11.94E-02
Repair			12.22E-02	
Sorting & management				36.13E-04
Transportation	03.05E-02	07.19E-02	07.12E-02	02.30E-02
Total	**03.92E+00**	**02.61E+00**	**01.56E+00**	**02.67E+00**
	ODP (CFC-11 eq/f.u.)			
	BAU	**BAU full use**	**Repair**	**OSH**
Production	17.90E-08	11.94E-08	05.97E-08	11.94E-08
Distribution & retail	78.69E-10	52.46E-10	28.15E-10	52.45E-10
Use	01.91E-08	01.27E-08	01.91E-08	01.89E-08
Repair			23.07E-10	
Sorting & management				41.44E-10
Transportation	02.34E-08	01.56E-08	05.46E-08	01.76E-08
Total	**22.94E-08**	**15.29E-08**	**13.85E-08**	**16.53E-08**
	POP (kg C_2H_4 eq/f.u.)			
	BAU	**BAU full use**	**Repair**	**OSH**
Production	23.70E-04	15.80E-04	07.90E-04	15.82E-04
Distribution & retail	01.65E-04	01.10E-04	60.00E-06	01.07E-04
Use	03.68E-04	02.45E-04	03.65E-04	04.06E-04
Repair			37.83E-06	
Sorting & management				62.22E-06
Transportation	03.97E-04	02.65E-04	09.27E-04	03.00E-04
Total	**33.00E-04**	**22.00E-04**	**21.80E-04**	**24.58E-04**
	Water use (m^3 /f.u.)			
	BAU	**BAU full use**	**Repair**	**OSH**
Production	02.50E+00	01.67E+00	83.35E-02	01.67E+00
Distribution & retail	64.80E-04	43.20E-04	23.40E-04	43.20E-04
Use	03.31E-02	02.20E-02	03.31E-02	03.41E-02
Repair			30.80E-04	
Sorting & management				48.58E-04
Transportation	41.25E-04	90.50E-04	96.30E-04	30.97E-04
Total	**02.54E+00**	**01.69E+00**	**88.07E-02**	**01.71E+00**
	End of table			

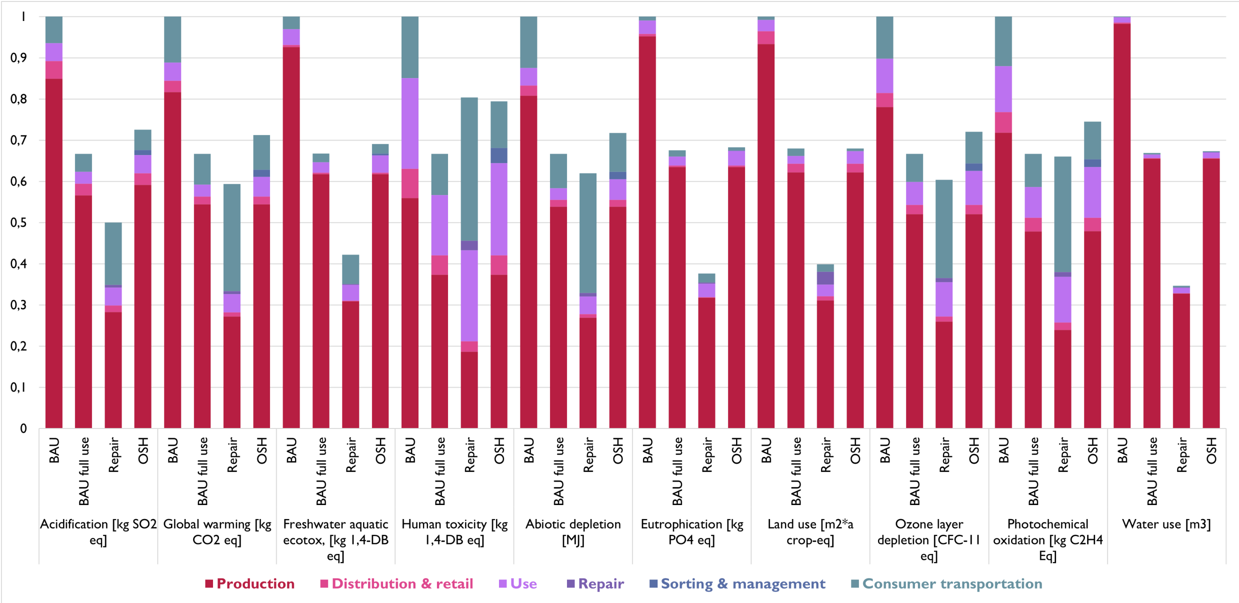

Figure C5: *Results for impact categories per f.u. for sensitivity analysis of full usage for business-as-usual normalized to current business-as-usual*

D

Appendix: Interviews with companies

In this appendix questions to Nudie Jeans and Repamera are stated. The questions were also asked in Swedish but are translated into English here.

D1 Nudie jeans

How does the customer travel to the repair location?

How are the repair kits sent and what do they contain?

How is the material in the repair kit produced?

What materials are required for on-site repairs?

How long does a garment last after being repaired?

What constitutes an "average" repair, and what is needed for it?"

How many times does a customer usually repair a pair of jeans?

What other transportation and what type (e.g. truck) occurs to and from the warehouse in addition to the transportation of new jeans to stores?

Are there any requirements or similar regarding running these transports at full capacity?

D2 Repamera

How much can one expect to extend the lifespan after doing a repair?

How many times would you say a garment is repaired on average before being discarded?

We are conducting our life cycle analysis on a pair of "generic" pants, so would it be reasonable to assume an average of three repairs, or do you think it could be lower?

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF ENVIRONMENTAL SYSTEMS ANALYSIS
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY