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Nudie Jeans co

A Comparative Life Cycle Assessment of Nudie Jeans' Repair and Reuse Concept

Master's Thesis in Industrial Ecology (MPTSE)

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Division of Environmental Systems Analysis
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2019
Report No. E2019:113

Master's thesis 2019:08

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In collaboration with IVL Swedish Environmental Research Institute
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Cover: The logotype of Nudie Jeans depicting the company's characteristic orange and black color scheme where their distinct casual black font hovers over a thick orange stripe.

Printed by Chalmers Digitaltryck
Gothenburg, Sweden 2019

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Abstract

As one of the largest and most polluting industries, the fashion industry plays a significant role regarding the ongoing degradation of the environment. Nudie Jeans is a Swedish denim company that has taken an active approach by contesting the current paradigm of producing fast fashion, which contributes to the throwaway society, which in turn contributes to polluting the environment. Instead, they focus on giving their jeans a narrative, where ageing and letting the jeans break in is encouraged by the means of their Repair and Reuse concept.

This Master's thesis has investigated to what extent this concept helps mitigate environmental impacts with respect to a studied pair of Nudie Jeans entire life cycle using the Life Cycle Assessment method with the help of the LCA software GaBi. A linear case, where the studied jeans were assumed to be discarded after their functional life time had expired, was compared to a circular case, which assumed an extension of the functional life time through repairing and reusing the jeans three times. These two cases where compared with regard to the environmental impact they cause per year that they are worn.

According to the results, the environmental impact decrease by extending the life time of the jeans. Thus, for each added event of reuse, the environmental load associated with the life cycle of the studied pair of Nudie Jeans decrease. However, the decrease occurs at an increasingly lower rate late with increasing number of reuses.

Active measures that can be taken in order to further reduce the Repair and Reuse system includes decreasing the environmental impact related to maintenance of the jeans and repairing the jeans. For example, decreasing the frequency of washing and tumble drying will decrease the environmental impact. Moreover, the paper bag that customers get when they repair their jeans at a Repair Shop, were identified to be a considerable source of environmental impact with regard to the Repair stage of the Repair and Reuse concept.

Valuable insights were identified, which indicate that Nudie Jeans is contributing to mitigating environmental impact within the fashion industry by promoting their Reuse and Repair concept. The results of this study imply that considerable environmental impact could be mitigated if more actors in the fashion industry implement an approach similar to Nudie Jeans' Repair and Reuse concept.

Keywords: Nudie Jeans, Repair and Reuse, Life Cycle Assessment, Circular Economy, IVL Swedish Environmental Research Institute.

Acknowledgements

This Master's thesis has been a really interesting journey, from beginning to end, and it is thanks due to a series of fortunate events, where one event lead unexpectedly to the other.

We would like to thank Tomas Rydberg at IVL, for making it possible for us to write this thesis at IVL's offices despite us turning down his other thesis proposals in favor of writing it at Nudie Jeans. We would also like to thank Lisa Hallberg, LCA expert at IVL, who introduced us to the LCA software GaBi. Furthermore, we would also like thank Simon Andersson, which has been our supervisor at IVL. Leaving IVL, we would also like to thank Matty Janssen, which is our joint supervisor/examinator at Chalmers, for all of his help and guidance throughout this project.

We would like to give our special thanks to Eliina Brinkberg, Environmental Manager at Nudie Jeans, for guiding us through this very interesting project. We hope we did not bother you too much with our incessant emails! Lastly, we would like to highlight Michael Lundin, Project Manager for the Repair and Reuse concept at Nudie Jeans, for giving us the idea to get in touch with Eliina in order to make our ideas become reality. Thank you!

Maja Nellström and Mate Saric, Gothenburg, June 5th of 2019.

Contents

List of Abbreviations

LCA	Life Cycle Assessment
f.u.	Functional Unit
ISO	International Organization for Standardization
LDLL	Lean Dean Lost Legend
GWP	Global Warming Potential [kg CO2 eq.]
AP	Acidification Potential [kg SO2 eq.]
EP	Euthrophication Potential [kg Phosphate eq.]
PM	Particulate Matter [kg PM2.5 eq.]
OLDP	Ozone Layer Depletion Potential [kg R11 eq.]
POCP	Photochemical Ozone Creation Potential [kg Ethene eq.]
IR	Ionising Radiation [kBq U235 eq.]
AD	Abiotic Depletion [kg Sb eq.]
HTP	Human Toxicity Potential [kg DCB eq.]
TEP	Terrestric Ecotoxicity Potential [kg DCB eq.]
MAEP	Marine Aquatic Toxicity Potential [kg DCB eq.]
FAEP	Freshwater Aquatic Ecotoxicity Potential [kg DCB eq.]
SAC	Sustainable Apparel Coalition
PEF	Product Environmental Footprint
ILCD	International Reference Life Cycle Data System

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Introduction

In 1987, the Report of the World Commission on Environment and Development: Our Common Future, also known as the Brundtland Report, stated that “Many present development trends leave increasing numbers of people poor and vulnerable, while at the same time degrading the environment”. This conclusion lead to the development of the concept Sustainable Development defined as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs".(Brundtland, 1987) Since the Brundtland Report was published, Sustainable Development has received increasing attention around the world and in 2015, the 2030 Agenda for Sustainable Development which include 17 Sustainable Development Goals (SDG:s) was adopted by all UN members. In order for the SDG:s to become a reality in all parts of the world, all levels of society need to contribute to the effort. However, the world’s most polluting industries have a significant responsibility towards improving their environmental performance in order for the SDG:s to be reached.

One of the world’s largest industries and also one of the most polluting is the textile and clothing industry (Resta & Dotti, 2015). The production of textiles and clothing requires large amounts of water, energy and other valuable resources. Also, the release of toxic and hazardous waste contributes to pollution of air, water and land (Eryuruk, 2015). There are several options for mitigating these environmental impacts but perhaps the simplest alternative has been overlooked, that is to say, to prolong the actual lifetime of the clothing. The reason why this mitigation measure has not been suggested previously might be that *fast fashion* has characterised the fashion industry in recent decades. However, an increasing opposition to the prevailing idea of fast fashion has lead to the emergence of fashion companies that defy this idea in favour of more durable fashion in alignment with the concept of circular economy.(Gartner, 2016)

Circular economy is a term used for economic systems built on re-circulation of material flows, in contrast to the prevailing linear economic model, where mass production and mass consumption are driving the economic growth. The idea of circular economy is to reduce virgin material, thus reducing waste generation in order to make the economy more sustainable. (Esposito et al., 2018) The European Commission has set up a programme regarding circular economy, where the goal is to make Europe’s economy more sustainable by "closing the loop" of product life cycles through the means of promoting recycling and reuse efforts (The European Commission, 2019).

Most fashion companies do not apply the idea of circular economy into their business models. However, one fashion company that does so is Nudie Jeans. They have chosen to implement a circular approach to fashion through their Repair and Reuse concept which extends the life time of their products (Nudie Jeans AB, 2017b). In an effort to improve their environmental performance and their green marketing, Nudie Jeans commissioned a comparative LCA study a year ago. However, the results from the conducted LCA have only been used within the company as a learning tool.[1] One reason for this was due to difficulties of translating said results into marketing. (Åslund Hedman, 2018) This is not a problem specifically tied to Nudie Jeans. Companies in general experience difficulties when communicating their environmental performance to customers through green marketing. (Rex & Baumann, 2007)

1.1 Aim

The overall aim of this study is to investigate the potential to mitigate environmental impact of the life cycle of a pair of Nudie Jeans by implementing Nudie Jeans' Repair and Reuse concept. Furthermore, the potential to improve the environmental mitigation of the Repair and Reuse concept will be studied.

[1] Eliina Brinkberg (Environmental Manager at Nudie Jeans), personal communication, November 8, 2018

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Background

2.1 Sustainability within the Fashion Industry

The fashion industry contributes to significant negative impacts related to all three pillars of sustainable development: economic, social and environmental development.

The fashion industry is currently valued at more than 2.5 trillion dollars, thus playing a significant part of global economic development. Since the beginning of the millennium, the industry has gone through significant growth. The production of clothing doubled between 2000 and 2014 but each item of clothing is kept half the time compared to 15 years ago. This increased purchasing and disposal rate within the fashion industry is significant for what we have previously referred to as fast fashion. (UNECE, 2018a)

The social aspect of sustainable development within the fashion industry is mainly related to the employees of the business. The fashion industry employs more than 75 million people all over the world and the working conditions for some of these people are not safe nor humane. This is particularly the case for the people working with the production of fast fashion. In some cases, the workers are exposed to hazardous substances and endure long working hours while being paid low wages.(UNECE, 2018a)

The negative environmental impacts of the fashion industry are considerable. The industry is responsible for about 20 % of global waste water generation and 10 % of global carbon emissions, which is more than the combined carbon emissions generated by all international flights and maritime shipping. Furthermore, it has recently been discovered that the textile industry contributes to large amounts of plastic entering the oceans. This is a growing concern worldwide due to adverse effects to the environment and human health attributed to ocean plastics. (UNECE, 2018a,b)

Mitigating the negative impacts caused by the fashion industry will likely require the major actors within the industry to collaborate through global initiatives. Many different initiatives striving to achieving a more sustainable fashion industry have been started by different organisations in the past. However, it was not until recently that the UN initiated a more comprehensible approach to address the sustainability issues related to the fashion industry. It started in a panel event held in 2018 called *Fashion and the SDGs: what role for the UN?* which resulted in the UN Alliance on Sustainable Fashion. (UNECE, 2018b)

This alliance later on launched the Fashion Industry Charter for Climate Action stating 16 principles and targets that 43 leaders have made a commitment to implement or support. Among these 43 leaders are fashion brands such as Adidas, Burberry, H&M Group, organisations such as Sustainable Apparel Coalition, China National Textile and the global NGO, WWF International. Allegdly, the principles and targets stated in the charter align with the goals of the Paris Agreement and the long-term vision is for the fashion industry to accomplish net zero emissions by 2050. A milestone on the path to achieving that vision is for the industry to reduce its GHG emissions by at least 30 % by 2030. Furthermore, companies or organisations willing to implement or support the principles stated in the charter are free to join the alliance. (UNECE, 2018a)

2.2 Circular Economy and the Waste Hierarchy

Circular economy can be defined as an economic model that involves optimisation of processes such as planning, resourcing, procurement, production and reprocessing, in order to maximise ecosystem functioning and human well-being. Environmental degradation is closely associated with the prevailing economic system, which is defined as a linear economic model that incentivise consumption in order to stimulate economic growth. In contrast to this, the circular economy model offers an alternative path to reach economic growth in a sustainable way.(Murray et al., 2017)

In order for a transition to a circular economy to occur, firms need to redesign the way they operate. Technologies and business models that promote renewability, logevity, reuse, repair and dematerialistion are of the essence (Esposito et al., 2018). Tying environmental policy to the Fashion Industry, the Waste Hierarchy is a framework that is regulated in the Waste Directive. It was developed by the European Commission with the purpose of enforcing guidelines on how waste should be managed. The hierarchy presents the following steps of treating waste flows in descending order of priority: prevention, minimisation, reuse, recycle, energy recovery and disposal. (The European Commission, 2008)

When examining how well the fashion industry aligns with the principles of the Waste Hierarchy, a clear trend can be identified. Several fashion companies offer their customers to take care of their worn out clothes and customers may then believe that they are doing a good environmental deed by handing in their clothing waste because they assume that the clothes will be recycled to make new clothes. However, this is not the case. Studies have concluded that a very small share (less than 1 %) of these collected clothes are being recycled. The clothes donated to stores are mainly (80 %) sold on the second hand market in poor countries around the world or used as blankets or isolation material. The rest (20 %) are either sold on the second hand market within the EU or is sent to landfill or incineration (Kärnstrand, 2017). However, there are fashion companies, such as Nudie Jeans, that adhere to the Waste Hierarchy to a greater extent, as compared to other fashion companies, by focusing on implementing reuse through repair schemes.

Reuse and recycling of clothing have been investigated in the article, *Environmental impact of textile reuse and recycling - A review* (Sandin & Peters, 2018a). The article include a review of 41 studies dealing with the environmental impacts of reusing or recycling textiles. One of the main findings of the review was that strong support exists for the claim that environmental impact is generally reduced through implementation of reuse and recycling instead of incineration and landfilling. Furthermore, it was found that reuse in general reduces environmental impact to a greater extent than recycling. Additionally, authors often assume that input of material to recycling processes can be seen as waste lacking environmental burdens. Moreover, situations where reuse and recycling may not be beneficial from an environmental point of view is revealed in the article. Such situations may occur for example if:

- The avoided production processes are relatively clean.
- Fossile energy is used for the recycling processes.
- Reuse result in increased consumer transports causing environmental impacts that exceed avoided environmental impacts caused by production of a new product. This may be avoided with sufficient extension of the use phase.

Regarding future research on reuse and recycling of textile clothing, the article recognises the need for more inventory data, for processes such as collection and sorting. (Sandin & Peters, 2018b)

2.3 Nudie Jeans

Nudie Jeans is a Swedish company that was founded in 2001 by Maria Erixon who is currently one of three owners of Nudie Jeans. At present, Nudie Jeans are sold in more than 50 different countries and Nudie Jeans Repair Shops that both sell new and reused jeans, while offering free repairs (with the condition of the jeans being Nudie Jeans), can be found in cities all over the world. The first Nudie Jeans Repair Shop was officially launched in 2013 and the first reused jeans were sold in stores beginning from 2012.[1] Furthermore, the first online collection of reused jeans was put on the market in 2018 and there has been a total of five so-called reuse drops, which are a kind of limited edition collection of reused jeans (Nudie Jeans, 2018a,b). Nudie Jeans have expanded a lot since the launch in 2001 but the company is still relatively small. In 2017, Nudie Jeans AB reported net sales of 450 MSEK (Nudie Jeans AB, 2017a). This figure can be compared to the net sales reported by H&M AB for the same year which was 200 000 MSEK (H&M Hennes & Mauritz AB, 2017).

Environmental and social sustainability constitutes the core of Nudie Jeans' business model. They produced their first organic t-shirts in 2004 and over the years the share of sustainable products have increased. By 2017, Nudie Jeans reached 100% organic cotton in all of their cotton products. Additional to the organic cotton, Nudie Jeans use recycled cotton and other recycled fibres such as wool and

[1] Eliina Brinkberg, personal communication, February 5, 2019

polyester in their products. (Nudie Jeans AB, 2017b)

Furthermore, Nudie Jeans promote and implement what they call the *eco cycle* which involves the steps: break-in, repair, reuse and recycle. (Nudie Jeans AB, 2017b). The break-in step of the eco cycle focuses on the use phase of a pair of jeans, where Nudie Jeans recommend the customers to air dry the jeans instead of washing them to often, which will save both water and energy. The repair step is implemented by offering free repairs of Nudie Jeans in all of their Repair Shops. The reuse step involves reusing either the jeans fabric or the actual jeans. The fabric from worn out Nudie jeans is mainly used as patches in the repair service but also to produce new products such as caps and backpacks. The jeans which are to be reused are collected from customers at the Repair Shops where they are resold after being repaired and cleaned.(Nudie Jeans AB, 2017b) The collected jeans that are not resold at the Repair Shops are sent to Nudie Jeans' stock Korallen in Borås, Sweden. Some of the jeans stored at Korallen are repaired and refurbished in order to be a part of the Nudie's online collection of reused jeans. The recycling step of the eco cycle is mainly implemented through the use of recycled fabrics in some of Nudie's jeans. Previously, this recycled fabric did not originate from Nudie jeans. However, Nudie Jeans have recently looked into the opportunity to recycle the fabric from the collected worn out jeans. The plan is to produce a new jeans model containing 20 % recycled Nudie Jeans fabric to be put on the market during the winter of 2019.[2]

For the future, Nudie Jeans have set targets to be met by 2020 in order to further increase their circularity. One of their goals is to increase the total number of collected Nudie Jeans by 15 % globally. They are also aiming to increase the total number of sold reused Nudie Jeans by 30 % globally. (Nudie Jeans AB, 2017b) However, a potential threat to Nudie Jeans' Repair and Reuse concept can be found in the Swedish legislation regarding management of clothing waste. The Swedish Environmental Code defines spent clothing as domestic waste, which in turn falls under the responsibility of affected municipalities according to the municipal waste monopoly. The Swedish Environmental Protection Agency (EPA) has stated that companies who attempt to handle spent clothing may do so under the condition that they intend to reuse them. However, intentions to use spent clothing for other purposes, such as recycling, are prohibited. This is a legislative area that can prove a hinder for clothing companies that take back used clothes. The Swedish EPA recommends a change in the law to make the municipal waste monopoly less strict in this area (Naturvårdsverket, 2016). However, the Swedish government has recently issued that they intend to implement extended producer responsibility (EPR) on clothing and textiles in an attempt to solve the issue of clothing waste accumulation in Sweden (Obminska, 2019). EPR on clothing and textiles would mean that the producers have economic and practical responsibility for collecting and managing the clothes and textiles at the end of their life. Nudie Jeans has already incorporated a system for collecting jeans at the end of their life at their Repair Shops. They might therefore have an advantage over their competitors. However, Nudie Jeans would have to extend their responsibility for collecting clothes to include all of the

[2] Eliina Brinkberg, personal communication, February 5, 2019

clothes they sell if EPR is implemented. EPR would also entail that demands would be put on producers to join an accredited collection system and that a share of the collected textile waste is prepared for reuse or material recycling. Furthermore, EPR could benefit measures taken to use the textile waste as raw material for new textile production. Nevertheless, EPR might affect actors on the second hand market in a negative way since they rely on large scale collection of second hand clothes. To what extent these actors will be affected depends on the actions of the producers responsible for the clothing and textile waste. (Naturvårdsverket, 2016)

2.4 Life Cycle Assessment of Clothing

Life Cycle Assessment is a tool for measuring the environmental performance of a product's entire life cycle from raw material extraction, via manufacturing and use-phase, to waste treatment. It is an accepted and widely used method with a series of standards provided by *The International Organisation for Standardisation* (ISO) (Muthu, 2015).

The apparel industry's first LCA was conducted in 2007 by Levi Strauss & Company. This LCA which included a set of Levi's products concluded that cotton cultivation and consumer care where the two main areas consuming largest amounts of water and energy. In order to gain further knowledge on the two main environmental impact areas, Levi Strauss conducted another LCA in 2013 which studied three different pants models. One of the main findings from the latter LCA was that fabric manufacturing, including yarn spinning, dying, weaving and fabric finishing, contributed significantly to climate change and consumption of non-renewable energy. Another important finding was that consumer care (or use phase) and fabric manufacturing are the most predominant processes when it comes to energy consumption and climate change impact.

The LCAs conducted by Levi Strauss are not the only LCAs to conclude that the use phase of clothing contributes significantly to environmental performance. In the *Handbook of Life Cycle Assessment (LCA) of Textiles and Clothing*, it is stated that the use phase is generally one of the main hotspots of clothes' life cycles (Muthu, 2015). Furthermore, a Norwegian study on laundry habits concludes that textile maintenance such as washing, drying, ironing, storage and mending, is often the most energy demanding part of the life cycle of clothing (Laitala et al., 2012).

2.5 Research Questions

The following research questions, denoted R1 and R2, have been formulated in an effort to achieve the overall aim, which is to investigate the possibilities of mitigating environmental impact of the life cycle of a pair of Nudie jeans by implementing Nudie Jeans's repair and reuse concept. Moreover, research question R2 was formulated in an effort to investigate mitigation measures other than the repair and reuse concept.

R1: To what extent does the Reuse and Repair concept mitigate the environmental impact of a pair of Nudie Jeans?
R2: Which measures can be taken in order to increase the environmental mitigation of the Repair and Reuse concept?

3
Life Cycle Assessment

This chapter presents the Life Cycle Assessment (LCA) which is the method used for the purpose of answering the research questions included in this thesis. LCA is used for evaluating the environmental impacts related to the life cycle of a specific product or service. The main steps of the LCA procedure are: definition of Goal and Scope, Inventory Analysis, Impact Assessment and Interpretation of results (Baumann & Tillman, 2004). These features are illustrated in figure 3.1.

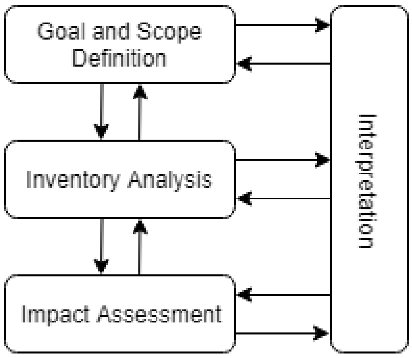

Figure 3.1: The LCA methodology where the boxes represent procedural steps and the arrows depict the order of which the procedural steps should be conducted. Arrows in both directions indicate the iterative nature of the procedure.

3.1 Goal

The goal of this LCA is to evaluate the environmental benefits of Nudie Jeans' Reuse and Repair concept by comparing a circular and a linear scenario for a pair of Nudie Jeans. More specifically, the life cycles of reused jeans and jeans that have not been reused will be compared.

Two audiences that hold consequential stakes regarding the results of this study are: Nudie Jeans and IVL Swedish Environmental Research Institute. Nudie Jeans is the main commissioner of the study. Their interests lie in being able to translate the LCA results into business development purposes. IVL Swedish Environmental Research Institute has an interest in the LCA results due to their involvement in the LinCS research project, which aims at evaluating the correlation of the this study's LCA results with an economic circularity indicator.

3.2 Scope

The scope of the study describes how the systems under study will be modelled and analysed by presenting the Functional Unit, Choice of Impact Categories and Method of Impact Assessment. Also, the scope defines the type of LCA to be conducted, System Boundaries, Data Quality Requirements and lastly, the Main Assumptions and Limitations are included in the Scope. (Baumann & Tillman, 2004)

3.2.1 Functional Unit

The functional unit for this study is defined as *one pair of Nudie Jeans used for one year*. This functional unit is applicable to both the linear and circular case which enables a comparison of the two scenarios.

3.2.2 Choice of Impact Categories

Guidelines from the textile trade organisations Sustainable Apparel Coalition (SAC) and the ISO-standard have been used when determining which impact categories to include in this study. SAC has analysed the main categories from the Product Environmental Footprint (PEF) methodology in terms of relevance to the fashion industry. Their conclusion was that seven of the fifteen listed impact categories are to be used for LCA:s on clothing. The seven impact categories that they chose and that will be included in this LCA are listed as follows (Thinkstep, 2016):

- Climate Change
- Ozone Depletion
- Particulate Matter
- Ionising Radiation
- Photochemical Ozone Formation
- Acidification
- Euthrophication

As a result of this thesis also focusing on circularity, Material Depletion was also chosen as an impact category of interest despite the fact that SAC advises against it due to alleged uncertainties related to this impact category. Moreover, SAC argues against using Toxicity as an impact category for the same reason applied to Material Depletion. Regardless to this, Toxicity was chosen for this LCA with the reasoning that Nudie Jeans has sufficient amounts of site specific data on toxicity from their suppliers. This reasoning is also applicable for the Material Depletion case. Hence, the seven impact categories presented above are complemented by the following impact categories (Thinkstep, 2016):

- Material Depletion
- Toxicity

The Toxicity impact includes four types of impacts: Freshwater Toxicity Potential, Human Toxicity Potential, Marine Aquation Ecotoxicity Potential and Terrestric Ecotoxicity Potential. Unit, characterisation method and areas of protection for the chosen impact categories are presented in table 3.1. Moreover, a description of each Impact Category included in this study is presented in appendix A.

Table 3.1: Impact categories included in the study. Also, unit, characterisation method and areas of protection for each impact category (Guinée, 2004).

Impact category	Unit	Method	Areas of Protection
Global warming potential (GWP)	Carbon dioxide (CO_2) eq.	CML2001	Human health, natural and man- made environment.
Acidification potential (AP)	Sulphur dioxide (SO_2) eq.	CML2001	Human health, natural and man- made environment and natural resources.
Eutrophication potential (EP)	Phosphate (PO_4^{3-}) eq.	CML2001	Natural and man- made environment and natural resources.
Particulate matter (PM)	Particulate matter ($PM2.5$) eq.	ILCD/PEF	Human health.
Ozone depletion potential (ODP)	Trichloroflouro-methane (CFC-11) eq.	CML2001	Human health, natural and man- made environment and natural resources.
Photechemical Ozone Creation Potential (POCP)	Ethylene (C_2H_4) eq.	CML2001	Human health, natural and man- made environment and natural resources.
Abiotic depletion (AD)	Antimony (Sb) eq.	CML2001	Natural resources or natural resources, human health and natural environment.
Ionisation radiation (IR)	kBq Uranium-235 ($U235$) eq.	ILCD/PEF	Human health, natural environment and natural resources.
Human Toxicity Potential (HTP)	1,4-Dichloro-benzene (DCB) eq.	CML2001	Human health.
Terrestrial Ecotoxicity Potential (TEP)	1,4-Dichloro-benzene (DCB) eq.	CML2001	Natural environment and natural resources.
Matrine Aquatic Ecotoxicity Potential (MAEP)	1,4-Dichloro-benzene (DCB) eq.	CML2001	Natural environment and natural resources.
Freshwater Aquatic Ecotoxicity Potential (FAEP)	1,4-Dichloro-benzene (DCB) eq.	CML2001	Natural environment and natural resources.

3.2.3 Method of Life Cycle Impact Assessment

As previously mentioned, Nudie Jeans is one of the intended audiences of this study. Since all employees at Nudie Jeans are not familiar with the LCA methodology, reason would have it to include weighting of the results in order to enable a more comprehensible communication of the results internally. However, the ISO14044 standard prohibits the use of weighting if the LCA is of comparative nature and if it is intended to be disclosed to the public. This LCA fulfills both of the mentioned criteria due to the fact this report is comparative in its nature and it will be disclosed to the public as public document according to Swedish Law. Therefore, weighting of the results will be excluded.(ISO 14044:2006, 2006)

The method of Impact Assessment choicen for this study is CML. It should be noted that for the LCIA method CML2001, Climate Change, Photochemical Ozone Formation and Material Depletion are denoted Global Warming Potential, Photochemical Ozone Depletion Potential and Abiotic depletion respectively.

This section presents elements, included in the Life Cycle Impact Assessment (LCIA), which are presented in figure 3.2. The purpose of the LCIA is to evaluate the inventory results in order to determine their magnitude and significance to the chosen environmental impact categories. The procedure involves step-wise aggregation of the inventory results through classification followed by characterisation. The results may be further aggregated through weighting. However, it is not mandatory according to the ISO-standard for LCA methodology to include weighting (Baumann & Tillman, 2004).

As presented in figure 3.1, optional elements (other than weighting) included in LCIA are: Normalisation, Grouping and Data Quality Analysis. Grouping, which entails that the indicators are sorted and possibly ranked, is excluded since it is deemed not relevant for this study. Weighting will not be included either since the ISO standard recommends that LCA to the public should not include this aggregation step.

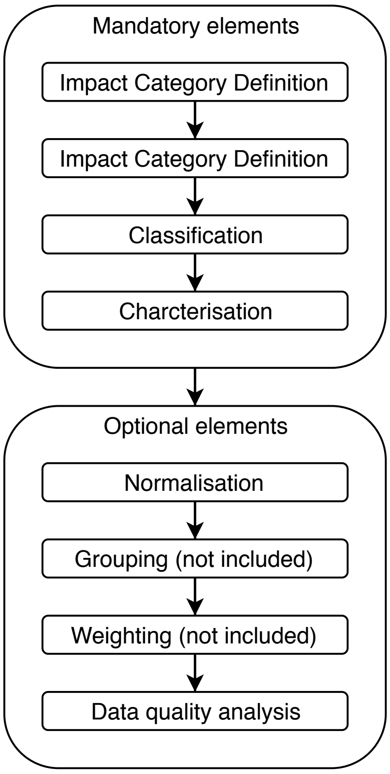

Figure 3.2: The mandatory and optional elements included in the Life Cycle Impact Assessment. Note that Grouping and Weighting are not included in this study.

3.2.3.1 Classification and Characterisation

Classification entails sorting of inventory data into the environmental impact they contribute to. Characterisation involve calculation of relative contributions of emissions and resources in order to determine the environmental impact related to each impact category. This is achieved by multiplying the intensities with specific equivalence factors. (Rydh et al., 2002) Classification and Characterisation have been conducted in GaBi using the life cycle impact assessment (LCIA) methods CML2001 and PEF/ILCD.

The impact assessment methods CML 2001 chosen for conducting the impact assessment method in GaBi. However, two of the impact categories where not available in CML 2001. Thus, PEF was chosen for these two impact categories. CML 2001 has been developed by the Institute of Environmental Sciences at Leiden University located in the Netherlands. CML 2001 entails a database (CML-IA), which contains characterisation factors which are updated continuously as new knowledge is available (GaBi, 2019). The LCIA method PEF/ILCD recommendations combines PEF (Product Environmental Footprint) and ILCD (The International Reference Life Cycle Data System). PEF have been established by the European Commission in an effort to establish a common method for quantification of the environmental performance of a product's life cycle (Thinkstep, 2019). ILCD recommendations aim at providing a common approach for consistent life cycle data of high quality (Commission, 2013). These recommendations are available in a handbook constructed by the European Commission.

3.2.4 Type of LCA

This LCA is an attributional. It involves a comparison of two distinct cases, one linear and one circular case. Thus, the LCA is comparative in nature and an attributional approach is more suitable than the consequential approach. Additionally, the LCA will be a cradle-to-grave assessment, thus including the entire life cycle of the jeans.

3.2.5 System Boundary

As mentioned above, a cradle-to-grave LCA will be conducted for this study. The *cradle* corresponds to the raw material extraction. The raw materials are extracted from different countries. Thus, more than one location for the raw material extraction will be included within the system boundary. The *grave* is the waste management of the jeans. (Baumann & Tillman, 2004)

The geographical boundary will include the countries involved in the cradle-to-grave life cycle of the jeans. The raw material extraction mainly takes place in India and Turkey and the production of the jeans mainly takes places in Italy and Tunisia. The geographical boundary for the waste management of the discarded jeans, the storage of the jeans, the use phase of the jeans and the repair system is set to Sweden as a way to delimit the study.

Additional system boundaries are related to capital goods such as machinery and vehicles. Production and maintenance of capital goods will not be included in the study due to lacking data availability and time restrictions. It should however be mentioned that the general idea is to include these aspects when performing an accounting LCA in order to obtain a complete assessment of the environmental impact from the product in question.(Baumann & Tillman, 2004)

As previously mentioned, the jeans can be reused through other alternatives than Nudie Jeans' own Repair and Reuse concept, for instance via second hand stores and ecommerce. These options are not included within the scope of this study.

3.2.6 Data Quality Requirements

Whenever available, site-specific data was used. For the processes and flows lacking site-specific data, general or average data was gathered from the the LCA software package GaBi.

Regarding raw material extraction and production of the studied jeans, site-specific data have been collected during the spring of 2018 since Nudie Jeans conducted a comparative LCA that year. This data is therefore available and will be used in this study as well. For data on emissions from energy consumption, average data will be used according to the standards on attributional LCA.(Baumann & Tillman, 2004)

3.2.7 Initial Assumptions and Limitations

First and foremost, it was assumed that the jeans are reused three times before being discarded. This study is limited to one model of jeans, the Lean Dean Lost Legend (LDLL) model. Furthermore, this study does not take variable sizes of the jeans into account. This study does not take into account for reuse options other than reuse through Nudie Jeans' reuse operations. Reuse of the fabric from the jeans to be used in products other than jeans are not included in this study. The fact that the jeans fabric deteriorates, which might lead to a requirement of more material for repair for each instance that they are reused, is not considered for this study. In other words, it is assumed that the same amount of material is used for each repair.

3.3 Inventory Analysis

3.3.1 Flowcharts of a Pair of Nudie Jeans

Two different flowcharts are presented below: One for the linear case representing zero reuse of the jeans and the other one illustrating the circular case representing three reuses. For the purpose of keeping the flowcharts comprehensible, the following simplifications have been made:

- Transportation processes which occur between each process are not illustrated in the flowchart.

- The energy and water input to the activities in the flowchart are depicted by arrows entering the system boundary.
- The emissions and waste generated from each activity in the flowchart are represented by arrows leaving the system boundary.

3.3.1.1 Flowchart representing the linear case

Figure 3.4 presents a flowchart of the linear case for the life cycle of a pair of Nudie jeans. The main activities involved in the life cycle of the linear case are: Production of Fabric, Production of Jeans, Storage, Use and Incineration. The input materials presented to the left in the figure are raw materials for the jeans, whereas the material inputs to the right are auxiliary materials which are not included in the jeans themselves. Moreover, figure B.1 in appendix B illustrating the main components of the LDLL jeans.

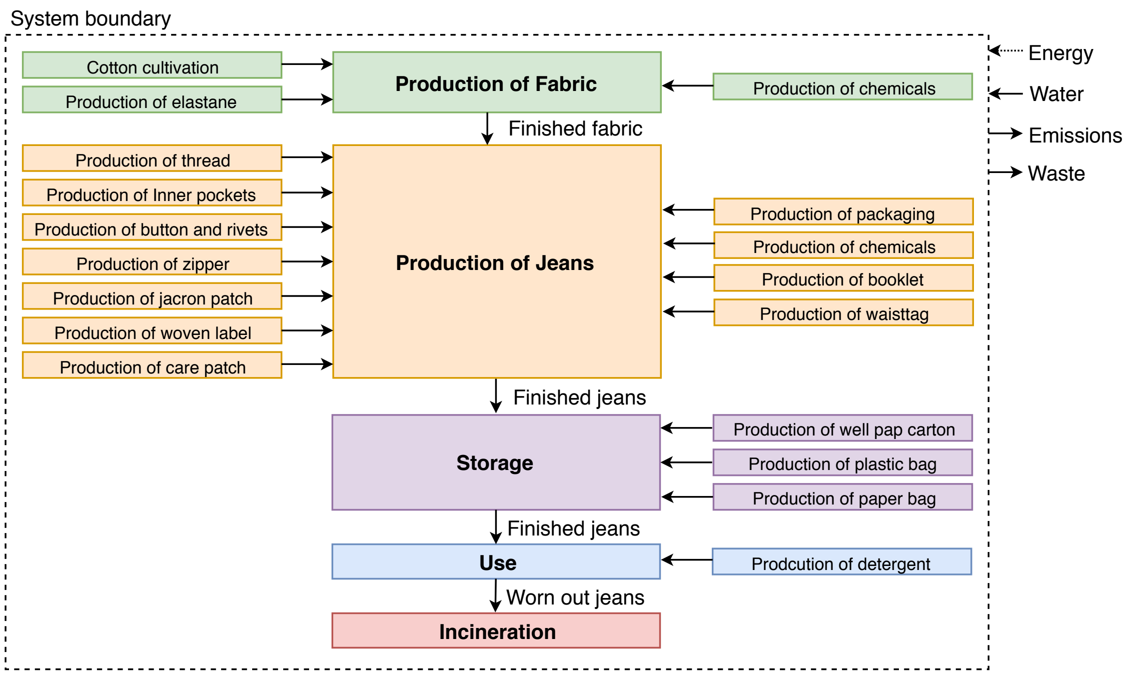

Figure 3.3: A flowchart depicting the linear case of the life cycle of a pair of LDLL Nudie Jeans. The boxes depict processes and the arrows flows of input and output material. A dotted arrow has been used to represent energy flow in order to illustrate that this is not a material flow.

3.3.1.2 Flowchart representing the circular case

Figure 3.4 presents a flowchart illustrating the circular case for the life cycle of a pair of Nudie Jeans. For the circular case, the jeans are brought back to the Repair Shop at the end of their use or reuse in order to get repaired. Afterwards, the jeans get their life cycles extended by being reused. Thus, the flowchart for the circular case is similar to the linear case with the exception that the activities Repair and Reuse is added after Use. The loop arrow after Reuse going to Repair illustrate the fact that the jeans can be repaired and reused multiple times.

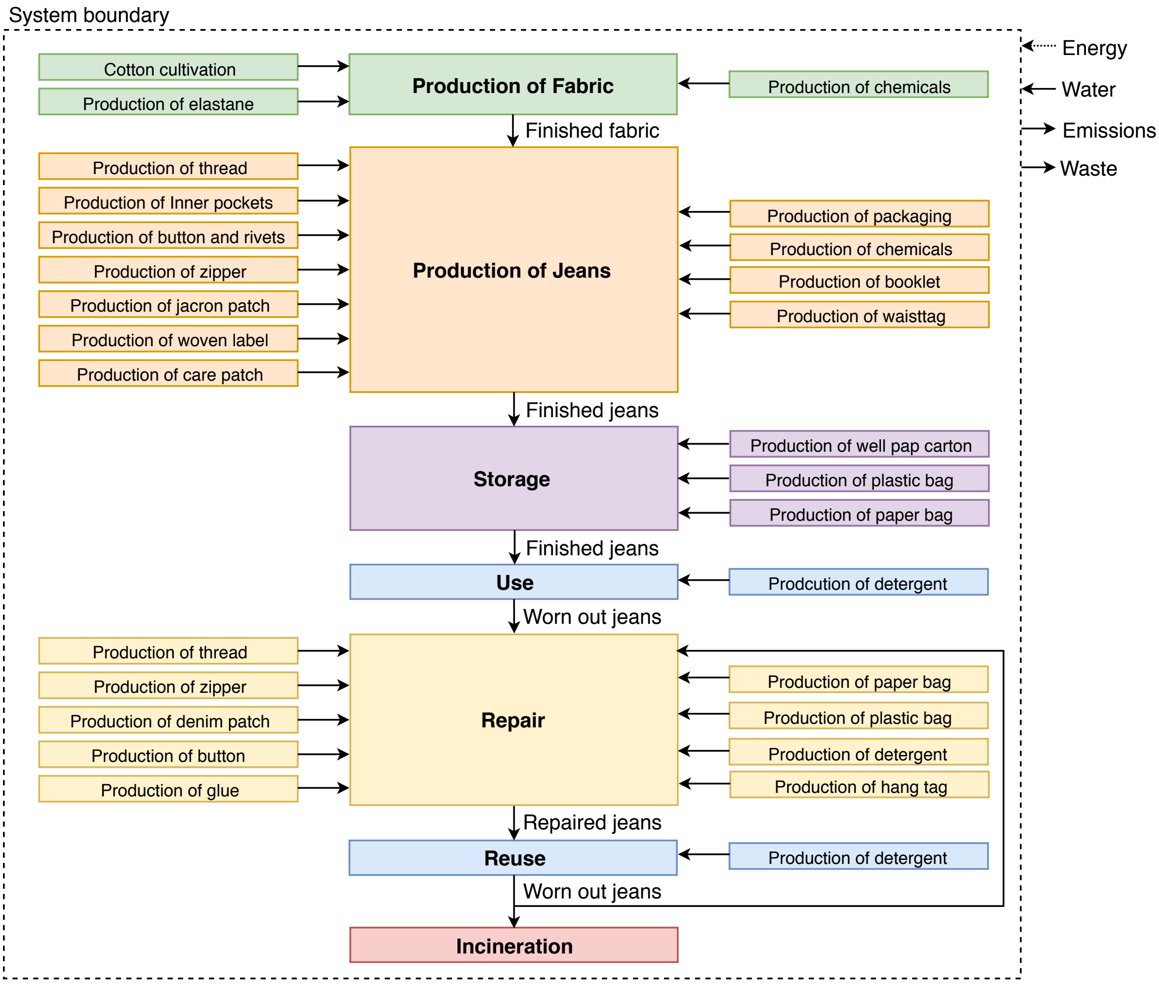

Figure 3.4: A flowchart depicting the life cycle of one pair of LDLL jeans. The boxes depict processes and the arrows flows of input and output material. A dotted arrow has been used to represent energy flow in order to illustrate that this is not a material flow.

3.3.2 The Activities of the Life Cycle and Allocation Procedures

This section includes a description the process steps involved in the activities of the life cycle of the jeans as well as the in- and outputs of energy and material required for each activity. The type of allocation procedure used for these energy and material flows are also described.

3.3.2.1 Production of Fabric

The fabric used for the LDLL jeans is called RR2716 Old Crispy and is manufactured in Robecchetto con Induno in Italy by the fabric manufacturer Candiani (Candiani, 2018). Figure 3.5 presents the process steps involved in the fabric production as well as the material inputs needed to produce the fabric.

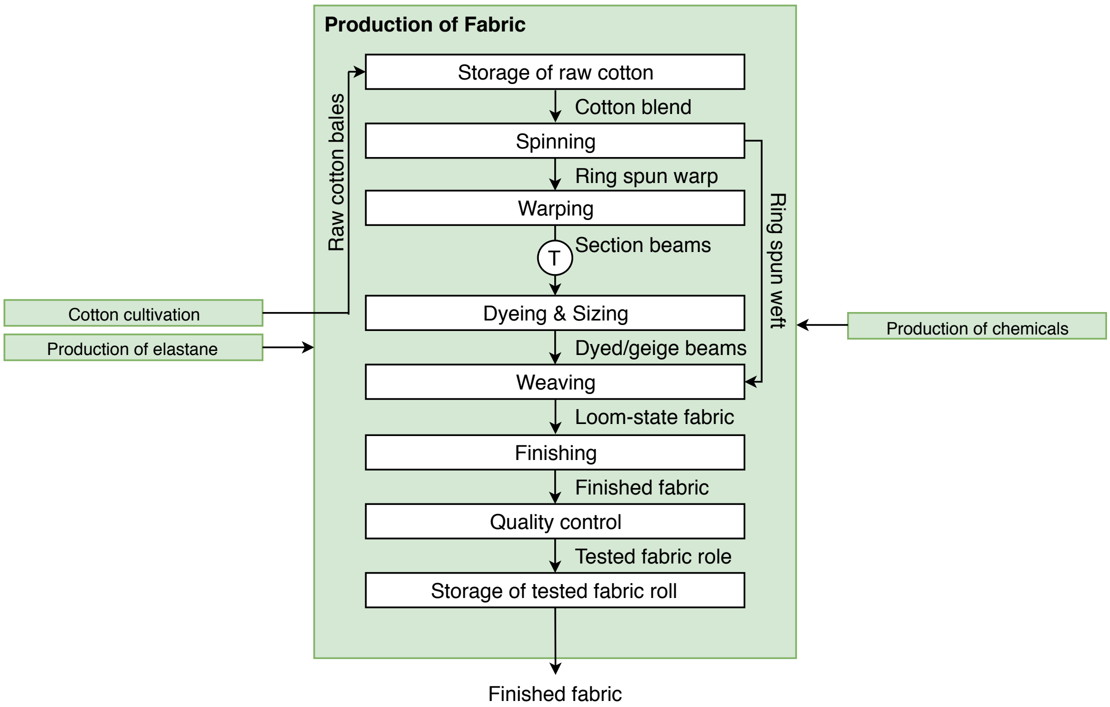

Figure 3.5: A flowchart depicting the process steps of the activity Fabric Production included the life cycle of a pair of LDLL Nudie Jeans. The circled T depicts a transportation process.

Process steps

As can be seen in figure 3.5, the raw organic cotton arrives in bales at the manufacturing facility where they are stored before being exposed to the spinning, where ring spun yarn and ring spun weft are produced. The ring spun yarn goes through warping to obtain section beams which are transported to dyeing and sizing in order to obtain dyed/greige beams. The ring spun weft and the dyed/greige beams goes through the weaving to obtain loom-state denim fabric. The consecutive process is the finishing which involves refining the fabric and sometimes treatments such as foaming, coating and overdyeing. The finished fabric is thereafter tested in order to control the quality of the fabric. Lastly, the tested fabric is packaged and stored before being transported to the Jeans Production facility in Tunisia. (Candiani, 2018)

Material inputs

As illustrated in figure 3.5, materials required for producing the fabric are: Organic cotton, elastane and chemicals. Additionally, Water is needed for the fabric production process. The organic cotton used in the fabric is cultivated in India and the elastane is purchased from Turkey. The water required for the fabric production is mainly groundwater which is extracted from a company owned wells. Some of the water used at the manufacturing facility is recycled through a system which entail filtering of untreated finishing water that is stored in tanks so that it can be used for washing machinery. Water is also recycled through recovery of steam condensate from the dyeing and finishing processes. (Candiani, 2018).

Material outputs
Emissions, waste and co-products are the material outputs generated at the production facility. The waste water is treated at a private purification plant and the solid waste which mainly contains mixed packaging and fabric waste is assumed to be treated at an incineration plant. The co-products generated at Candiani include fabrics other than Old Crispy. (Candiani, 2018) Generated co-products involve allocation issues related to the flows of energy and material. In accordance with the ISO-standard, mass-allocation has been conducted in order to deal with this issue.

Energy inputs
The energy used at the facility include electricity from the Italian grid mix, diesel and natural gas. Additionally, energy for heating the facility is derived from natural gas (Candiani, 2018). As for the waste, mass-allocation was used in order to obtain energy required to produce the Old Crispy fabric used for one pair of the LDLL jeans.

3.3.2.2 Production of Jeans

The Jeans Production occurs at the production facility, Denim Authority located in Ras Jebel in Tunisia (Denim Authority, 2018). Figure 3.6 presents the process steps involved in producing the jeans. Also, the material inputs needed to produce the finished jeans are presented in the figure.

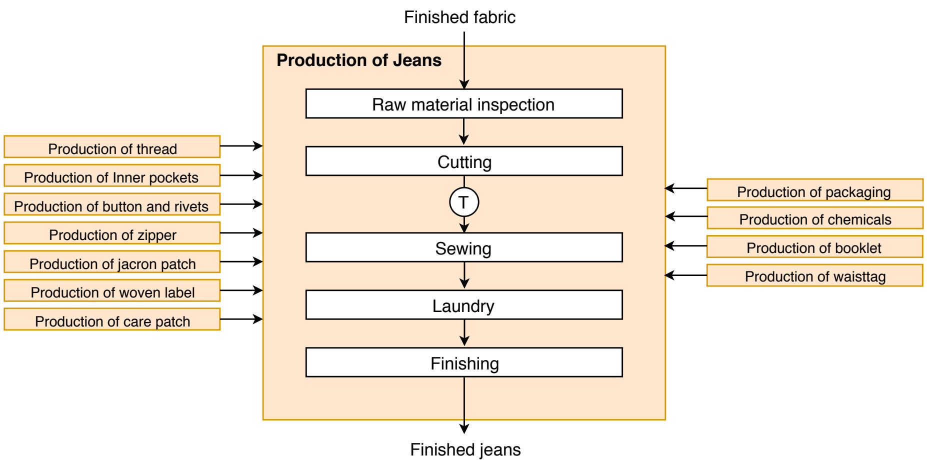

Figure 3.6: A flowchart depicting the process steps of the activity fabric production included the life cycle of a pair of Nudie Jeans. The circulated T represents transportation.

Process steps
As can be seen in figure 3.6, the first process step for producing the jeans is raw material inspection. After inspection of the raw material, the fabric is cut and then transported to the sewing facility where the jeans are sewn. The jeans are then washed in order to obtain the correct nuance. Lastly, the finishing process is where aesthetic as well as functional properties are provided, for example fading.

Material inputs
As illustrated in figure 3.6, materials other than fabric needed to produce the LDLL jeans are: thread, inner pockets, button and rivets, zipper, jacron patch, woven label, waisttag, care patch and a booklet. The production also requires water, chemicals and packaging material for transporting the finished jeans from the facility. The primary source of water at the production facility is ground water and water from the state network. Most of the water used at the production facility is consumed during the washing process. (Denim Authority, 2018)

Material outputs
The material outputs generated from Production of Jeans are: emissions, waste and co-products. The solid waste generated at the facility mainly consists of raw cotton, paper, plastic and denim fabric which is collected by the municipal waste management trucks. (Denim Authority, 2018) Other than LDLL jeans, Denim Authority produces co-products in terms of other models of jeans and also shirts (Denim Authority, 2018). Thus, the inventory data was allocated to one pair of LDLL jeans. This allocation procedure was conducted based on mass of produced product and co-products, respectively.

Energy inputs
At the jeans production facility, electricity and heavy fuel oil are used for supplying energy (Denim Authority, 2018). In order to obtain allocated energy for producing one pair of LDLL jeans, mass-allocation was conducted.

3.3.2.3 Storage

The jeans are initially stored at the warehouse, Korallen in Borås in Sweden before they are transported to Nudie Jeans' Repair Shops and different retailers. According to the system boundary of this study, only storage at Repair Shops and retailers located in Sweden was included. Figure 3.7 presents the process steps involved in Storage. Also, the material inputs required for Storage are presented in the figure.

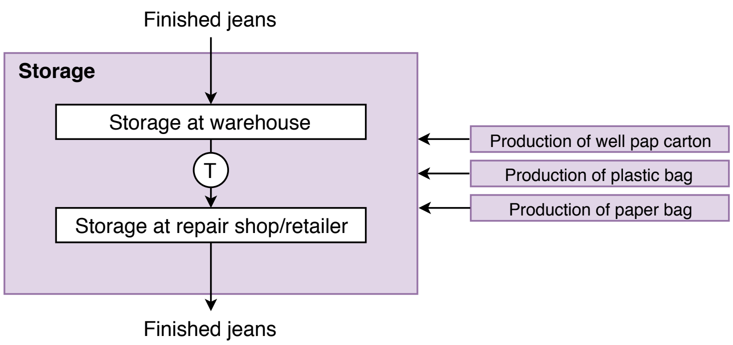

Figure 3.7: A flowchart depicting the process steps and auxiliary materials needed for Storage included in the life cycle of a pair of Nudie Jeans. The circulated T represents transportation.

Process steps
As presented in figure 3.7 the jeans are first stored at a warehouse (Korallen). The warehouse does not only store Nudie Jeans. About 35 % of Korallens warehouse is utilised by Nudie Jeans and the rest is utilised by other companies. Regarding the time aspects, the jeans are stored for 8-10 weeks at the warehouse before being transported to Nudie Jeans' Repair Shops and retailers all over the world. At the Repair Shops and retailers the jeans are stored before being bought by consumers and thus transported from the Repair Shop or retailer to the user. It is assumed that the jeans are stored for an equal amount of time at the repair shops and retailers as they are at the warehouse, that is to say 8-10 weeks.

Material inputs
The material inputs to Storage are finished jeans, packaging material and water. The packaging material include plastic bags and cartons used for transporting the jeans from the warehouse to the Repair Shops and retailers. Furthermore, a paper bag is used for transporting the jeans from the Repair Shops and retailers to the user.

The water usage for storage at the Repair Shops and retailers are assumed to be negligible. However, for the water usage at the warehouse, allocation had to be conducted since products other than the LDLL jeans are stored at the warehouse. The allocation was based on the share of the warehouse that is utilised by Nudie Jeans. Also, assumptions were made regarding how many jeans are stored at the warehouse by Nudie Jeans. The calculations conducted for the allocation procedure are presented in appendix D.

Material outputs
Material outputs from Storage include: emissions, waste and co-products. For the Repair Shops and retailers, generated waste water is assumed to be negligible based on the assumption that water use for these storage facilities also is negligible. Co-products for the warehouse include products stored by companies other than Nudie Jeans and clothing stored by Nudie Jeans that are not jeans. The same is applicable for retailers. Regarding the Repair Shops, co-products include clothing other than jeans. As previously mentioned, the allocation procedure is presented in D.

Energy inputs
The warehouse consumes energy in terms of electricity and district heating. As for the water use, allocation was conducted in order to obtain the energy needed to store one pair of LDLL jeans. The calculation procedure for determining the allocated energy is presented in appendix D.

3.3.2.4 Use and Reuse

Use and Reuse occurs at the customers who buy a new pair of Nudie Jeans or a pair that have been repaired. Figure 3.8 presents the process steps for Use and Reuse and the required material input. Only one figure is used for Use and Reuse since these two activities are considered to be exactly the same in terms of material in- and outputs as well as energy use. Moreover, according to the system boundary of this study, only Use and Reuse in Sweden is included.

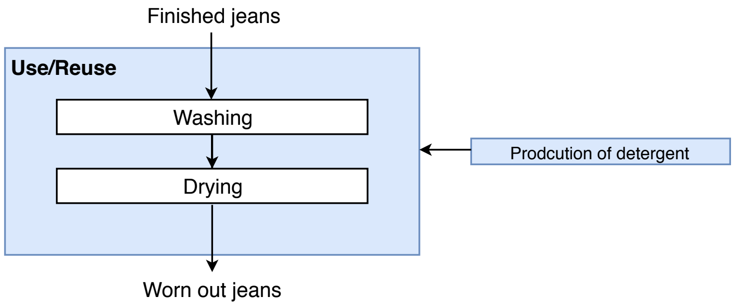

Figure 3.8: A flowchart depicting the process steps for the Use and Reuse.

Process steps

As seen in the figure 3.8, Use and Reuse involve the maintenance procedures: washing and drying. It has been assumed that ironing can be neglected. It is estimated that the jeans are used, on average, for 1,5 years before being repaired or discarded. This estimate have been obtained through calculations based on data collected from customers at Repair Shops. The equation used for this calculation is presented in appendix C. Furthermore, it is assumed that the Use and Reuse phase is equally long, that is to say 1,5 years.

Material inputs

Other than the LDLL jeans, the material inputs are detergents and water needed for washing the jeans. The calculation procedure for determining allocated amount of detergent and water is presented in appendix D.

Material outputs

Material outputs for Use and Reuse include: emissions and waste. Regarding outputs of waste, it is assumed that the amount of solid waste is negligible. However, washing and drying does generate waste water. It is assumed that the amount of generated waste water is the same amount as water used for washing the jeans.

Energy inputs

Energy inputs include electricity use for the washing machine and the tumble dryer. The amount of energy used for the washing procedure depends on the washing temperature and washing frequency. The assumption is made that the jeans are washed at 40 °C and that they are used 6 times before being washed. These assumptions are based on the results from a Norwegian study conducted in 2010 where surveys were used to obtain the results (Laitala et al., 2012). In order to determine the the washing frequency, an assumption had to be made regarding how often the jeans are used. The assumption was made that the jeans are worn on average three times per week. However, no study have been found to base this assumption on. For energy consumption related to tumble drying, the assumption was made that the jeans are tumble dried each time they are washed. Allocated energy for washing and tumble drying is calculated in a similar manner as allocated water use. The calculation procedure for determining allocated energy use is presented in appendix D.

3.3.2.5 Repair

Firstly, it should be noted that the Repair process only applies to the circular case. Figure 3.9 presents the process steps involved in the repair procedure as well as material inputs needed for repairing the jeans.

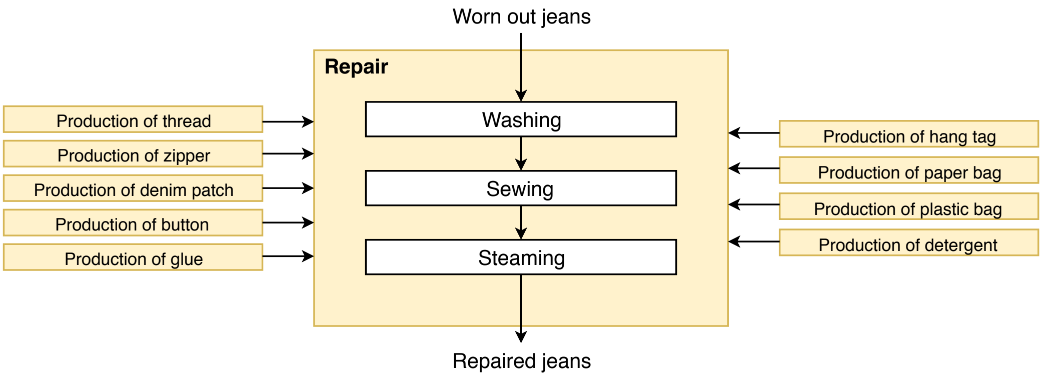

Figure 3.9: A flowchart depicting the process steps for Repair.

Process steps

As illustrated in figure 3.9, Repair involve the following process steps: washing, sewing and steaming. In terms of material and energy use, the washing procedure for Repair is considered to be the same as for the washing procedure for Use and Reuse. Furthermore, only repair procedures conducted in Sweden are included in this study according to the defined system boundary.

The repaired jeans, referred to as reuse jeans, can be divided into three categories: reuse jeans for the initial owner, reuse jeans sold in a Repair Shop and reuse jeans sold online. The following applies for the three categories:

- Reuse jeans for the initial owner involve a customer handing in their worn out jeans to a repair shop and then retrieving them once they have been repaired.
- Reuse jeans sold in a repair shop entail a customer handing in their jeans that they no longer want to keep. These jeans are repaired at the Repair Shop and then sold to another customer.
- Reuse jeans sold online also entail customers submitting unwanted jeans to a Repair Shop. The unwanted jeans are repaired and refurbished at a Repair Shop located in Göteborg and then sold online at Nudie Jeans' webpage.

Material inputs

Material inputs additional to the LDLL jeans include: detergent, water for washing and steaming, materials needed for repairing the jeans. Also, a plastic or paper bag is used as packaging material. The allocated amount of detergent was calculated according to equation D.8 in appendix D, where number of washes was set to one.

Allocated water used for the washing procedure have been calculated according to equation D.11 in appendix D. The calculation procedure for determining the allocated amount of water used for steaming is presented in appendix D.

The material needed for repairing jeans are: thread, glue, fabric, buttons, zippers and hang tags. However, all of theses materials are not needed for each repair. Therefore, an average amount of material needed to repair one pair of LDLL jeans was determined based on data gathered from customers. A description of this calculation is presented in appendix C. Furthermore, it should be noted that production of the denim patch was modelled as Production of Fabric at Candiani.

A paper bag is used for jeans that are repaired in Repair Shops and a plastic bag is used for repaired jeans being sold online. In order to allocate packaging material for one pair of jeans, a fraction was used based on the number of jeans sold online and in Repair Shops. The calculation procedure for obtaining the allocated amount of paper and plastic bags is presented in appendix D.

Material outputs
The generated outputs include emissions and waste. Waste water is generated from the washing procedure and the amount of waste water is assumed to be the same as amount of water used for the washing procedure.

Energy inputs
The repair process requires energy for washing and sewing. Allocated energy needed for the washing procedure has been calculated in the same manner as for Use and Reuse. The energy required for sewing depends on the amount of time that the sewing machine is used. The calculation procedure for determining allocated energy used for sewing is presented in appendix C.

3.3.2.6 Incineration

The End-of-Life treatment of the jeans is incineration at an incineration plant. According to defined system boundary, only incineration taking place in Sweden is included.

Material in- and outputs
The material input to the Incineration include worn out LDLL jeans and main outputs include emissions and solid waste in terms of ashes.

Energy outputs
Energy is generated from incineration and this energy can be utilised for district heating. Conducting system expansion instead of allocation takes this aspect into consideration. For this LCA, system expansion is not conducted but this option is investigated through a sensitivity analysis where Incineration is included.

3.4 Data Collection

The collected data for each activity was managed in Microsoft Excel and submitted to the LCA software, GaBi. The data collection procedure for each activity presented in the flowchart is presented below.

3.4.1 Production of Fabric

The inventory data for Production of Fabric have primary been obtained through a data collection form which was sent to Candiani in 2018 (Åslund Hedman, 2018). The content of the data collection form can be found in appendix E.1. However, the answers from Candiani will not be disclosed due to confidentiality. Certain complementary data on amounts of chemicals were collected through e-mail conversations with Candiani. Furthermore, input and output data for energy and material that relate to extraction of the raw materials and production of auxiliary materials have been obtained through modelling in GaBi.

All inventory data and modelling choices in GaBi related to Production of Fabric are presented in table D.3. Assumptions for specific inventory data are presented in table D.4 in appendix D. Regarding transports, inventory data and modelling choices in GaBi for Production of Fabric are presented in table D.5 in appendix D. Assumptions for the transportation processes are presented in table D.6 in appendix D.

3.4.2 Production of Jeans

A majority of the inventory data for Production of Jeans have been obtain through a data collection form sent to Denim Authority in 2018 (Åslund Hedman, 2018). The questions, but not answers, included in the data collection form is presented in appendix E.2. Furthermore, inputs and outputs of energy and material related to extraction of raw materials and production of auxiliary materials have been obtained through modelling in GaBi.

Several of the chemicals required for the washing procedure where not available in the GaBi dataset. Thus, alternative chemicals where chosen in order to enable modelling in GaBi. These alternative chamicals are presented in table D.9 in appendix D. The grounds for the choices are presented in the table as well.

Table D.3 includes all inventory data and modelling choices in GaBi related to Production of Jeans. Assumptions for specific inventory data are presented in table D.8 in appendix D. Inventory data and modelling choices in GaBi related to transports for Production of Jeans are presented in table D.10 in appendix D. Assumptions for the transports are presented in table D.11 in appendix D.

3.4.3 Storage

Inventory data for storage at the warehouse have primarily been collected through a data collection form sent to the Korallen in 2019. The content but not the answers of the data collection form can be found in table E.3 in appendix E.3. Regarding inventory data for the storage at Repair Shops and retailers, no site specific data have been collected. Instead, estimations and assumptions have been conducted in order to obtain the inventory data for these process steps. Furthermore, all input and output of energy and material related to production of auxiliary materials have been obtained through modelling in GaBi.

All inventory data and modelling choices in GaBi related for Storage are presented in table D.12. Assumptions made for specific inventory data are presented in table D.13 in appendix D. Inventory data and modelling choices in GaBi related to transports for Production of Fabric are presented in table D.14 in appendix D. Assumptions for the transports are presented in table D.15 in appendix D.

3.4.4 Use and Reuse

Inventory data collected for Use and Reuse is not site specific. Most data have been gathered from studies on laundry habits (Laitala et al., 2012) and online sources on energy consumption for washing and drying (Energimyndigheten, 2011) (Bosch, 2019) as well as consumption of detergent (Ecolabelling Denmark, 2011). Also, assumptions have been made related to washing and drying frequency. Furthermore, input and output data related to production of detergent have been obtained through modelling in GaBi where these data depend on the amount of produced detergent.

All inventory data and modelling choices in GaBi for Use and Reuse, are presented in table D.16. Assumptions made for specific inventory data are presented in table D.17 in appendix D. Inventory data and modelling choices in GaBi related to transports for Use and Reuse are presented in table D.18 in appendix D and assumptions for the transport are presented in table D.19 in appendix D.

3.4.5 Repair

The inventory data for Repair have mainly been collected through mail correspondence and a data collection form sent to Michael Lundin, the Project Coordinator for the Repair and Reuse concept at Nudie Jeans. This data collection form is presented in table E.9 appendix E.4. Also, data gathered from Nudie Jeans' customers at Nudie Repair Shops in Sweden have been used. Moreover, in- and output data related to extraction of the raw materials and production of auxiliary materials have been obtained through modelling in GaBi.

Table D.20 includes all inventory data and modelling choices in GaBi related to energy and material used for Repair. Assumption for specific inventory data are presented in table D.21 in appendix D. Inventory data and modelling choices in GaBi related to transports for Repair are presented in table D.22 in appendix D and assumptions for these transports are presented in table D.23 in appendix D.

3.4.6 Incineration

The incineration process have been modelled in GaBi. Thus, all in- and output data, except for amount of incinerated material, related to Incineration have been obtained from modelling in GaBi.

Table D.12 presents the inventory data and modelling choices in GaBi for Incineration. Furthermore, assumptions made for specific inventory data are presented in table D.13 in appendix D. Inventory data and modelling choices in GaBi related to transports for Incineration are presented in table D.14 in appendix D. Also, assumptions for the transports are presented in table D.15 in appendix D.

4

Results and Discussion

4.1 Characterisation Results

The results include the linear case compared to the circular case in terms of the studied impact categories. The linear case involve zero reuse of the jeans whereas the circular case involve three reuses. The results are presented below where the contribution from the main activities of the life cycle of the LDLL jeans are depicted. Trends identified from the results and discussion of the results are presented below the figures.

4.1.1 Global Warming Potential

Figure 4.1 and table D.26 in appendix D.8 presents the results of Global Warming Potential (GWP100). The figure show that the circular case constitutes less than half of GWP100 for the linear case. Moreover, for the linear case, the largest contributor to GWP is Production of Fabric followed by Storage and Transports. For the circular case, Production of Fabric is the largest contributor as well, followed by Use/Reuse and Transports.

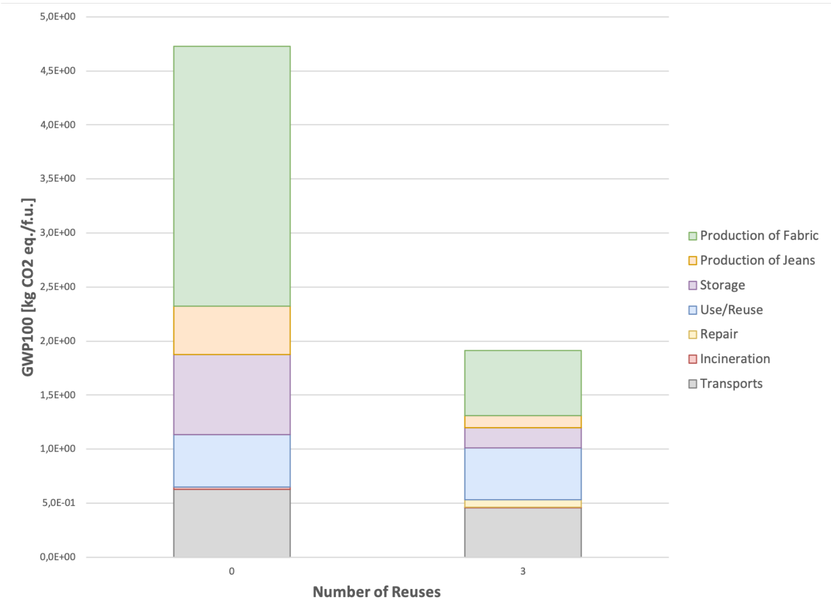

Figure 4.1: Stacked barcharts depicting the results of Global Warming Potential (GWP100) for the activities involved in the life cycle of a pair of LDLL jeans. A linear case (zero reuse) is compared to a circular case (three reuses).

4.1.2 Acidification Potential

Figure 4.2 presents the characterisation results for Acidification Potential (AP) where the impact from each main acitivty is depicted. However, the results are also presented in table D.26, which can be found in appendix D.8. It can be seen in the figure that AP for the circular case constitutes less than half of AP for the linear case. Furthermore, it can be seen in the figure that Production of Fabric is the greatest contributor to AP for the linear case. Moreover it can be seen that the contribution from Production of Jeans, Storage, Use/Reuse and Transports are similar in size. Regarding the circular case, Use/Reuse is the greatest contributor followed by Production of Fabric and Transports.

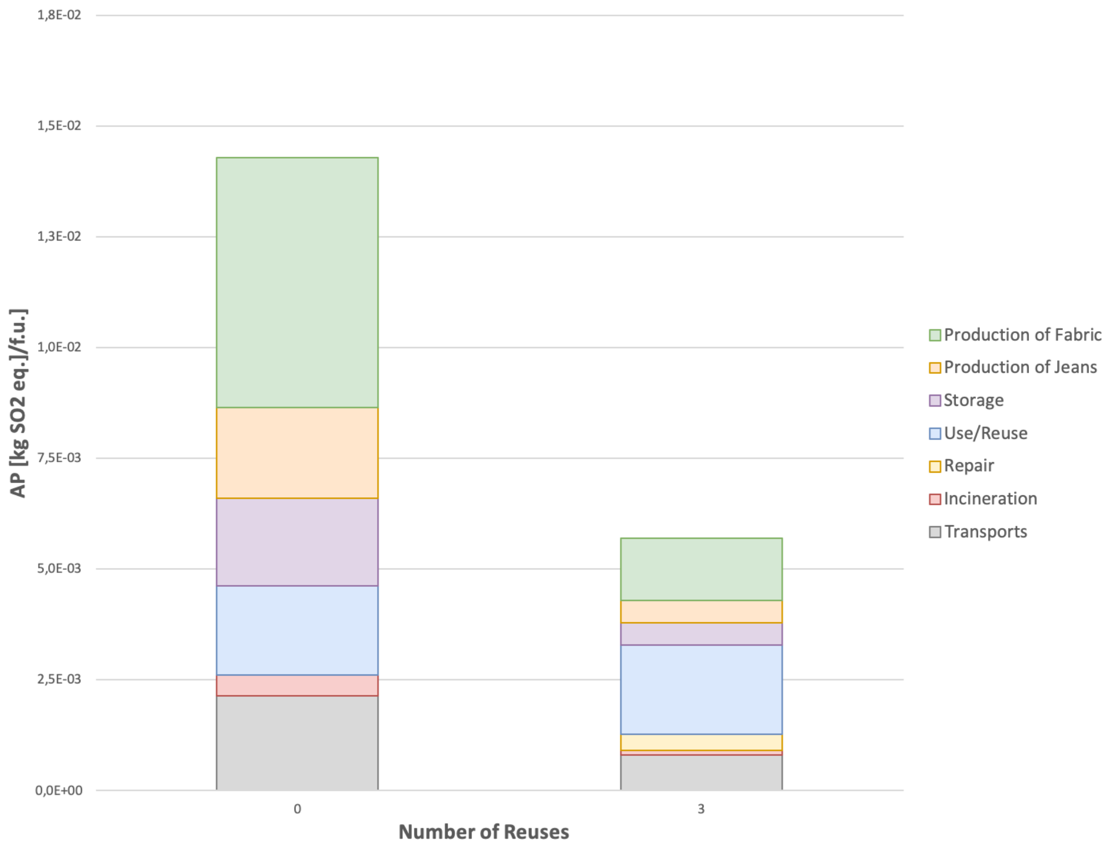

Figure 4.2: Stacked barcharts depicting the results of Acidification Potential (AP) per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case (zero reuses) is compared to a circular case (three reuses).

4.1.3 Euthrophication Potential

Figure 4.3 presents the characterisation results for Eutrophication Potential (EP) where the contribution from each main acitvity is depicted. The results are also presented in table D.26, which can be found in appendix D.8. The figure illustrates that EP for the circular case constitutes about half of EP for the linear case. It can also be seen in the figure that the greatest contributor to EP for the linear case is Production of Fabric, followed by and Use/Reuse and Production of Jeans. Regarding the circular case, the greatest contributor to EP is Use/Reuse followed by Production of Fabric and Production of Jeans.

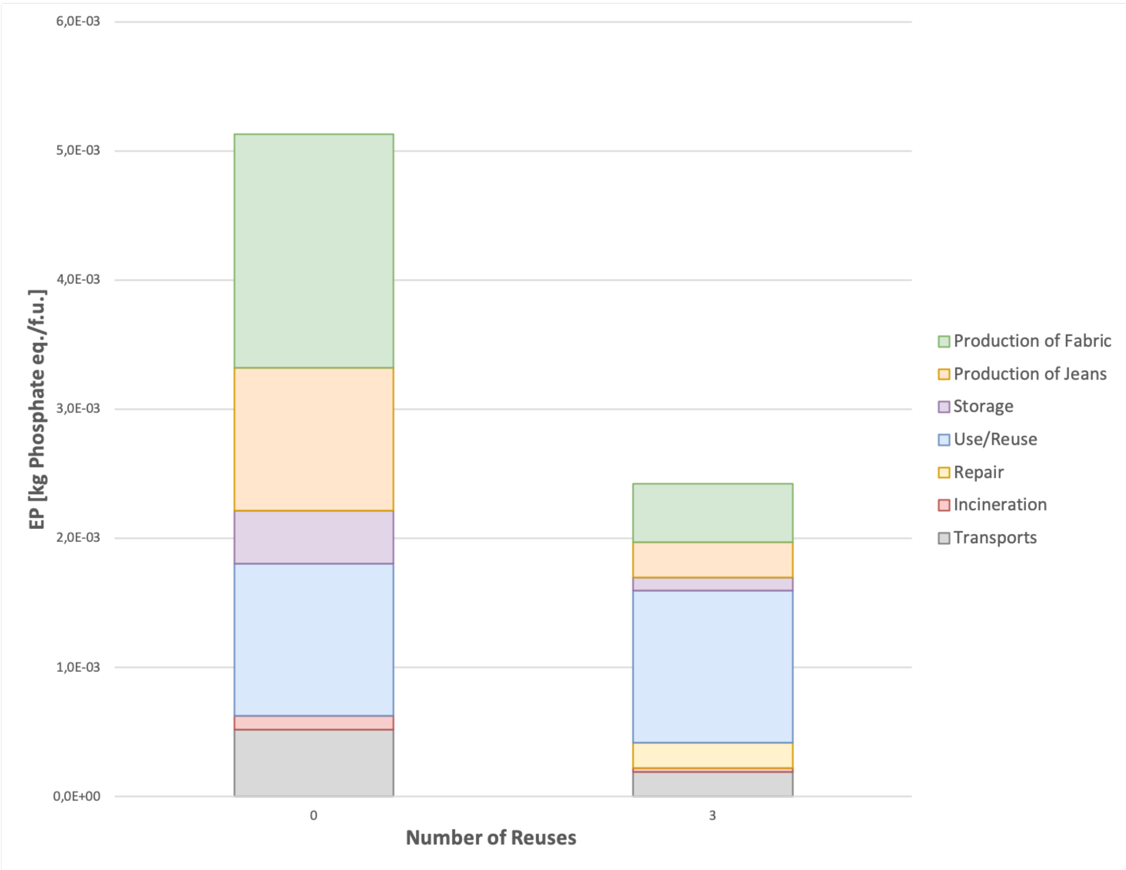

Figure 4.3: Stacked barcharts depicting the results of Euthrophic Depletion (EP) per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case (zero reuses) is compared to a circular case (three reuses).

4.1.4 Particulate Matter

Figure 4.4 presents the characterisation results for Particulate Matter (PM) where the contribution from each activity of the life cycle is depicted. The results are also presented in table D.26 in appendix D.8. It can be seen in the figure that PM for the circular case constitutes about one third of the impact for AP for the linear case. For both cases, the largest and the second largest contributor to PM are Production of Fabric and Production of Jeans, respectively. For the linear case, the third largest contribute to PM is Transports. The third largest contributor to the circular case is Use/Reuse.

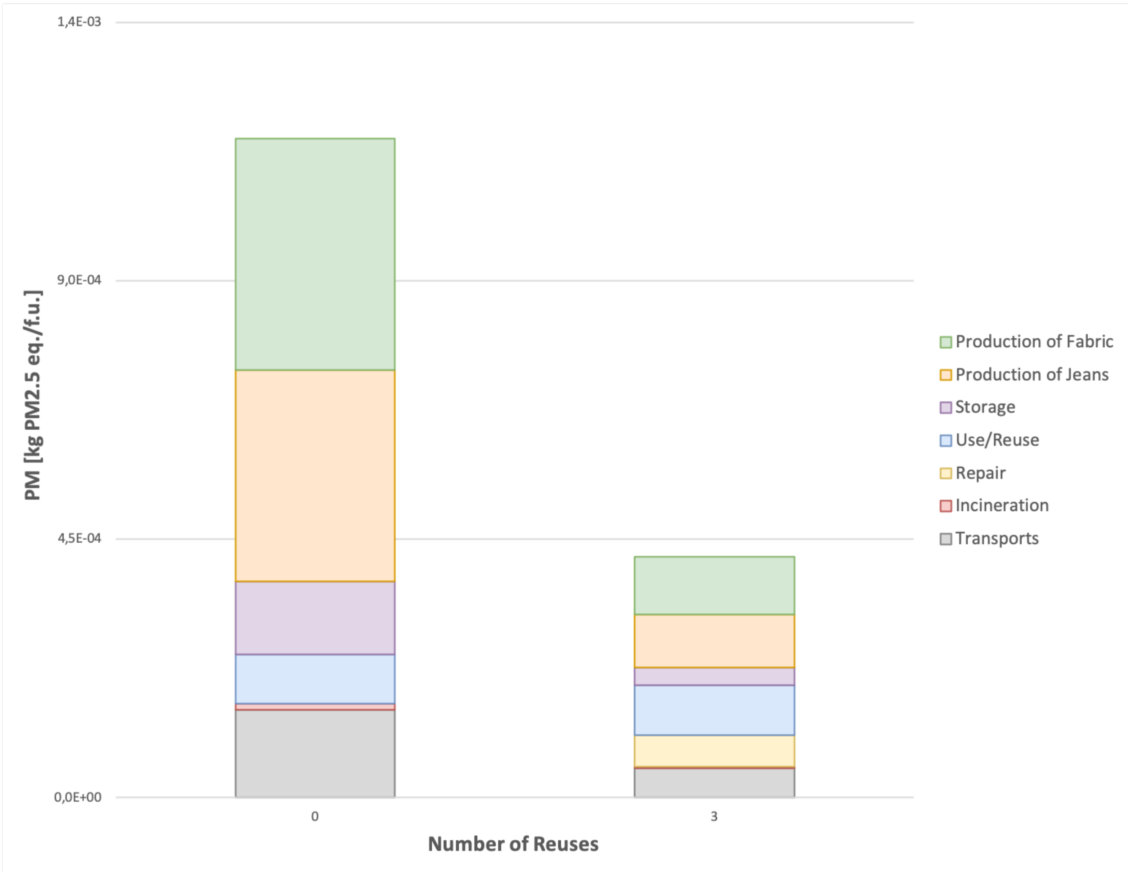

Figure 4.4: Stacked barcharts depicting the results of Particulate Matter in terms of the functional unit, for the process steps involved in the life cycle of a pair of LDLL jeans. A linear case (zero reuses) is compared to a circular case (three reuses).

4.1.5 Ozone Layer Depletion Potential

The characterisation results for Ozone Layer Depletion Potential (OLDP) where the contribution from the main activities in the life cycle are depicted, are presented in figure 4.5 and in table D.26 in appendix D.8. First and foremost, the figure illustrates that the circular case constitutes less than half of the impact from the linear case. Moreover, as can be seen in the figure, Production of Jeans is the dominating contributor to the linear case. The second and third largest contributor to the linear case are Storage and Production of Fabric. Regarding the circular case, the greatest contributor to OLDP is Production of Jeans relatively closely followed by Repair. The third largest contributor OLDP for the circular case is Storage.

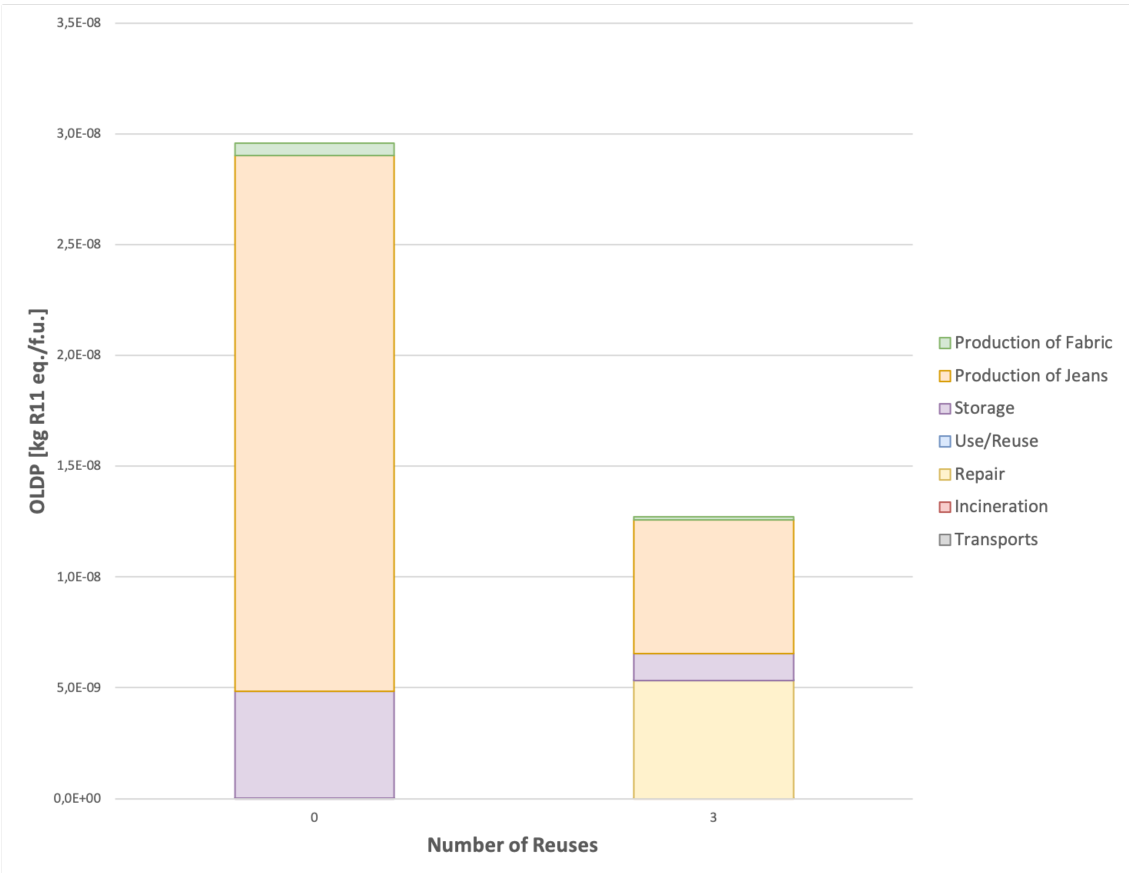

Figure 4.5: Stacked barcharts depicting the results of Ozone Layer Depletion Potential (OLDP) per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case (zero reuses) is compared to a circular case (three reuses).

4.1.6 Photochemical Ozone Creation Potential

The characterisation results for the main activities regarding Photochemical Ozone Creation Potential (POCP) is presented in table 4.6 and in table D.26 in appendix D.8. The figure illustrates that POCP for the circular case constitutes about one third of POCP for the linear case. For both cases, the largest contribution to POCP is Production of Jeans. For the linear case, the second largest contribution to POCP are Production of Fabric followed by Storage and Use/Reuse. Note that the contribution from Storage and Use/Reuse is equal. For the circular case the second and third largest contribution to POCP are Use/Reuse and Production of Fabric.

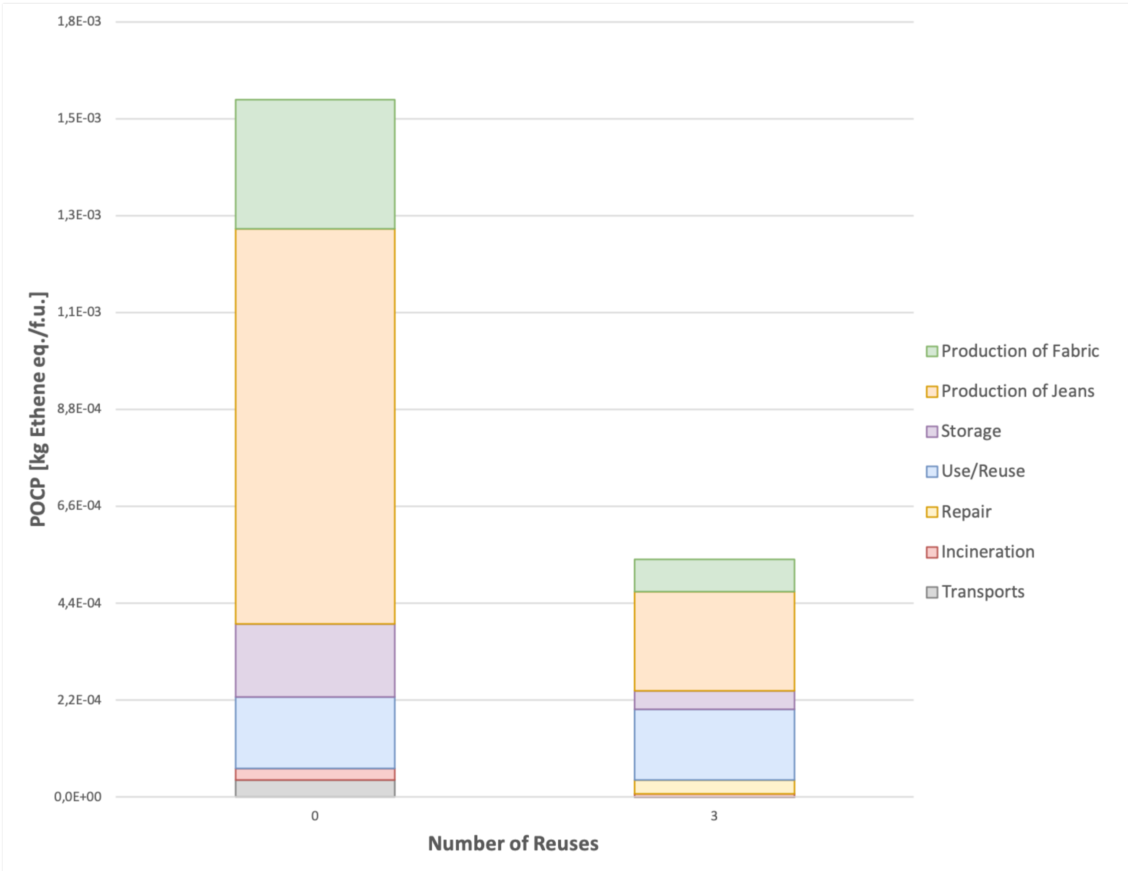

Figure 4.6: Stacked barcharts depicting the results of Photochemical Ozone Creation Potential (POCP) per functional unit, for the process steps involved in the life cycle of a pair of LDLL jeans. A linear case (zero reuses) is compared to a circular case (three reuses).

4.1.7 Ionising Radiation

The characterisation results for Ionising Radiation (IR) for the main activities of the life cycle are presented in figure 4.7 and in table D.26 in appendix D.8. It can be seen in the figure that IR for the circular case constitutes about two thirds of IR for the linear case. It can also be seen in the figure that the dominating contributor to IR for both the linear and the circular case is Use/Reuse. For both of the cases, the second and third largest contributor to IR is Storage and Production of Fabric, respectively.

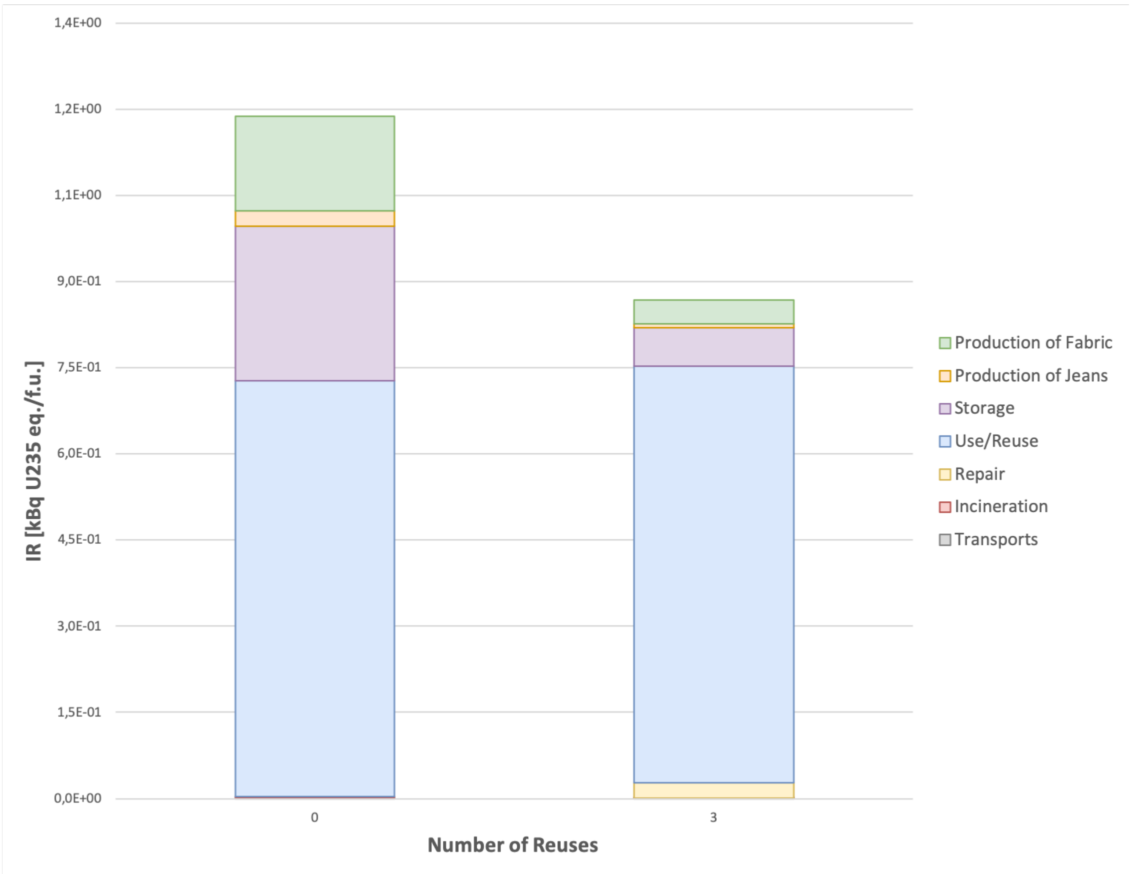

Figure 4.7: Stacked barcharts depicting the results of Ionizing Radiation Potential (IRP) per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case (zero reuses) is compared to a circular case (three reuses).

4.1.8 Abiotic Depletion

Figure 4.8 presents the characterisation results for Abiotic Depletion (AD) where the impact from each main activity is depicted. The results are also presented in table D.26, which can be found in appendix D.8. The figure illustrates that AD for the circular case constitutes less than half of AD for the linear case. The figure also illustrates that the largest contributing activity to the linear (0 reuses) and the circular case is Production of Jeans, followed by Use/Reuse and Production of Fabric.

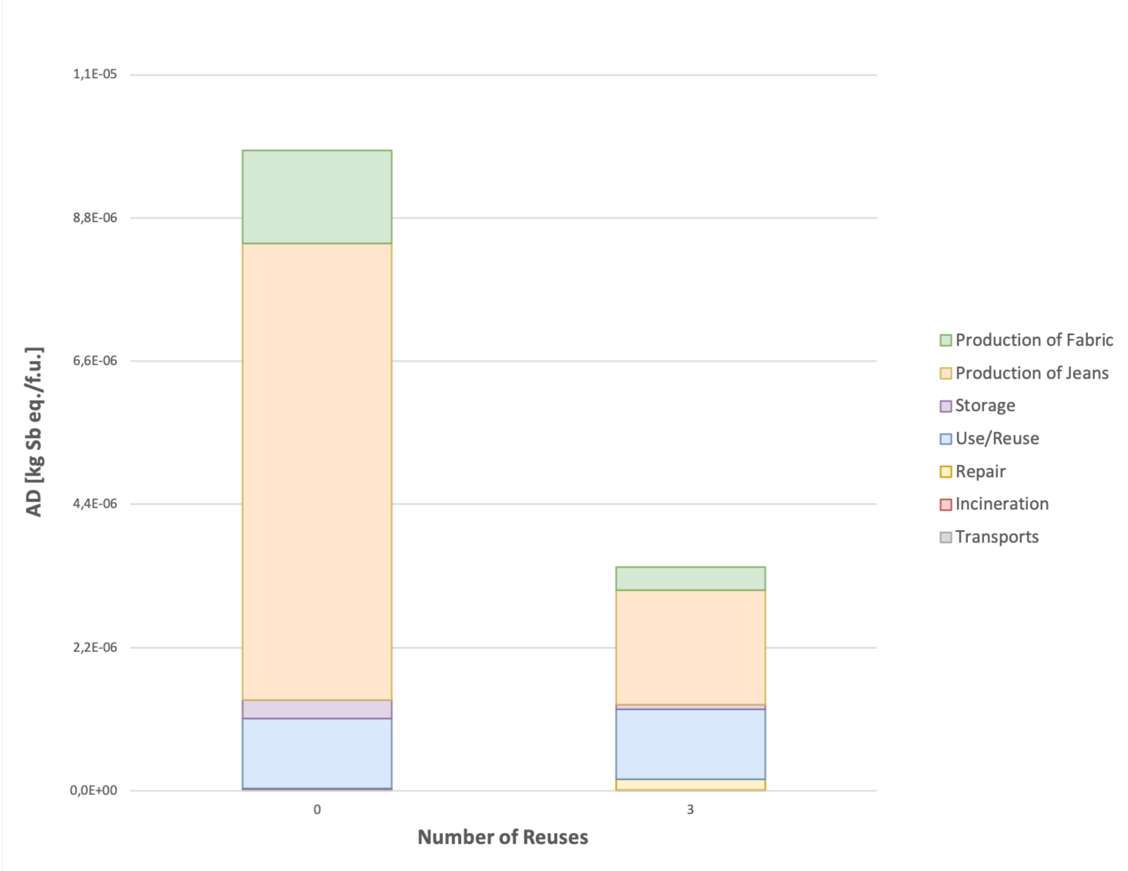

Figure 4.8: Stacked barcharts depicting the results of Abiotic Depletion (AD), per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case (zero reuses) is compared to a circular case (three reuses).

4.1.9 Human Toxicity Potential

The characterisation results of Human Toxicity Potential (HTP) for each main activity is presented in figure 4.9 and in table D.26 in appendix D.8. As can be seen in the figure, HTP for the circular case constitutes less than half of HTP for the linear case. It can also be seen in the figure, the greatest contributor to HTP is Production of Jeans for both the linear and the circular case. For the linear case, the second largest contributor is Production of Fabric followed by Storage. For the circular case, it can be seen that Use/Reuse is the second largest contributor to HTP, followed by Production of Fabric.

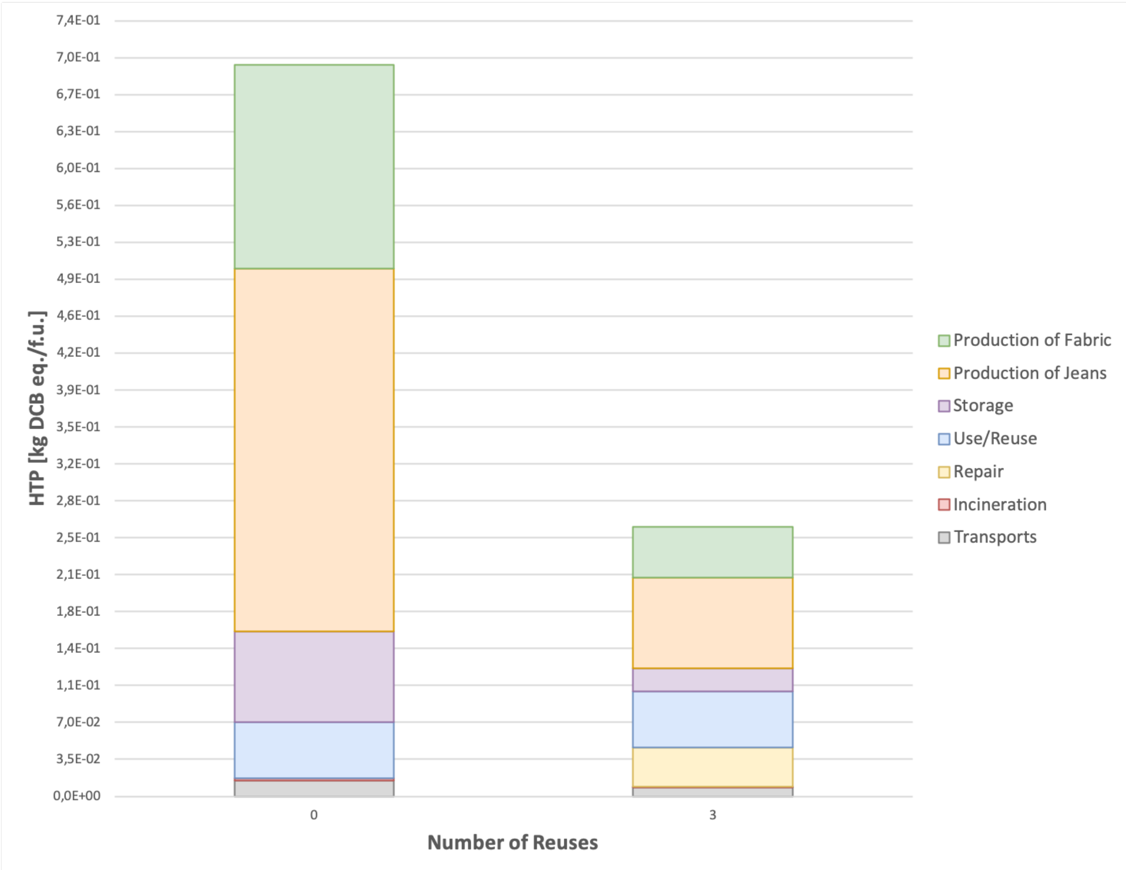

Figure 4.9: Stacked barcharts depicting the results of Human Toxicity Potential (HTP) per the functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case (zero reuses) is compared to a circular case (three reuses).

The characterisation results for Terrestrial Ecotoxicity Potential (TEP), Marine Aquatic Toxicity Potential and Freshwater Aquatic Ecotoxicity Potential (FAEP).

4.1.10 Terrestrial Ecotoxicity Potential

Figure 4.10 presents the results of Terrestrial Ecotoxicity Potential (TEP) for each main activity of the life cycle. The results are also presented in table D.26 in appendix D.8. In the figure, it can be seen that TEP for the circular case (3 reuses) constitutes about half of TEP for the linear case. Moreover, for the linear case (0 reuses), the largest contribution to TEP is Production of Jeans. The second largest contributor for the linear case is Storage and Use/Reuse, since theses to activities contributes equally. Th third largest contributor to the linear case is Production of Fabric. Regarding the circular case (3 reuses), the greatest contributor to TEP is Use/Reuse followed by Repair and Production of Jeans.

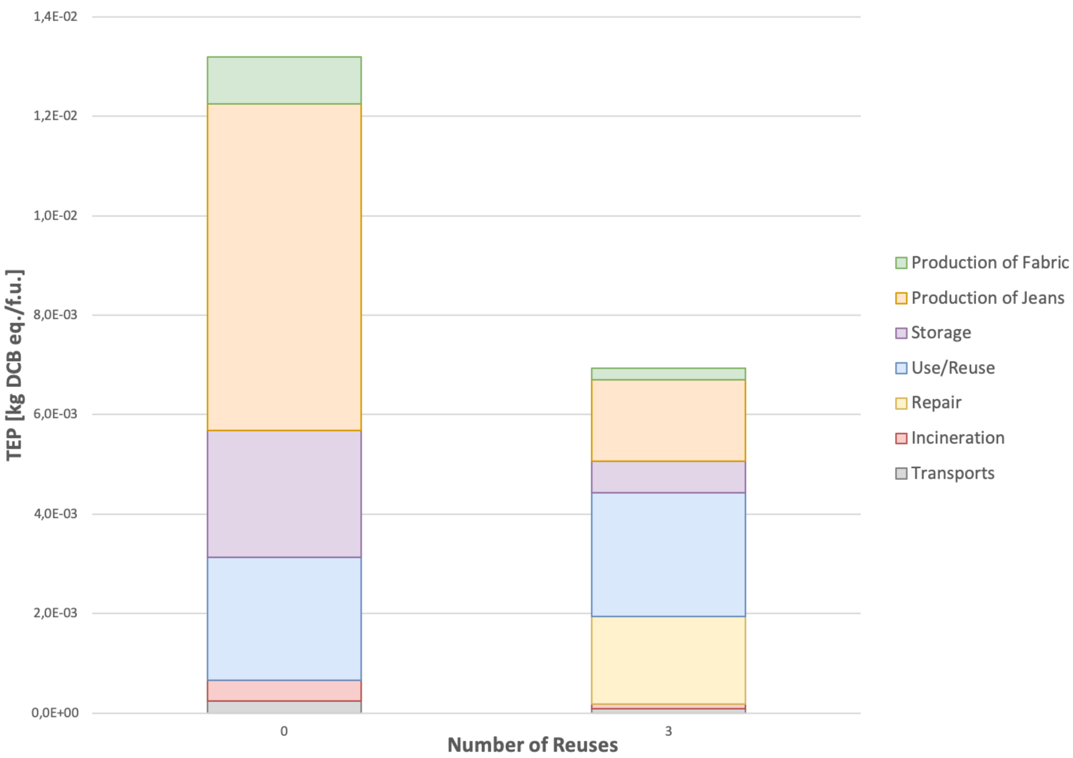

Figure 4.10: Stacked barcharts depicting the results of Terrestrial Ecotoxcity Potential (TEP) per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case (zero reuses) is compared to a circular case (three reuses).

4.1.11 Marine Aquatic Ecotoxicity Potential

Figure 4.11 presents the characterisation results for Marine Aquatic Ecotoxicity Potential (MAEP) where the contribution from the main activities of the life cycle are depicted. The results are also presented in table D.26 in appendix D.8. As can be seen in the figure, MAEP for the circular case constitutes about half MAEP for the linear case. It can also be seen in the figure that MAEP for the linear case can be attributed to Production of Fabric, Production of Jeans, Storage and Use/Reuse. Their individual contribution to MAEP is almost equal but the greatest contribution is assigned to Use/Reuse. For the circular case (3 reuses), Use/Reuse is the greatest contributor to MAEP as well. The second and third largest contributor to MAEP for the circular case are Storage and Production of Fabric.

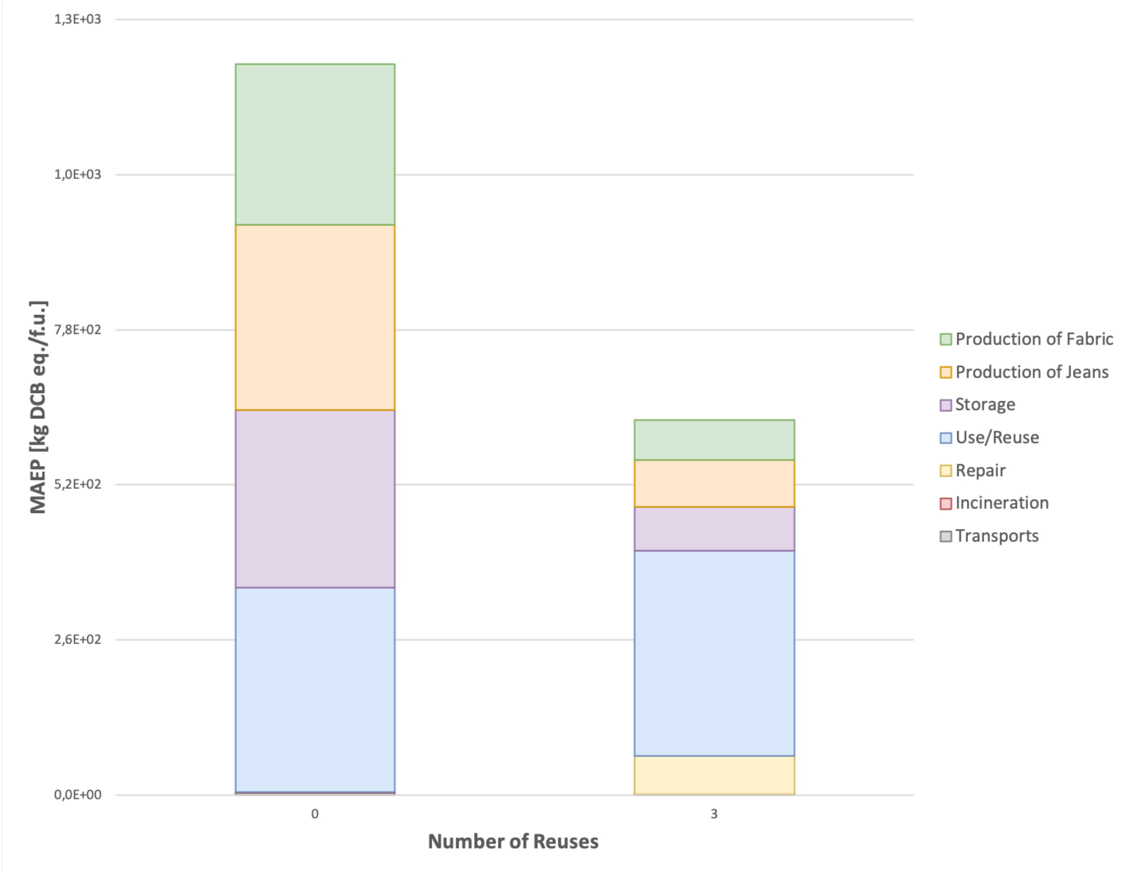

Figure 4.11: Stacked barcharts depicting the results of Marine Aquatic Ecotoxicity Potential (MAEP) in terms of the functional unit, for the process steps involved in the life cycle of a pair of LDLL jeans. A linear case (zero reuses) is compared to a circular case (three reuses).

4.1.12 Freshwater Aquatic Ecotoxicity Potential

The characterisation results of Freshwater Ecotoxicity Potential (FAEP) for each main activity are presented in figure 4.12 and in table D.26. The figure illustrates that FAEP for the circular case constitutes about half of the FAEP for the linear case. The figure also illustrates that Production of Jeans is the dominating contributor to FAEP for the linear case. Thereafter follows Production of Jeans and Use/Reuse. Repair constitutes the greatest contributor to FAEP for the circular case, followed by Production of Jeans and Use/Reuse.

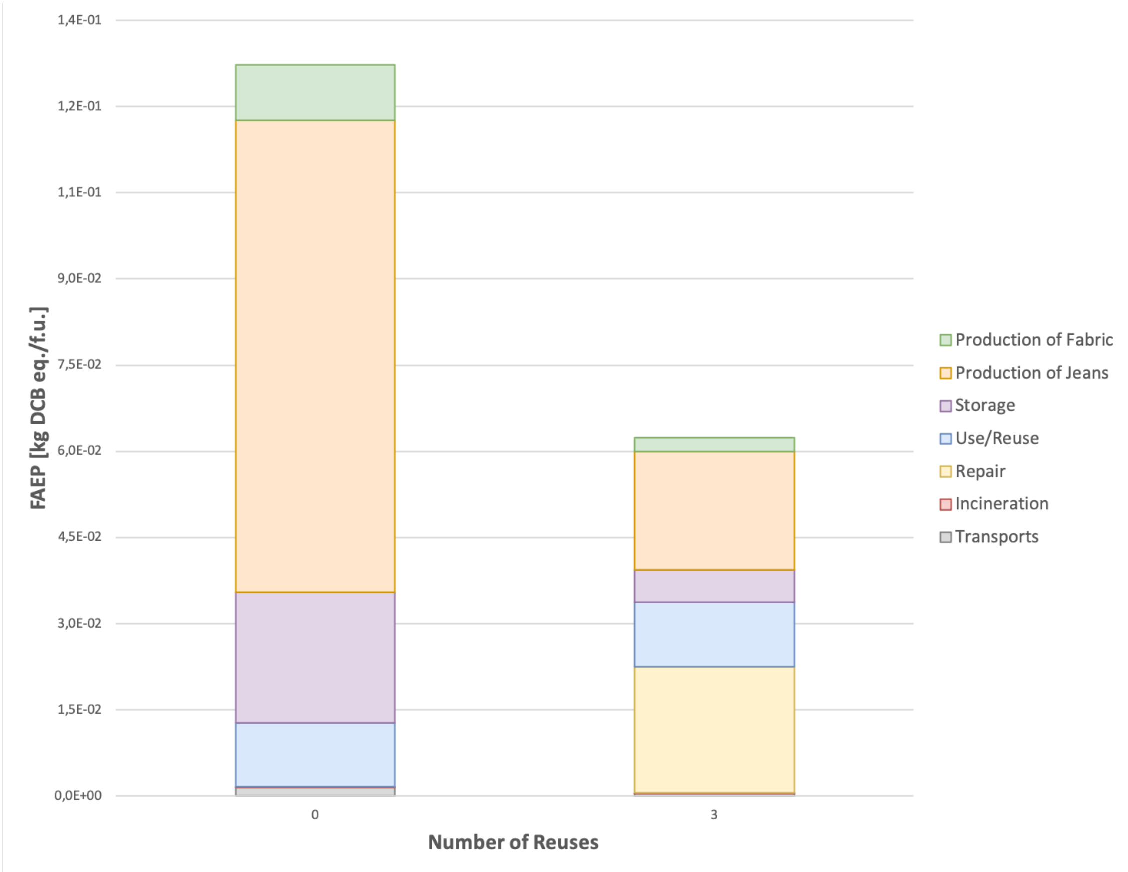

Figure 4.12: Stacked barcharts depicting the results of Freshwater Aquatic Ecotoxicity Potential (FAEP) per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case (zero reuses) is compared to a circular case (three reuses).

Certain trends can be observed from the characterisation results presented above. One obvious trend is that the impact is less for the circular case compared to the linear case for all impact categories. More specifically, the impact from the circular case is less than half of the impact from the linear case for all impact categories with the exception of Ionisation Radiation (IR). An explanation to this is that Use/Reuse is heavily dominated by electricity consumption from the modelled Swedish grid. Thus, the high value for IR is explained by the fact that Sweden has a big share of nuclear power attached to the electricity generation, which is considerable source to ionisation radiation. Additional trends related to the activities contributing to environmental impact are the following:

- For all impact categories, Use/Reuse contributes equally to the linear and circular case.
- Incineration contributes marginally (less than 5 %) to the impact for all impact categories.
- Production of Jeans constitutes the greatest contributor to six of the twelve impact categories for the linear case and four of the impact categories for the circular case.
- Production of Fabric constitutes the greatest contributor to four of the impact categories for the linear case and two of the impact categories for circular case.
- Use/Reuse constitutes the greatest contributor to two of the impact categories for the linear case and five of the impact categories for the circular case.
- Repair constitutes the greatest contributor to one of the impact categories.

The results presented above imply that Production of Jeans, Production of Fabric and Use/Reuse are the three main activities contributing to significant environmental impact. The inventory data for Production of Jeans and Production of Fabric are primarily site specific. However, the data collected for Use/Reuse are mostly based on assumptions and estimations. One large uncertainty related to Use/Reuse is how often the jeans are worn which affects how often they are washed and tumble dried. Thus, putting effort on obtaining empirical data through surveys would contribute to increasing the reliability of the results. Furthermore, it would be beneficial to study different types of behaviours related to the Use/Reuse phase in order to establish certain categories, which describe how well various groups of people treat their jeans. This would be appropriate to do from a comparative perspective, where such an LCA could be communicated in an effort to help people change their habits to the better in order to reduce environmental impact.

Transports throughout the life cycle of the LDLL jeans were also something that were assumed to a great extent due to a couple of reasons. One, some subcontractors kept the location of their processes hidden. Two, use behaviour is difficult to determine, especially when it comes to determining how customers travel to and from the Repair Shops. Three, upstream processes, such as material extraction of cotton, are also very difficult to track. Therefore, estimates based on educated guesses were performed with the guidance of IVL. Two standard estimations were 100 km and 500 km transports, respectively. Since these estimations are very rough, more site-specific data regarding locations would likely improve the reliability of the results significantly. A customer survey on means of transportation and distances travelled to and from Repair Shops or retailer would also improve the reliability of the results. Furthermore, a sensitivity analysis on assumed transport distances and means of transportation for the customers could have provided insight regarding the robustness of the results.

Furthermore, the significance of the results in a larger sense could have been investigated though normalisation where the results are related to a relevant reference flow. For example, a potential reference flow for Global Warming Potential could be carbon budget per year and capita. Additionally, they could also be compared to other activities that emit carbon dioxide, such as car transports, air freight or dietary choices in order to make the results become more intuitive. Moreover, when comparing the results from this study with the previous LCA conducted in collaboration with Nudie Jeans, it may seem as though the results differ significantly. The previous LCA on LDLL jeans determined that GWP for the jeans were 16,6 kg CO_2 equivalents and the results from our study conclude that GWP for the LDLL jeans is 4,7 kg CO_2 equivalents. However, the functional unit differs for these two results. The previous LCA used the functional unit *one pair of an average sized jean manufactured by Nudie Jeans and consumed in Sweden, over its full lifetime of 200 use cycles* (Åslund Hedman, 2018) whereas this LCA has the functional unit *one pair of Nudie Jeans used for one year*. This showcases the importance in presenting the results in a comprehensible fashion to persons that are not familiar with LCA-methodology, lest the results could be misinterpreted.

Regarding uncertainties, a major uncertainty tied to the results is number of reuses. This value was assumed on the basis for what seems reasonable from the authors' point of view. Thus, the reliability of the characterisation results would increase if data were available regarding how many times the jeans are reused. This data could for example be retrieved through empirical study methods, such as conducting surveys on behavioural matters associated with jeans usage in order to improve the accuracy of the modelled impacts regarding the use phase.

A methodological choice affecting the results is the choice of life cycle impact assessment (LCIA) method. CML 2001 and ILCD/PEF are well established an commonly used LCIA:s but the robustness of the results could be reviewed by conducting a sensitivity analysis on other LCIA methods. This would also provide information regarding the difference between different LCIA methods.

Since Nudie Jeans has the ambition to utilise the results of this LCA for marketing purposes, these types of challenges need to be taken into consideration. Especially due to the fact that Nudie Jeans, through their Environmental Manager, has expressed a form of confusion as to how they should be able to use the LCA results toward customers in marketing in clear and comprehensible way that is easy to understand. Furthermore, this example also stresses the importance of conducting standardised LCA:s in the whole industry in order for customers to make sense of the LCA results by comparing different alternatives in terms of their environmental performance. However, conducting LCA:s as of now is relatively expensive and time consuming and therefore it might not be realistic to assume that the entire fashion industry will conduct LCA:s on all of their products. At least not until regulatory measures are put in place which forces the companies to conduct LCA:s on products. In this case, Nudie Jeans will have an advantage since they have already familiarised themselves with the concept of LCA.

4.2 Contribution Analyses

Two different contribution analyses have been conducted in order to provide information about the underlying processes and their shares to each studied impact category. One contribution analysis involve environmental impact for the linear case whereas the other one involve the Repair activity.

4.2.1 Contribution Analysis for the Linear Case

Processes that account for over 5 % of the studied impacts are identified in order to highlight the major hotspots in terms of processes within the life cycle of the studied LDLL jeans. It should be noted that all of the studied processes have been related to the total respective impacts for the linear case. Identified trends from the results of analysis and a discussion are presented below the figures.

4.2.1.1 Global Warming Potential, Acidification Potential and Euthrophication Potential

Figure 4.13 illustrates that the process that contributes the most to GWP100 is Electricity grid mix which relates to the Production of Fabric in Italy. This process also constitutes the greatest contributor to AP, together with Cotton Cultivation. The figure also illustrates that Cotton Cultivation is the process that contributes the most to EP.

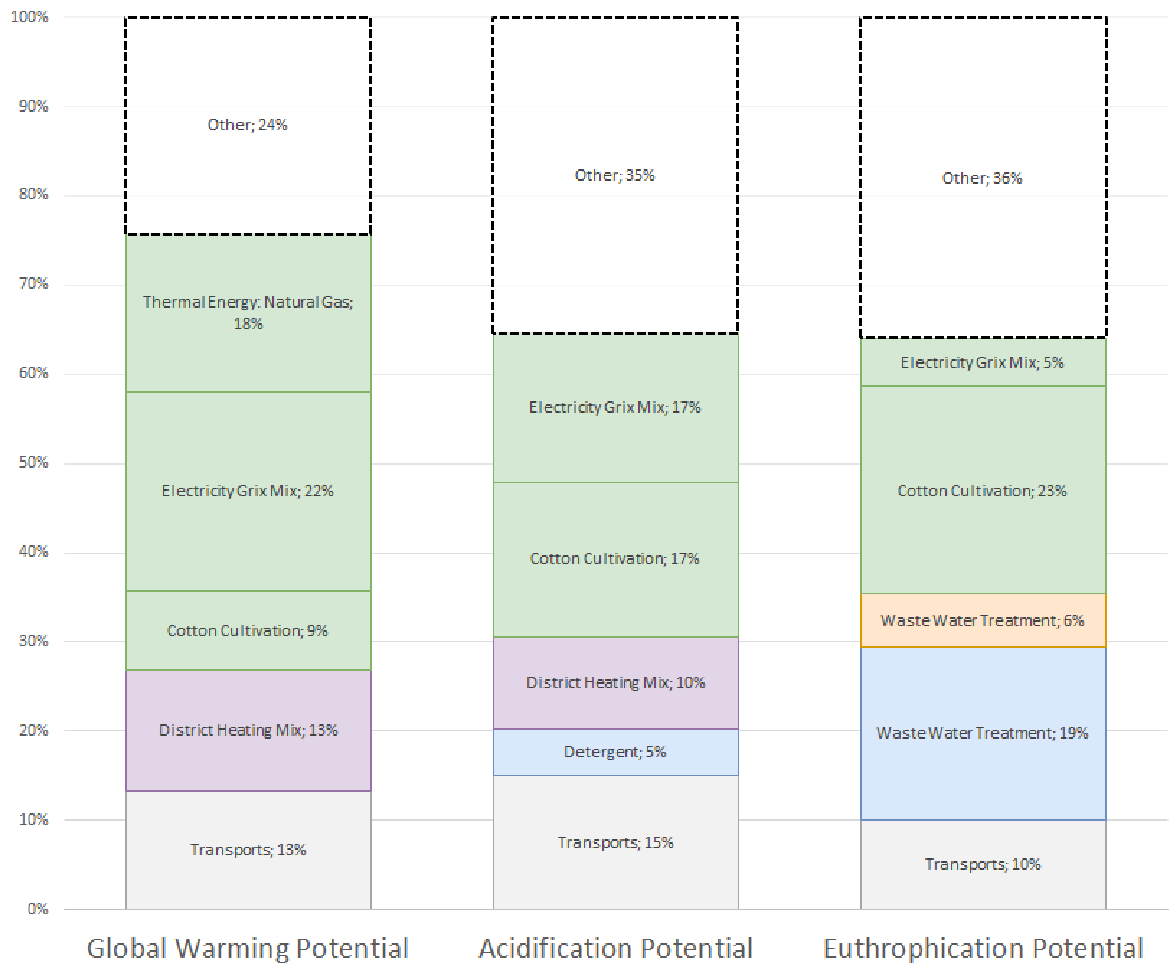

Figure 4.13: Stacked barcharts illustrating the processes that contributes to more than 5 % of the total impacts of GWP, AP, EP for the linear case.

4.2.1.2 Particulate Matter, Ozone Layer Depletion Potential and Photochemical Ozone Creation Potential

Figure 4.13 displays the processes that contribute to more than 5 % of total Particulate Matter (PM), Ozone Olayer Depletion Potential (OLDP) and Photochemical Ozone Creation Potential (POCP), respectively. The figure shows that Cotton Cultivation contributes the most to PM. For OLDP and POCP, Production of Polyester Thread constitutes the greatest contributor.

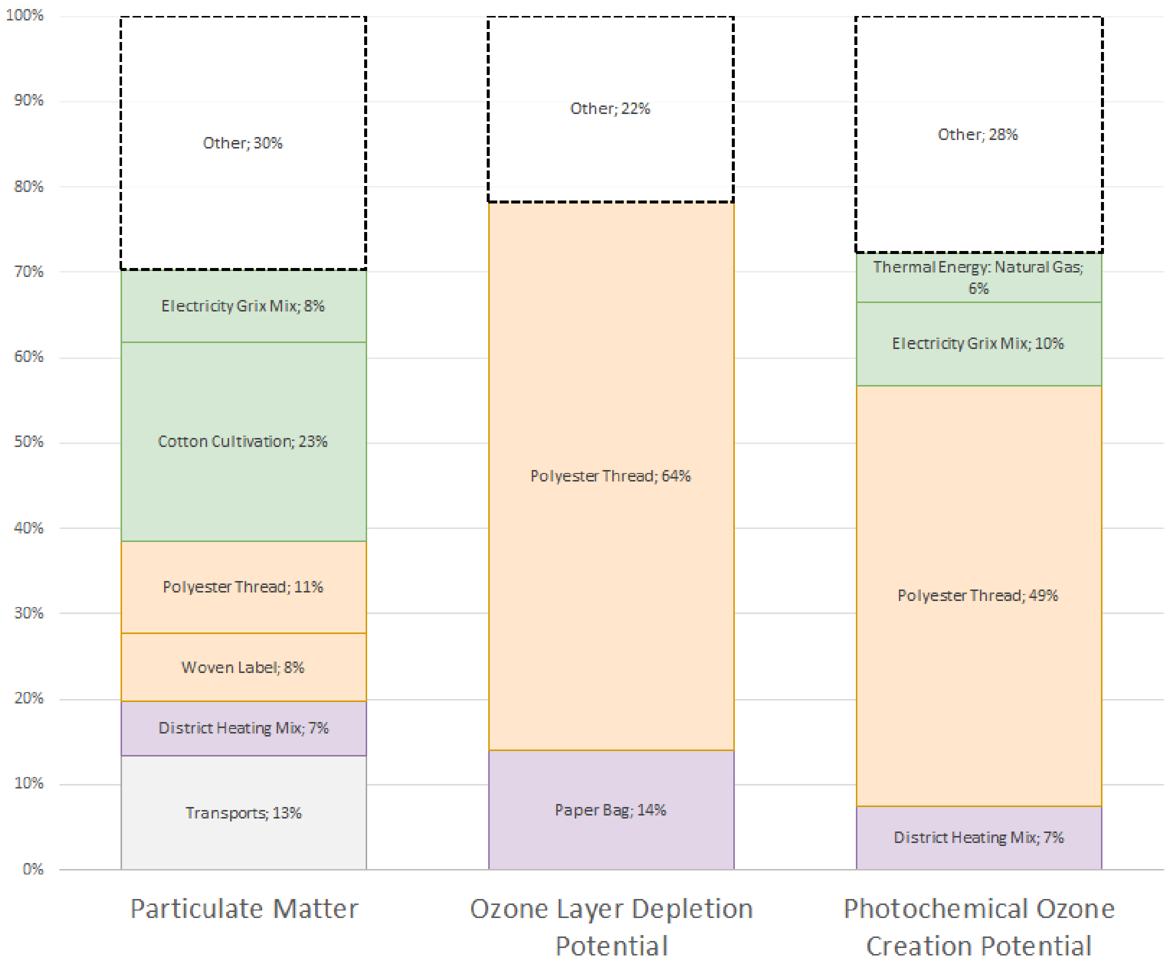

Figure 4.14: Stacked barcharts illustrating the processes that contributes to more than 5 % of the total impacts of PM, OLDP and POCP for the linear case.

4.2.1.3 Ionisation Radiation, Abiotic Depletion and Human Toxicity Potential

As can be seen in figure 4.13, there are two processes that account for the most significant impact for IR: Electricity Grid MIx (Italy) and Cotton Cultivation. It can also be seen in the figure that the process that contributes the most to AD is Production of Button and Rivets whereas Production of Polyester Thread contributes the most to HTP.

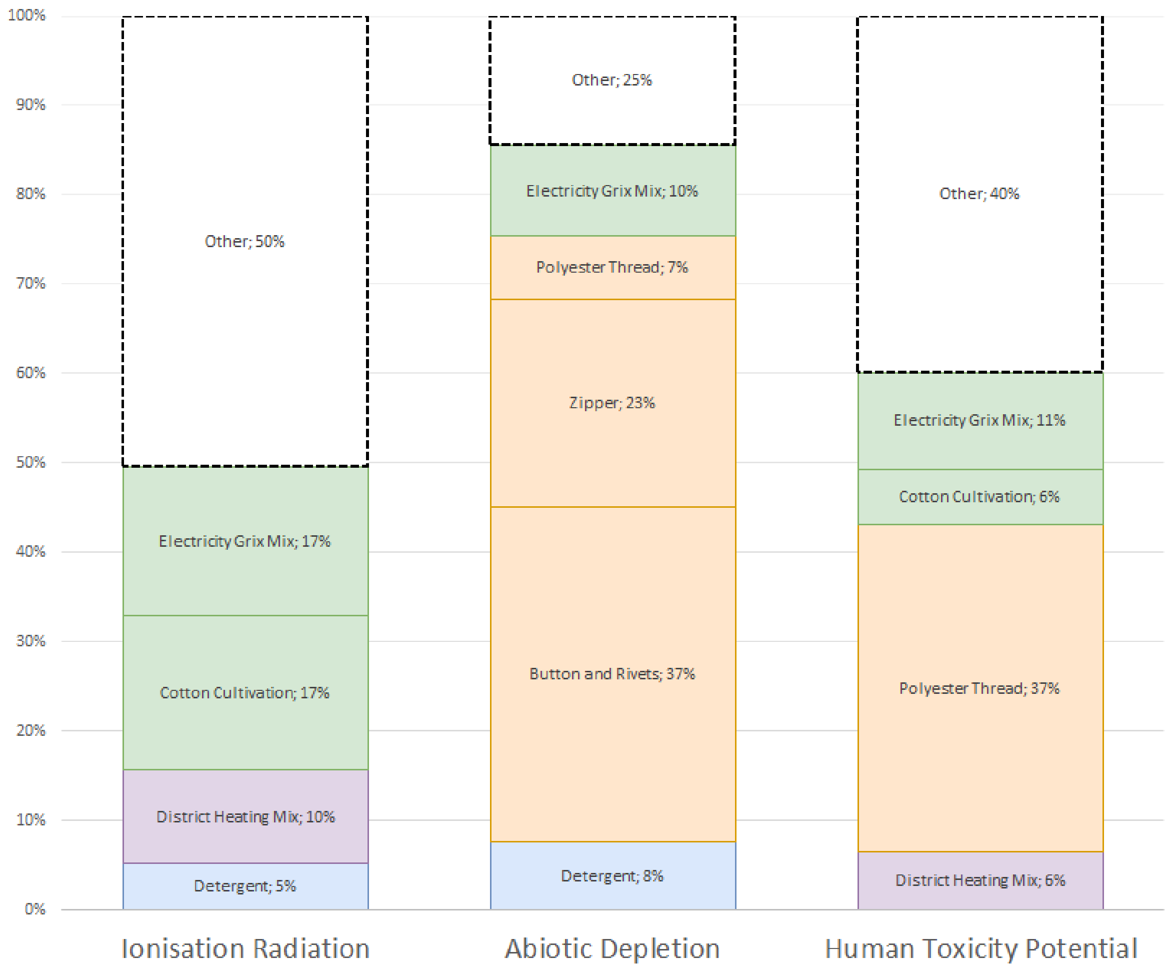

Figure 4.15: Stacked barcharts illustrating the processes that contributes to more than 5 % of the total impacts of IR, AD and HTP for the linear case.

4.2.1.4 Terrestrial Ecotoxicity Potential, Marine Aquatic Ecotoxicity Potential and Freshwater Aquatic Ecotoxicity Potential

In figure 4.16 it can be seen that Production of Polyester Thread accounts for the largest share of the impact related to TEP. Furthermore, District heating mix related to Storage in Sweden contributes the most to MAEP. It can also be seen in the figure that Production of Polyester Thread is the process that contributes the most to FAEP.

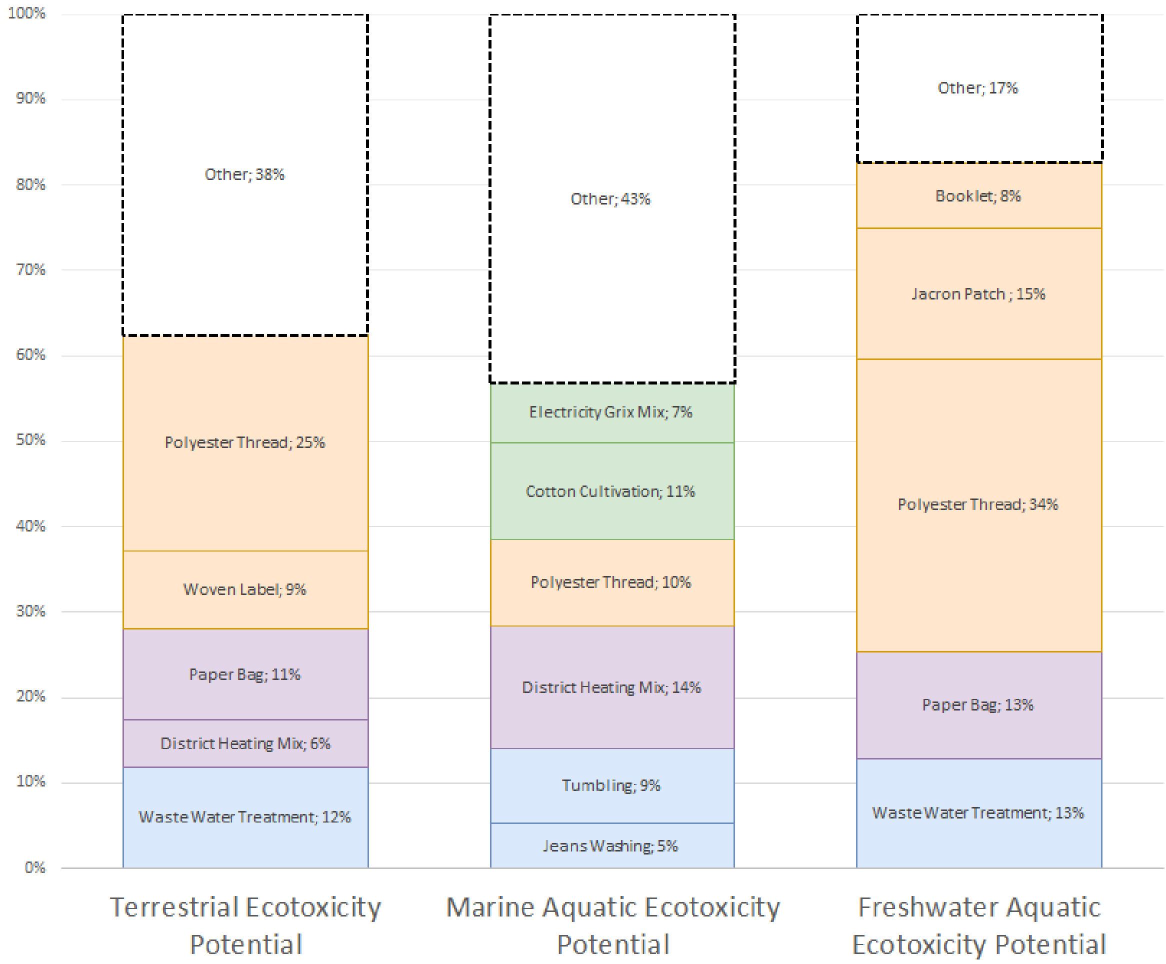

Figure 4.16: Stacked barcharts illustrating the processes that contributes to more than 5 % of the total impacts of TEP, MAEP, FAEP for the linear case.

From the results of the analysis on processes contributing to the linear case, it was found that:

- Production of polyester thread constitutes the greatest contributor to five of the impact categories.
- Cotton cultivation constitutes the greatest contributor to four of the impact categories.
- Electricity grid mix (Italy) related to Production of Fabric constitutes the greatest contributor to three of the impact categories.

- Production of button and rivets constitutes the greatest contributor to one of the impact categories.
- District heating mix (Sweden) which relates to Storage constitutes the greatest contributor to one of the impact categories.

These results of the contribution analysis for the linear case indicate that the processes electricity grid mix (Italy), cotton cultivation and production of polyester thread are significant contributors to environmental impact. However, it should be noted that the impact from these processes have been obtained from through modelling in GaBi where suitable datasets ave been chosen. Thus, the impact is not based on site specific data. In order to investigate the accuracy of these results, measures such as using other datasets in GaBi or other LCA softwares could be taken in an effort to determine if the results change in any significant manner. Site specific data would most likely contribute to more reliable results but it may not be realistic to strive for site specific data when it comes to processes related to extraction of raw materials.

4.2.2 Contribution Analysis for Repair

This contribution analysis study the processes that contribute to environmental impact related to Repair. Therefore, the processes that contribute to more than 5 % of the studied impacts are identified and displayed in the barcharts presented below. Trends identified from the results if the analysis as well as a discussion of the results are presented below the figures.

4.2.2.1 Global Warming Potential, Acidification Potential and Euthrophication Potential

Figure 4.17 illustrate the processes that contribute to more than 5% of Global Warming Potential (GWP100), Acidification Potential (AP) and Euthrophication Potential (EP) for Repair. As can be seen in the figure, GWP for Repair are mostly derived from the overall Transports. Regarding AP, the major share of impact constitutes of Production of Paper bags. The same goes for EP.

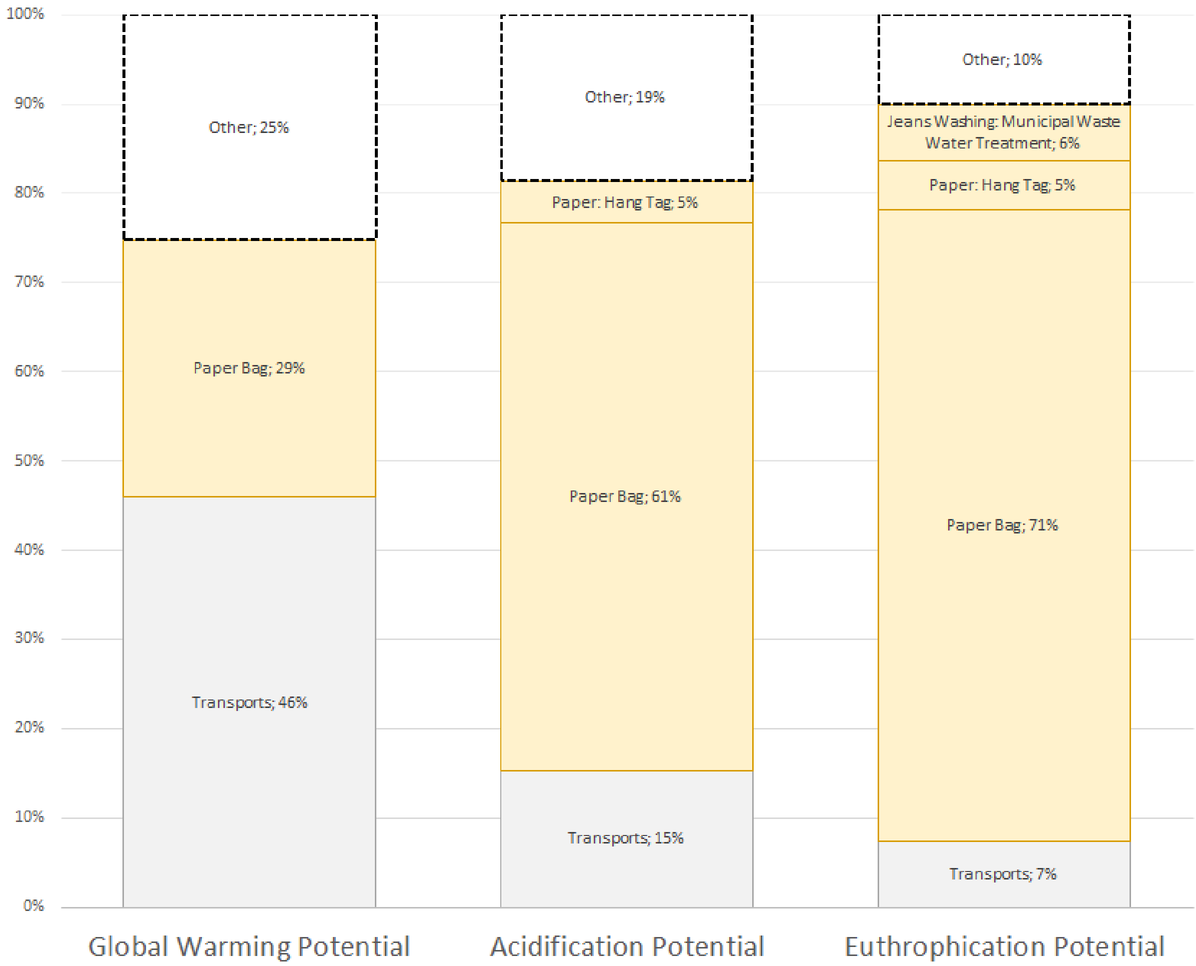

Figure 4.17: Stacked barcharts illustrating the processes that contributes to more than 5 % of the total impacts of GWP, AP, EP for Repair.

4.2.2.2 Particulate Matter, Ozone Layer Depletion Potential and Photochemical Ozone Creation Potential

Figure 4.18 illustrate the processes that contribute to more than 5% of Particulate Matter (PM), Ozone Layer Depletion Potential (OLDP) and Photochemical Ozone Creation Potential (POCP) for Repair. As is evident in the figure, the production of Paper Bags is the greatest contributor to PM, OLDP and POCP.

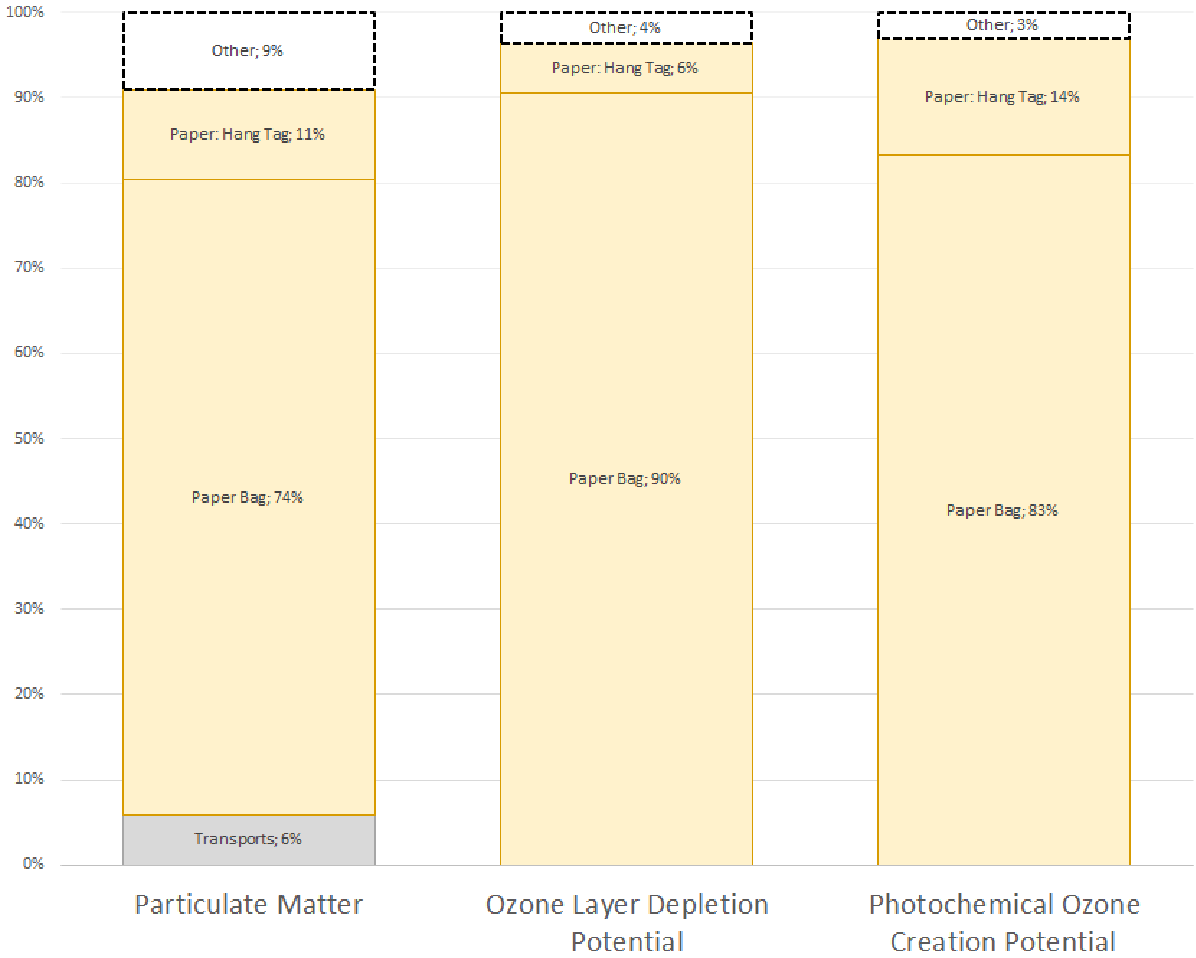

Figure 4.18: Stacked barcharts illustrating the processes that contributes to more than 5 % of the total impacts of PM, OLDP and POCP for Repair.

4.2.2.3 Ionisation Radiation, Abiotic Depletion and Human Toxicity Potential

Figure 4.19 presents the processes that contribute to more than 5% of Ionisation Radiation (IR), Abiotic Depletion (AD) and Human Toxicity Potential (HTP) for Repair. Starting with IR, it can be deduced from figure 4.19 that Production of Paper Bags is the dominating processes in terms of contribution to impact. The same applies to AD and HTP.

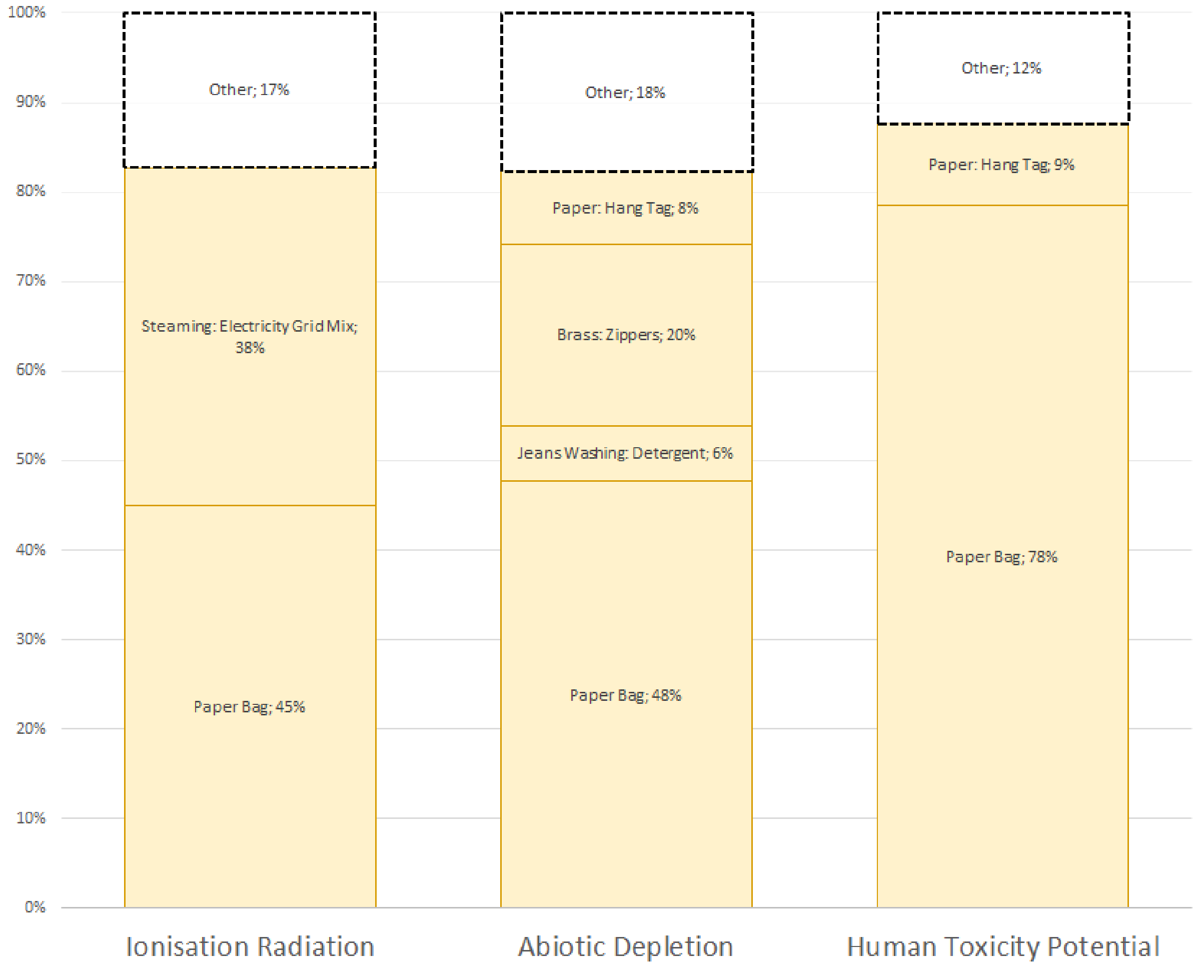

Figure 4.19: Stacked barcharts illustrating the processes that contributes to more than 5 % of the total impacts of IR, AD and HTP for Repair.

4.2.2.4 Terrestrial Ecotoxicity Potential, Marine Aquatic Ecotoxicity Potential and Freshwater Aquatic Ecotoxicity Potential

The processes that contribute to more than 5% of Terrestrial Ecotoxicity Potential (TEP), Marine Aquatic Ecotoxicity Potential (MAEP) and Freshwater Aquatic Ecotoxicity Potential (FAEP) for Repair are presented in figure 4.20. The figure shows that Paper Bag production dominates the impacts with respect to TEP. This is also the case for MAEP and FAEP

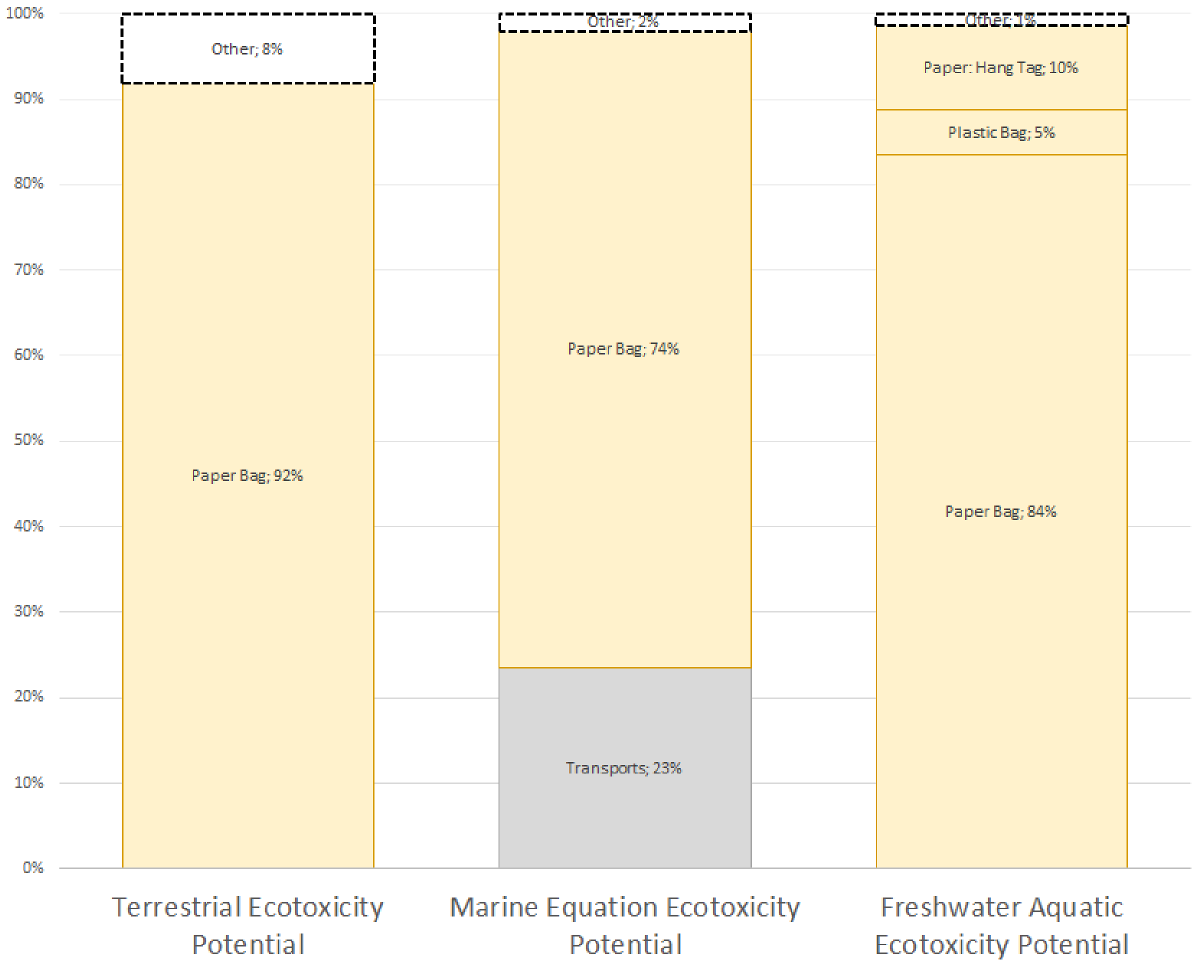

Figure 4.20: Stacked barcharts illustrating the processes that contributes to more than 5 % of the total impacts of TEP, MAEP and FAEP for Repair.

From the results of the contribution analysis for the repair activity, it was found that:

- Production of paper bag constitutes the greatest contributor to eleven of the twelve the impact categories.
- Transports constitutes the greatest contributor to one of the twelve impact categories.

These results reveal that paper bag production contributes significantly to environmental impact from Repair for a majority of the impact categories. This result indicates that improving the environmental performance of this process could decrease the environmental impact in general from Repair. The impact could also be mitigated by reducing the use of paper bags. As for several of the auxiliary materials used during the life cycle of the jeans, the environmental impact from production of the paper bags have been obtained from modelling as kraft paper production in GaBi. The conclusion that this process contributes significantly with respect to the Repair operation should therefore be questioned. An option for assessing the robustness of the results regarding Repair would be to investigate how the results would change if a different process for paper bags were used. This option was considered for this study but no appropriate and equivalent dataset was found in GaBi. On the other hand, it could also be argued that the mass of the paper bags is more considerable in relation to the other mass flows related to the Repair. The other mass flows were based on an average amount of materials that are used when repairing one pair of jeans, such as thread, buttons and glue. The mass of these listed items are notably lower than the mass of paper bags, which can be a probable explanation as to why the paper bags dominate in terms of all of the studied impact categories.

However, there is a disadvantage with utilising a contribution analysis approach on results that are not primarily based on site-specific data. There is a risk that certain processes and their corresponding environmental impacts may be exaggerated, meanwhile other potential impacts derived from other processes are reduced. This is especially apparent with one material input category that goes into the studied pair of jeans, namely the chemicals. Firstly, some chemicals have not been disclosed at all due to confidentiality reasons. These chemicals have thus been modelled according to literature studies of similar jeans production processes. Secondly, inventory data in GaBi were missing for several of the chemicals that were specified by the suppliers in the questionnaires. Therefore, a similar approach was taken in this case. That is to say, chemicals of similar properties were deduced based on literature studies.

For this study, the site-specific data were mainly obtained from data collection forms conducted for the previous LCA by Nudie Jeans. These data questionnaires are another cause for caution in regards to uncertainty. Even though we argue that a contribution analysis can be used to assess the validity of the results when site-specific data have been obtained, it is also a matter of how and from whom this data is supplied.

The inventory data related to material use for Repair were collected through surveys, which had some inconsistencies. As a consequence, these inconsistencies in the inventory analysis were identified and resolved. For instance, some customers submitted purchase dates that were obviously fallacious in the sense that the submitted dates preceded the founding date of Nudie Jeans. These entries were therefore excluded from the analysis of this study. Furthermore, entries that were blank were removed in their entirety. Moreover, the questionnaire regarding the task of identifying all mass and energy flows within the Repair operation was based on recommendations from the Repair Artist Michael Lundin, at Nudie Jeans, that estimated the amount of these flows based on prior experience. However, if Nudie Jeans incorporated standard procedures, where the Repair Artists could document these flows continuously, it would further benefit the results of future LCA studies by providing more accurate Repair inventory data.

4.3 Sensitivity Analyses

Two different sensitivity analyses has been conducted in order to test the robustness of the results. The results of this analysis can be found below. The first sensitivity analysis include the effects of changing number of reuses for the linear case whereas the second one involve system expansion instead of allocation for Incineration.

4.3.1 Sensitivity Analysis on Number of Repair and Reuse Instances

The contribution analysis for each impact category has been extended, from only comparing the linear scenario to a case with three reuses, to including one, two, four and five reuse instance. Trends found from the sensitivity analysis are presented below the figures.
Figure 4.21 illustrates a trend of increased environmental gains the more times the jeans are reused. Furthermore, the percentage difference of reusing the jeans one time to three times as compared to reusing the jeans three times to five times is more significant. Moreover, the greatest mitigated impact is achieved for Photochemical Ozone Creation Potential followed by Abiotic Depletion and Particulate Matter.

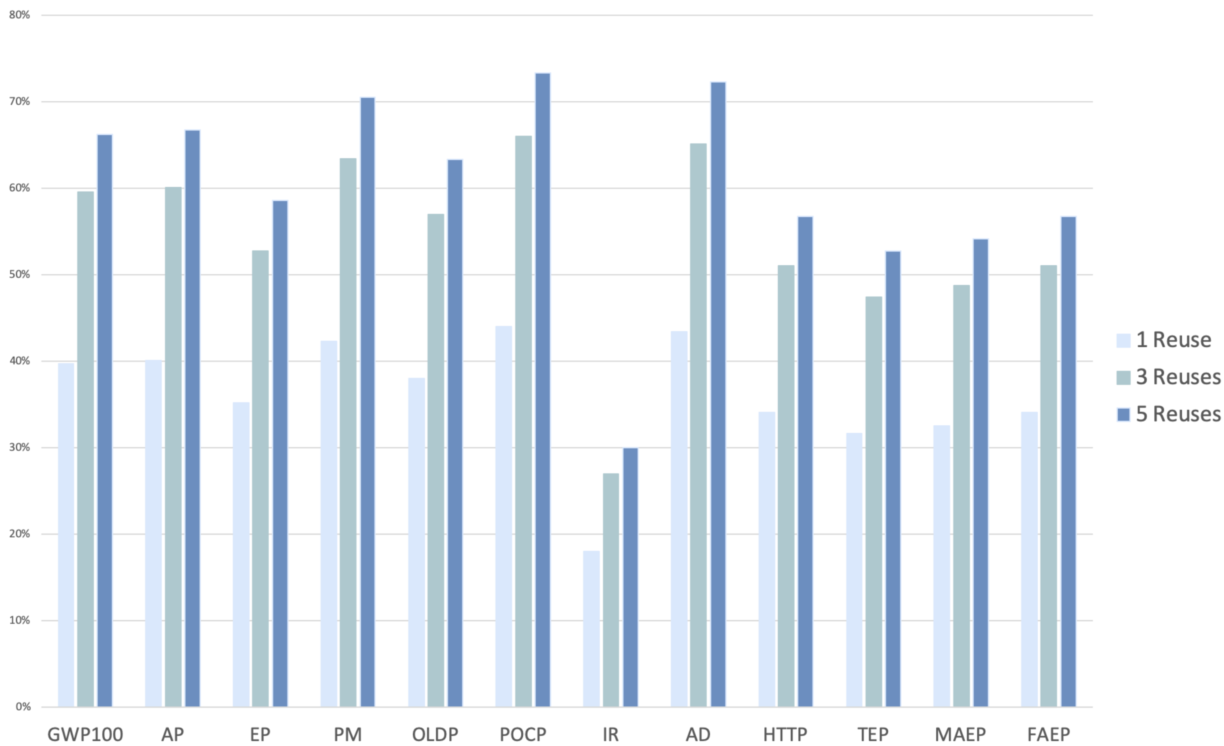

Figure 4.21: A figure illustrating the mitigated impacts, in percentages, from reusing the studied jeans a number of one, three and five times as compared to the linear case.

The following trends were identified in regard to the results displayed in figure 4.21:

- When the number of reuse instances increase, the decrease in environmental impact is not of linear character.
- When the number of reuse instances increase, the environmental impact of the Reuse operation increases.
- The environmental impacts of the Use/Reuse phase of the life cycle is constant in all of the studied impacts
- The Incineration process contributes to an almost negligible part of the environmental degradation.

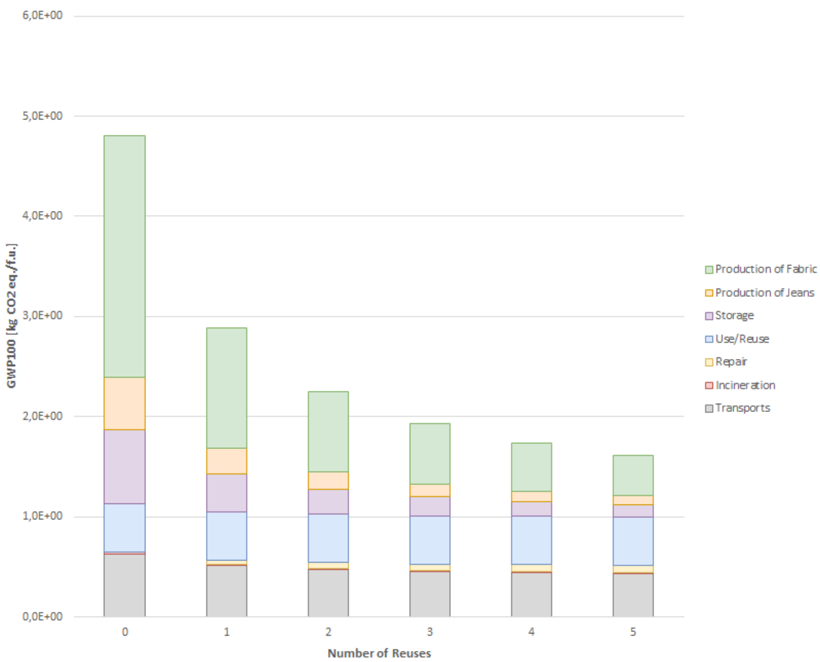

Figure 4.22: Stacked barcharts depicting the characterisation results of Global Warming Potential (GWP100), per functional unit, for the process steps involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.

Figure 4.22 displays a sensitivity analysis of GWP100 in terms of number of reuses. Is is combined by a contribution analysis approach. The trends that can be identified are the following:

- When the number of reuse instances increase, the decrease in environmental impact of the Production of Fabric, Production of Jeans and Storage decrease significantly.
- The Use/Reuse phase is constant.
- The Repair phase increases marginally with respect to an increasing amount of reuses.
- The Transports decrease marginally with respect to an increasing amount of reuses.

These trends indicate that the environmental impact the production phase of the jeans cause can be repayed by increasing the amount of time the jeans are used by extending their life time with the help of the Repair and Reuse concept. The rate of change of decreasing environmental impact in terms of the production phase is much more significant to the relatively modest rate of change of increasing environmental impact caused by the Reuse and Repair concept. All other impact categories are displayed in Appendix F.

4.3.2 Sensitivity Analysis on System expansion

Whether or not to include system expansion when conducting an attribution LCA debated among the LCA community. The ISO standard states that allocation should be avoided if possible by conducting system expansion. However, Tillman among others argue that system expansion should not be included in an attributional LCA (Baumann & Tillman, 2004). Thus, a sensitivity analysis has been conducted in order to determine whether or not the results differ when choosing system expansion instead of allocation for incineration.

The system expansions related to incineration takes into account that the heat generated by incineration can be utilised in the district heating system. Taking this into account entails that the environmental load from producing that heat from an alternative source is subtracted from the whole studied life cycle.

Conducting system expansion in order to avoid allocation did not affect the results in an significant way for most of the impact categories. For all impact categories, except one, system expansion resulted in the value for Incineration changing less than 2 %. MAEP, however, proved to result in a much more significant value, namely around 76 %, where Incineration obtained a negative value. However, this impact category did not affect the total results in terms of the same impact category in a substantial way.

5

Conclusions

The two research questions defined for this thesis will be assessed below according to the obtained results of the study.

> **R1**: To what extent does the Reuse and Repair concept mitigate the environmental impact of a pair of Nudie Jeans?

The results indicated that by extending the life time of the jeans through reuse, the environmental impact decreases. This conclusion apply to all of the impact categories included in the study. Based on comparing the linear case (0 reuses) with the circular case (3 reuses), the amount of mitigated environmental impacts with regard to all of the studied impact categories was found to be above 30 %, with the exception of IR for which a mitigation of slightly below 20 % is obtained. Furthermore, the results of the sensitivity analysis showed a non-linear decrease in terms of environmental impact when adding further reuse instances. In other words, for each added reuse event, the environmental load associated with the production phase of the jeans decreased but the decrease flattens out with increasing number of reuses. Thus, the reduction of environmental impact faces a limit when approaching the actual Repair and Reuse activity of the life cycle for increasing amounts of reuse events.

> **R2**: Which measures can be taken in order to increase the environmental mitigation of the Repair and Reuse concept?

Since the impact from Use/Reuse activity remained constant independent of reuses it can be concluded that the Use/Reuse phase plays an significant role in improving the Repair and Reuse concept further. Active measures that can be taken could be to decrease the amount of washing and tumble drying seeing that these account for the highest impact regarding the Use/Reuse phase of the life cycle of the studied jeans. Regarding Repair, one process was deemed to be critical in terms of environmental impact. This process is the paper bag production. Thus, packaging that contain materials, which are not as environmentally degrading, could be an alternative as opposed to the paper bag Nudie Jeans have today. Also, paper bag consumption could be reduced by suggesting to customers that they not use a bag for their repaired jeans.

In conclusion, the aim of the study was fulfilled and valuable insights were identified. The assessment of the research questions indicate that Nudie Jeans, as a company, is contributing to reducing environmental impact by promoting their Reuse and Repair concept. If bigger actors in the fashion industry follow the example of Nudie Jeans, environmental impact from the fashion industry as a whole can likely be reduced significantly.

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A
Appendix: Impact Category Definition

A.1 Global Warming Potential

Global Warming is defined as the impact of anthropogenic emissions on radiative forcing of the atmosphere. Increased radiative forcing leads to an increased absorption of heat radiation. Global warming causes a wide range of adverse effects to ecosystems, human health and to material welfare. (Guinée, 2004).

The gases that enables Global Warming are referred to as greenhouse gases (GHG:s) and include the following: carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons ($CFCs$), nitrous oxide (N_2O) and other trace gases (Baumann & Tillman, 2004). These GHG:s contribution to global warming differs since their ability to absorb infrared radiation differs. In order to compare the greenhouse gases impact on Global warming, they have been assigned a Global Warming Potential (GWP) index based on their ability to absorb infrared radiation. The GWP index for a specific GHG is defined as the ratio between increased infrared radiation caused by 1 kg of the GHG in question and the increased infrared absorption caused by 1 kg of CO_2. Thus, the GWP index is expressed in terms of CO_2 equivalents (Guinée, 2004).

Furthermore, GWP:s is dependent on time. Thus, GWP for a specific GHG differs depending on what time horizon is chosen. 20 and 50 years are considered to be shorter time horizons, which provide insight regarding short-term effects. Cumulative effects of GHG are considered when looking at longer time horizons such as 50 and 100 years. Which time horizon to chose for a specific study is decided upon by the practitioner.(Guinée, 2004). For this study, a time horizon of 100 years was chosen for GWP.

A.2 Acidification Potential

Acidifiaction is a consequence of emitted acids reaching surface soils and waters. Consequence of acidification include adverse effects to ecosystems and biological organisms which may cause for example fish mortality and forest decline (Guinée, 2004). Other consequences of acidification include leaching of toxic metals from rocks and soils and destruction to monuments and buildings. The substances primarily contributing to acidification are: SO2, NOx, HCl and NH3. Theses substance have the common property of forming acidifying H^+ ions. A substance ability to form H^+ ions is therefore used in order to determine acidification potential (AP). (Baumann & Tillman, 2004)

AP for a certain substance is defined as the ratio between number of H+ ions produced for 1 kg substance and number of H^+ ions produced for 1 kg SO2. Thus, AP represent the maximum acidification caused by a substance and is expressed in terms of SO2 eqivalents. (Baumann & Tillman, 2004)

A.3 Eutrophication Potential

Eutrophication occurs due to excessive flows of fertilisers to soil and waters. Key substances that cause euthrophication are nitrogen oxides and phosphates. Eutrophication is local in its nature and the consequences of euthrophication include significant issues in lakes and oceans because that it can trigger an increase of algal blooming, which leads to oxygen deficiency. Furthermore, it also harms the biological diversity in aqueous environments since it makes the waters more turbid, which hinders sunlight from penetrating the waters. Biological diversity is also put at risk further due to the fact that euthrophication alters the nutritional levels to an extent which can be harmful to local organisms affected by the environmental impact.(Mezjakab, 1998). Euthropication Potential is measured in terms of kg PO_4^{3-} equivalents.

A.4 Particulate Matter

Ever since the infamous London Smog occurred in the fifties, the concern about particulate matter (PM) has been high. It caused several deaths until policy makers took measures in reducing the emissions of PM drastically.(Saliba & Massoud, 2011) Particulate matter come in many forms. The forms are variable to what origin particulate matter has. There are three forms: marine, desert and urban aerosols. Urban aerosols are mostly constituted of anthropogenic activities, such as: vehicle emissions, industrial processes and power plants amongst others.(Saliba & Massoud, 2011)

The unit for the impact category indication is kg PM2.5 equivalents. The indicator measures particulate matter with the condition that they have a diameter of less than 2.5 micrometers. (Commission, 2013)

A.5 Ozone Depletion Potential

The thinning of the stratospheric ozone layer due to emissions from antropogenic activities is referred to as Stratospheric ozone depletion. The consequence of Stratospheric ozone depletion is that a greater fraction of UV-B radiation reaches the surface of the earth which may cause adverse effect to the health of both humans and animals. Moreover, harmful impacts may be caused to terrestrial and aquatic ecosystems as well as biochemical materials and cycles.

The ozone layer is destroyed by ultra violet (UV) radiation, visible light and certain catalysing substances, for instance: H, OH, NO, Cl and Br. The ozone depletion potential (ODP) of a substance can be defined as the change in the stratospheric ozone column, in steady state, caused by amount of emissions of the substance in question relative to the change in this column, at steady-state, due to emissions of CFC-11 (Trichlorofluoromethane). The unit used for ODP is CFC-11 (or R-11). (Baumann & Tillman, 2004)

A.6 Photochemical Ozone Creation Potential

Ozone is a photooxidant formed in the lower atmosphere (troposphere) from Volatile Organic Compounds (VOCs) and carbon monoxide (CO) in the prescence of nitrogen oxides (NOx). The formation of photooxidants, which are known as summer smog, Los Angelses smog or secondary air pollution, may cause adverse effects to ecosystems, crops and human health. (Guinée, 2004)

Photochemical Ozone Creation Potential (POCP) can be defined as the potential capacity of an organic compound to form ozone in the troposphere. Ethene has been set as a reference, thus the unit for POCP is ethene equivalents. (Guinée, 2004)

A.7 Abiotic Depletion

Abiotic resources include both non-renewable and renewable non-living resources such as iron ore, crude oil and wind energy. How impact assessment should be conducted for abiotic depletion is highly debated, Thus, there is a wide variety of methods developed for this impact category which differ when it comes to viewing resource depletion as an environmental problem.

Abiotic depletion can be defined as the ratio between the quantity of extracted and recoverable reserves of the resource in question (Guinée, 2004). Furthermore, abiotic depletion used for CML2001 has the unit Sb (Antimony) equivalents.

A.8 Ionisation Radiation

The Ionisation Radiation (IR) takes into account for the impacts from both direct exposure to radiation and release of radioactive substances. Human health and animals are harmed by exposure to ionising radiation. IR is measured in number of atoms decaying per unit time. For the CML2001 method, this value is referred to number of atoms decaying per unit time for uranium-235 in order to express IR in terms of terms of kBq U^{235} equivalents. (Guinée, 2004)

A.9 Toxicity Potential

In this LCA, the following types of toxicity are examined: Terrestrial, Freshwater, Human, Marine Aquatic. Measuring toxicity is a complicated in the sense that there are many systems interacting in complex manners. For instance, there exists a vast amount of chemicals, which are all unique and cause different sorts of impacts. To aggregate these into toxicity potentials are therefore a difficult task to perform.

There are two main categories regarding toxicity potentials: human toxicity and eco-toxicity. Furthermore, the latter can be divided into the following subcategories: Freshwater, Marinewater and Terrestrial eco-toxicity. Toxicity is calculated in terms of PEC, predicted environmental concentration, and PNEC, predicted no-effect level according to equation A.1. In the mentioned equation, the studied chemical and its effects are compared to a reference chemical. When addressing human toxicity, ADI, the acceptable daily intake, indicator is used instead.(Baumann & Tillman, 2004)

$$\text{Toxicity Potential} = \frac{(PEC/PNEC)}{(PEC/PNEC)_{ref}} \tag{A.1}$$

B

Appendix: Components of the Lean Dean Lost Legend Jeans

Figure B.1 illustrates the main components of the Lean Dean Lost Legend Jeans jeans included in the study. However, the laundry care patch is not depicted since it is placed inside the jeans. Furthermore, the waisttag and the booklet that are placed on the jeans before they are sold are not presented in the figure. The same applies for the hangtag that is placed on reuse jeans before they are resold.

Figure B.1: The main components of the Lean Dean Lost Legend jeans.

C

Appendix: Nudie Jeans Repair Data

This appendix demonstrates the processed form of Nudie Jeans' inventory analysis of their jeans model Lean Dean Lost Legend 3.3.

C.1 Use Cycle

The average time period that one pair of jeans is used before they are repaired or discarded have been calculated according to equation C.1, where $Yr_{repaired}$ is the year when the jeans where handed in for repair, Yr_{bought} is the year when the jeans where repaired and $n_{tot.\ repairs}$ is the number of times that the jeans have been repaired.

$$t_{use} = \frac{Yr_{repaired} - Yr_{bought}}{n_{tot.\ repairs}} \tag{C.1}$$

C.2 Materials for Repair

During the time period between 2017 and 2019, Nudie Jeans have carried out an extensive inventory analysis with respect to their repair processes. In other words, data has been collected from Nudie Jeans customers whenever they have submitted their jeans for repair. This data collection has been documented in an excel sheet, which displays the following information: Jeans Model, Repair Option, Year Bought, Year Handed in for Repair and Amount of Repairs.

Afterwards, the data was processed further in order to better fit the scope of this study. Because this study focuses on the jeans model Lean Dean Lost Legend, all other jeans model data was excluded in this assessment. Furthermore, data regarding material and energy inputs with respect to the constituents in the list below were obtained by Michael Lundin, Repair and Reuse Artist at Nudie Jeans, through the means of a questionnaire and email correspondence. The following repair options were identified: Back Pockets, Bar Tacks, Button/Rivet, Coin Pocket, Crotch, Exterior Pocket, Hemming, Inside Pockets, Knee, Leg Opening, Seat, Thigh, Yoke and Zipper.

Table C.1 showcases the results of the processed data of the Nudie Jeans inventory analysis. Material and energy balances associated with all of the repair processes are also illustrated in order to translate these into meaningful impacts.

Table C.1: Table showing all of the material inputs that go into the Repair system.

Repair Process	**Amount (min)**	**%**	**Average amount (min)**
Back Pockets	3,5	0,065	0,23
Bar Tacks	2,0	0,001	0,002
Belt Loop	3,5	0,006	0,021
Button/Rivet	2,0	0,001	0,003
Coin Pocket	7,5	0,000	0,000
Crotch	10	0,560	5,6
Exterior Pocket	25	0,003	0,072
Knee	7,5	0,044	0,33
Leg Opening	7,5	0,006	0,043
Seat	7,5	0,002	0,013
Thigh	7,5	0,033	0,25
Yoke	7,5	0,008	0,064
Zipper	38	0,031	1,2
Hemming	5,0	0,10	0,51
Inside Pockets	5,0	0,11	0,57
Other	0,0	0,023	0,000
Total	139	1	8,88
Mass of thread per repair operation (g)		**Energy consumption (Wh)**	
1,5		13	

D

Appendix: Life Cycle Inventory Data

Table D.1 presents the modelling choices (database and dataset) in GaBi for transportation used in the life cycle of a pair of LDLL Nudie Jeans. Thus, these modelling choices are applied to the transportation processes for each process step in the life cycle which are presented in table D.5, D.10, D.14, D.18, D.22, D.25. The dataset for transportation by truck was chosen based on guidance from IVL. The same goes for transports by car. RoRo ship was chosen since the sea freight distances are not that long between the studied areas within the system boundary.

Table D.1: Modelling choices in GaBi for the means of transportation used for the life cycle of a pair of Lean Dean Lost Legend jeans.

Trp	**Database**	**Dataset**
Truck	Thinkstep	GLO, 2017: Truck, 28-32 t tot weight, MPL 22 t, Euro 5, load factor 0.85
Ship	Thinkstep	GLO, 2017. Ship, RoRo
Car	Thinkstep	GLO, 2017: Car petrol, Euro 4, engine size up to 1, 4l

Table D.2: Explanations of the abbreviations used in GaBi for geographical regions.

Abbreviation	**Explanation**
GLO	Global
RER	Europe
RoW	Rest of the World
EU-28	European Union (EU) which consists a group of 28 countries that operates as an economic and political block.
DE	Germany
IT	Italy
SE	Sweden

D.1 Production of Fabric

Table D.3 presents the inventory data for Production of Fabric. The table also includes the modelling choices, in terms of databases and datasets, used in GaBi. Assumptions for specific inventory data or modelling choices in GaBi are presented in table D.4. Furthermore, it should be noted that:

- Emissions are modelled in GaBi where the amount depend on amount of energy use. Thus, emissions are not included in the table.
- Abbreviations for geographical regions can be found in table D.2.
- Sodium dithionite is an alternative name for sodium hydrosulphite.
- Indigo dye was not available in GaBi and was therefor modelled as Azo dye on the basis that Azo dyes consists of organic compounds and Indigo dye is an organic compound.

Table D.3: Inventory data and modelling choices in GaBi for Production of Fabric.

	Amount	Unit	Reference	Database	Dataset
Material					
Raw organic cotton	6,5E-01	kg/f.u.	(Candiani, 2018)	Textile exchange	GLO, 2012: Cotton fiber (organic) (at gin gate)
Elastane	1,3E-02	kg/f.u.	(Candiani, 2018)	Thinkstep	DE, 2017: Thermoplastic poly(urethane) (TPU, TPE-U), adhesive
Auxiliary material					
Pre-reduced indigo	1,8E-03	kg/f.u.	(Candiani, 2019)	Thinkstep	GLO, 2017: Azo dye
Caustic soda	2,3E-04	kg/f.u.	(Candiani, 2019)	Thinkstep	IT, 2020: Sodium hydroxide (caustic soda) mix (100%)
Sodium hydrosulphite	4,5E-04	kg/f.u.	(Candiani, 2019)	Ecoinvent 3.5	PER, 2018: Market for sodium dithionite
Potassium permanganate	9,0E-04	kg/f.u.	(Candiani, 2019)	Ecoinvent 3.5	GLO, 2018: Market for potassium permanganate
Potato starch	3,6E-04	kg/f.u.	(Candiani, 2019)	Ecoinvent 3.5	GLO, 2018: Market for potato starch
Water					
Total water use	4,7E+01	kg/f.u.	(Candiani, 2018)	Thinkstep	EU-28, 2020: Tap water
Energy					
Electricity	3,8E-03	MWh/f.u.	(Candiani, 2018)	Thinkstep	IT, 2014: Electricty grid mix
Diesel	4,1E-02	MJ/f.u.	(Candiani, 2018)	Thinkstep	IT, 2014: Thermal energy from light fuel oil
Natural gas	3,2E+01	MJ/f.u.	(Candiani, 2018)	Thinkstep	IT, 2014: Thermal energy from natural gas
Waste					
Solid spillage	4,2E-02	kg/f.u.	(Candiani, 2018)	ELCD /CEWEP	EU-28, 2006: Waste incineration of municipal solid waste
Fabric waste	3,3E-05	kg/f.u.	(Candiani, 2018)	Thinkstep	IT, 2017: Textile in waste incineration plant
Waste water	3,1E+01	kg/f.u.		Thinkstep	EU-28, 2020: Municipal waste water treatment (mix)
Main product					
Finished fabric	6,6E-01	kg/f.u.	(Denim Authority, 2018)		

Table D.4: Assumptions and estimations for specific inventory data and GaBi modelling presented in table D.3

	It was assumed that:
Auxiliary material	
Pre-reduced indigo	Environmental load from production of pre-induced indigo is similar to environmental load from production of azo dye.
Water	
Water use	The unit for water use should be m_3 instead of litre (stated in the data collection form) since this would correspond correctly with the value for water use given in Candianis sustainability report from 2016.
Waste	
Waste water	Amount of waste water can be estimated to amount of water used at the facility.

The transportation processes involved in Production of Fabric are presented in table D.5. Means of transportation have been assumed for all transportation processes except for the finished fabric and the section beams. Transportation routes have been assumed for all transportation processes. Assumptions for specific transportation processes are presented in table D.6. Furthermore, it should be noted that:

- Abbreviations for geographical regions can be found in table D.2.
- Modelling choices for means of transportation can be found in table D.1.
- Transportation for sodium hydrosulphite, potassium permanganate and potato starch is not included. The reason is that the dataset "market for" which have been used for theses substances, already include transportation between producers and customer.
- A value that is marked with an asterik for the distance denotes that the given transportation distance has been estimated based on an educated guess.

Table D.5: Transportation processes for Production of Fabric.

	From	**To**	**Means of transportation**	**Distance (km)**	**Reference distance/location**
Material					
Raw organic cotton	India, Unknown	Robecchetto con Induno, Italy (Candiani)	Truck	1 177	(Via Michelin, 2019)/ (Candiani, 2018)
			Ship	7 221	(Sea-Distances, 2019)
Elastane	Turkey, Unknown	Robecchetto con Induno, Italy (Candiani)	Truck	2455	(Via Michelin, 2019)/ (Candiani, 2018)
Auxiliary material					
Pre-reduced indigo	Unknown, Unknown	Robecchetto con Induno, Italy (Candiani)	Truck	1 000*	
Caustic soda	Unknown, Unknown	Robecchetto con Induno, Italy (Candiani)	Truck	1 000*	
Energy					
Diesel	Unknown, Unknown	Robecchetto con Induno, Italy (Candiani)	Truck	1 000*	
Waste					
Solid spillage	Robecchetto con Induno, Italy (Candiani)	Unknown, Unknown	Truck	100*	
Fabric waste	Robecchetto con Induno, Italy (Candiani)	Unknown, Unknown	Truck	100*	
Section beams	Robecchetto con Induno, Italy (Candiani	Robecchetto con Induno, Italy (Candiani)	Truck	3	(Candiani, 2018)
Main product					
Finished fabric	Robecchetto con Induno, Italy (Candiani)	Ras Jebel, Tunisia (Denim Authority)	Truck	183	(Via Michelin, 2019)
			Ship	865	(Sea-Distances, 2019)

Table D.6: Assumptions for transportation processes for Production of Fabric.

	It was assumed that:
Material	
Raw organic cotton	Cultivation of organic cotton in India takes place in Mumbai.
Elastane	The elastane production in Turkey takes place in Istanbul.

D.2 Production of Jeans

Table D.7 presents the inventory data and the modelling choices in GaBi for Production of Jeans. Table D.9 presents the alternative substances chosen for the washing procedure and the reasoning behind the choices. Assumptions for specific inventory data are presented in table D.8. Furthermore, it should be noted that:

- Emissions are modelled in GaBi where the amount depend on amount of energy use. Thus, emissions are not included in the table.
- Abbreviations for geographical regions can be found in table D.2.
- The second column from the left represents the main components of material and auxiliary material.
- A value that is marked with an asterisk denotes that the value has been estimated based on an educated guess.

Table D.7: Inventory data and modelling choices in GaBi for Production of Jeans.

		Amount	Unit	Reference	Database	Dataset
Material						
Finished fabric		6,6E-01	kg/f.u.	(Candiani, 2018)		
Thread	Polyester	5,0E-02*	kg/f.u.		Ecoinvent 3.5	RoW, 2018: Market for polyester resin, unsaturated
Inner pockets	Organic cotton	4,0E-02*	kg/f.u.		Textile Exchange	GLO, 2012: Cotton fiber (organic) (at gin gate)
	Printing chemicals	2,0E-04	kg/f.u.		Thinkstep	GLO, 2017: Reactive dyes
Button and rivets	Brass	1,3E-02	kg/f.u.	(Berning, 2019b)	Thinkstep	RER, 2017: Brass: 80 % Copper, 20 % Zink
Zipper	Brass	8,0E-03	kg/f.u.		Thinkstep	RER, 2017: Brass: 80 % Copper, 20 % Zink
	Polyester (ribbon)	1,0E-03	kg/f.u.		Thinkstep	RER, 2017: Polyester (PET) fabric
Jacron patch	Printed jacron paper	2,0E-02*	kg/f.u.		Ecoinvent 3.5	RoW, 2018: Offset printing, per kg printed paper
	Acrylic polymers	1,0E-04	kg/f.u.		Ecoinvent 3.5	GLO, 2017: Soaping agent (acrylic polymer)
Woven label	Woven fabric	1,0E-02*	kg/f.u.		CottonInc	GLO, 2017: Textile manufacturing - woven fabric
Care patch	Polyester	7,0E-03*	kg/f.u.		Thinkstep	RER, 2017: Polyester (PET) fabric
	Printing chemicals	3,5E-05	kg/f.u.		Thinkstep	GLO, 2017: Disperse dyes
Auxiliary material						
Booklet	FSC paper	1,0E-02	kg/f.u.	Weighing	Ecoinvent 3.5	RoW, 2018: Offset printing, per kg printed paper
Waisttag	Recycled paper, printing chemicals	4,0E-03	kg/f.u.		Ecoinvent 3.5	RoW, 2018: Offset printing, per kg printed paper
Packaging	Card board	1,1E-01	kg/f.u.		Thinkstep/ FEFCO	RER, 2017: Corrugated board excl. paper production (open paper input)
	Biodegradable plastic	5,5E-03	kg/f.u.		Ecoinvent 3.5	RER, 2018: Extrusion, plastic film
Resine 3D (Nofelding NFC, Nearfinish 10X NF)		2,2E-03	kg/f.u.	(Denim Authority, 2019)	Ecoinvent 3.5	RER, 2018: Market for glyoxal
Soaping agent (Neareserve DSW)		6,1E-08	kg/f.u.	(Denim Authority, 2018)	Thinkstep	GLO, 2017: Soaping agent (acrylic polymer)
PP spray		1,2E-06	kg/f.u.	(Denim Authority, 2018)	Ecoinvent 3.5	GLO, 2018: Market for potassium permanganate
Neutralisation agent (META)	Sodium metabisulfite	7,3E-07	kg/f.u.	(Denim Authority, 2018)	Thinkstep	DE, 2017: Hydrogen peroxide
Dirty (Oragne LG-L)		3,6E-03	kg/f.u.	(Denim Authority, 2019)	Ecoinvent 3.5	GLO, 2018: Market for cadmium sulfide, semiconductor-grade
Washing pumice		6,3E-01	kg/f.u.	(Denim Authority, 2019)	Thinkstep	EU-28, 2017: Washing pumice
Water						
Water use		1,5E-03	m^3/f.u.	(Denim Authority, 2018)	Thinkstep	EU-28, 2020: Tap water
Energy						
Electricity		4,4E-02	kWh/f.u.	(Denim Authority, 2018)	Thinkstep	REF, 2014: Electricity from natural gas, medium voltage, production mix
Diesel		8,1E-05	MJ/f.u.	(Denim Authority, 2018)	Thinkstep	RoW, 2014: Thermal energy from heavy fuel oil
Waste						
Solid waste (excl. fabric)		8,7E-03	kg/f.u.	(Denim Authority, 2019)	ELCD/ CEWEP	EU-28, 2006: Waste incineration of municipal solid waste
Denim fabric waste		9,3E-02	kg/f.u.	(Denim Authority, 2018)	ELCD/ CEWEP	EU-28, 2015: Incineration of textile fraction in municipal solid waste
Waste water		6,3E-02	m^3/f.u.	(Denim Authority, 2019)	Thinkstep	EU-28, 2020: Municipal waste water treatment (mix)
Main product						
Finished jeans		7,2E-01	kg/f.u.	(Denim Authority, 2018)		

Table D.8: Assumptions for inventory data related to Production of Jeans, which are presented in table D.7.

		It was assumed that:
Material		
Inner pockets	Printing chemicals	Amount of printing chemicals used correpsonds to 0,5 weight% of organic cotton used for the inner pockets.
Zipper		The zipper weighs the same as the zipper used for jeans produced by Bobo.
Jacron patch	Acrylic polymers	Amount of acrylic polymers used corresponds to 0,5 weight% of the jacron paper.
Care patch	Printing chemicals	Amount of printing chemicals used corresponds to 0,5 weight% of the polyester used for the patches.
Auxiliary material		
Waisttag	Recycled paper, printing chemicals	The same amounts as used for the hang tag.
Packaging	Card board	The weight of one cardboard box is 2 kg (18 jeans fit in one card board box).

Table D.9: The alternative substances used for modelling in GaBi and the reasoning behind the choices.

Substance	Alternative	Reasoning
Resine 3D (Noefelding NFC, Nearfish 10X NF)	Glyoxal	Glyoxal is one of the most commonly used finishing resins for cotton denim fabrics (Litim et al., 2017).
Soaping agent (Neareserve DSW)	Soaping agent (acrylic polymer)	Acrylic polymers are used as soaping agents within the textile finishing industry according to the key dataset information in GaBi.
PP spray	Potassium permanganate	The abbreviation PP stands for potassium permanganate (Kanl, 2015).
Neutralisation agent (META)	Hydrogen peroxide	Hydrogen peroxide is used as a neutralisation agent for indigo dye, which is the dye used for the jeans fabric (Sarkar, 2015).
Dirty (Orange LG-L)	Cadmium sulphide	Cadmium sulphide is used.for yellow to orange pigmentation of textiles (Kim et al., 2019).

The transportation processes for Production of Jeans are presented in table D.10. Means of transportation for all transportation processes, except between cutting an sewing, have been assumed. Transportation routes for all transportation processes have been assumed. Assumptions for specific transportation processes are presented in table D.11. Furthermore, it should be noted that:

- Abbreviations for geographical regions can be found in table D.2.
- Modelling choices for means of transportation can be found in table D.1.
- Transportation of finished fabric from Production of Fabric to Production of Jeans is not included since this transportation process have already been accounted for in table D.5.

- A value that is marked with an asterik for the distance denotes that the given transportation distance has been estimated based on an educated guess.

Table D.10: The transportation processes for Production of Jeans.

		From	To	Means of transportation	Distance (km)	Reference distance/location
Material						
Inner pocket		Kayseri, Turkey (Orta Andalou)	Ras Jebel, Tunisia (Denim Authority)	Truck	2 495	(Via Michelin, 2019)/ (Orta, 2019)
				Ship	469	(Sea-Distances, 2019)
	Organic paper	Unknown, Unknown	Kayseri, Turkey (Orta Andalou)	Truck	500*	
	Printing chemicals	Unknown, Unknown	Kayseri, Turkey (Orta Andalou)	Truck	500*	(Orta, 2019)
Button and rivets		Wuppertal, Germany (Berning)	Ras Jebel, Tunisia (Denim Authority)	Truck	1 416	(Via Michelin, 2019)/ (Berning, 2019a)
				Ship	598	(Sea-Distances, 2019)
	Brass	Unknown, Unknown	Wuppertal, Germany (Berning)	Truck	500*	(Berning, 2019a)
Zipper		Sousse, Tunisia (YKK)	Ras Jebel, Tunisia (Denim Authority)	Truck	151	(Via Michelin, 2019)/ (YKK, 2019)
	Brass	Unknown, Unknown	Sousse, Tunisia (YKK)	Truck	500*	(YKK, 2019)
	Polyester (ribbon)	Unknown, Unknown	Sousse, Tunisia	Truck	141	(Via Michelin, 2019)/ (YKK, 2019)
Jacron patch		Padova, Italy (Officina 3)	Ras Jebel, Tunisia (Denim Authority)	Truck	474	(Via Michelin, 2019)/ (Officina 3, 2019)
				Ship	598	(Sea-Distances, 2019)
	Jacron paper	Unknown, Unknown	Padova, Italy (Officina 3)	Truck	495	(Officina 3, 2019)
	Acrylic polymers	Unknown, Unknown	Padova, Italy (Officina 3)	Truck	495	(Officina 3, 2019)
Woven label	Woven fabric	Istanbul, Turkey (A-TEX)	Ras Jebel, Tunisia (Denim Authority)	Truck	1 726	(Via Michelin, 2019)/ (A-TEX, 2019)
				Ship	469	(Sea-Distances, 2019)
Care patch		Unknown, Unknown	Ras Jebel, Tunisia (Denim Authority)	Truck	10	(Via Michelin, 2019)
	Polyester	Unknown, Unknown	Unknown, Unknown	Truck	500*	
	Printing chemicals	Unknown, Unknown	Unknown, Unknown	Truck	500*	
Auxiliary material						
Booklet		Herning, Denmark (A-TEX)	Ras Jebel, Tunisia (Denim Authority)	Truck	1 965	(Via Michelin, 2019)/ (A-TEX, 2019)
				Ship	598	(Sea-Distances, 2019)
Waisttag		Istanbul, Turkey (A-TEX)	Ras Jebel, Tunisia (Denim Authority)	Truck	1 726	(Via Michelin, 2019)/ (A-TEX, 2019)
				Ship	469	(Sea-Distances, 2019)
Packaging	Card board	Menzel Jemil, Tunisia (ML emballage)	Ras Jebel, Tunisia (Denim Authority)	Truck	13	(Via Michelin, 2019)/ (Denim Authority, 2018)
	Biodeg. plastic	Unknown, Italy (Remaplast)	Ras Jebel, Tunisia (Denim Authority)	Truck	81	(Via Michelin, 2019)/ (Denim Authority, 2018)
				Ship	598	(Sea-Distances, 2019)/ (Denim Authority, 2018)
Soaping agent (Neareserve DSW))		Unknown, Italy (Nearchimica	Ras Jebel, Tunisia (Denim Authority)	Truck	81	(Via Michelin, 2019)/ (Denim Authority, 2018)
Neutralisation agent (META)		Tunis, Tunisia (Yosra Chimie)	Ras Jebel, Tunisia (Denim Authority)	Truck	10	(Via Michelin, 2019)/ (Denim Authority, 2018)
Stone		Sousse, Tunisia (Chimitex)	Ras Jebel, Tunisia (Denim Authority)	Truck	150	(Via Michelin, 2019)/ (Denim Authority, 2018)
		Unknown, Italy (Bozetto)	Ras Jebel, Tunisia (Denim Authority)	Truck	81	(Via Michelin, 2019)/ (Denim Authority, 2018)
				Ship	598	(Sea-Distances, 2019)
Energy						
Diesel		Unknown, Tunisia (Agil)	Ras Jebel, Tunisia (Denim Authority)	Truck	500*	(Via Michelin, 2019)/ (Denim Authority, 2018)
Waste						
Solid waste		Ras Jebel, Tunisia (Denim Authority)	Unknown, Unknown	Truck	10	(Via Michelin, 2019)
Denim fabric waste		Ras Jebel, Tunisia (Denim Authority)	Unknown, Unknown	Truck	10	(Via Michelin, 2019)
Main product						
Finished jeans		Ras Jebel, Tunisia (Denim Authority)	Borås, Sweden (Korallen)	Truck	2 004	(Via Michelin, 2019)/ Korallen
				Ship	752	(Sea-Distances, 2019)

Table D.11: Assumptions and estimations for the transportation processes for Production of Jeans presented in table D.10

		It was assumed that:
Material		
Zipper	Polyester (ribbon)	The production takes place in Tunis in Tunisia.
Jacron patch	Jacron paper	The production takes place in Rome in Italy.
	Acrylic polymers	The production takes place in Rome in Italy.
Care patch		The production takes place in Tunis in Tunisia.
Auxiliary material		
Packaging	Biodegradable plastic	The production in Italy is located in Rome.
Soaping agent	Neareserve DSW	The production in Italy is located in Rome.
Stone		The production in Italy is located in Rome.
Energy		
Diesel		The production in Tunisia is located in Tunis.
Waste		
Solid waste		The production takes place in Tunis in Tunisia.
Denim fabric waste		The production takes place in Tunis in Tunisia.

D.3 Storage

Table D.12 presents the inventory data and modelling choices for Storage. Assumptions for specific inventory data are presented in table D.13. Furthermore, it should be noted that:

- Emissions are modelled in GaBi where the amount depend on amount of energy use. Thus, emissions are not included in the table.
- Abbreviations for geographical regions can be found in table D.2.

Table D.12: Inventory data and modelling choices in GaBi for Storage.

	Amount	Unit	Reference	Database	Dataset
Material					
Finished jeans	7,2E-01	kg/f.u.	(Denim Authority, 2018)		
Auxiliary material					
Well-pap carton	2,1E-02	kg/f.u.	(Avisera, 2019)	Thinkstep/ FEFCO	RER, 2017: Corrugated board excl. paper production (open paper input)
Plastic bag	5,0E-02	kg/f.u.	(Korallen, 2019)	Ecoinvent 3.5	RER, 2018: Extrusion, plastic film
Paper bag	1,2E-01	kg/f.u.	(Avisera, 2019)	Ecoinvent 3.5	RER, 2018: Kraft paper production (unbleached)
Water					
Water use (Korallen)	1,5E-02	m3/jeans	(Korallen, 2019)	Thinkstep	EU-28, 2020: Tap water
Energy					
Electricity (Korallen)	2,3E+00	kWh/f.u.	(Korallen, 2019)	Thinkstep	SE, 2020: Electricity grid mix
District heating (Korallen)	7,9E+00	kWh/f.u.	(Korallen, 2019)	Thinkstep	EU-28, 2020: District heating mix
Electricity (Repair Shop/Retailer)	4,6E+01	kWh/f.u.	(Energimyndigheten, 2011)	Thinkstep	SE, 2020: Electricity grid mix
Waste					
Waste water	1,5E-02	m3/f.u.		Thinkstep	EU-28, 2020: Municipal waste water treatment (mix)
Main product					
Finished jeans	7,2E-01	kg/f.u.	(Denim Authority, 2018)		

Table D.13: Assumptions for Storage data presented in table D.12.

	It is assumed that:
Auxiliary material	
Well-pap carton	18 jeans are packaged in one carton (15-20 jeans per carton according to Korallen).
Water	
Water use (Korallen)	The jeans are stored at Korallen for 10 weeks (8-10 weeks of storage according to Korallen).
Energy	
Electricity (Korallen)	80 weight% of the clothes stored at Korallen are jeans.
District heating (Korallen)	The same as for electricity (Korallen).
Electricity (Repair Shop/Retailer)	60 weight% of the collection stored at repair shop/retailer are jeans, 500 jeans are stored and the average store size is 40 m2.
Waste	
Waste water	Amount of waste water is the same as amount of water use.

The transportation processes for Storage are presented in table D.14. Transportation routes have been assumed for all transportation processes. Means of transportation is known for the transportation of finished jeans from Korallen. For all other transportation processes, means of transportation have been assumed. Assumptions for specific transportation processes are presented in table D.15. Furthermore, it should be noted that:

- Abbreviations for geographical regions can be found in table D.2.
- Modelling choices for means of transportation can be found in table D.1.
- Transportation of finished jeans from Production of Jeans to Storage to is not included since this transportation process have already been accounted for in table D.10.
- A value that is marked with an asterik for the distance denotes that the given transportation distance has been estimated based on an educated guess.

Table D.14: Transportation processes for Storage.

	From	To	Means of transportation	Distance (km)	Reference distance/location
Auxiliary material					
Well-pap carton	Unknown, Sweden (Avisera)	Borås, Sweden (Korallen)	Truck	754	(Via Michelin, 2019)/ (Avisera, 2019)
	Borås, Sweden (Korallen)	Unknown, Sweden (Repair shop/Retailer)	Truck	246	Google maps
Plastic bag	Unknown, Unknown	Borås, Sweden (Korallen)	Truck	500*	
	Borås, Sweden (Korallen)	Unknown, Sweden (Repair shop/Retailer)	Truck	246	Google maps
Paper bag	Unknown, Romania (Avisera)	Borås, Sweden (Korallen)	Truck	2 279	(Via Michelin, 2019)/ (Avisera, 2019)
	Borås, Sweden (Korallen)	Unknown, Sweden (Repair shop/Retailer)	Truck	246	Google maps
	Unknown, Sweden (Repair shop/Retailer)	Unknown, Sweden (User)	Car	50*	
Main product					
Finished jeans	Borås, Sweden (Korallen)	Unknown, Sweden (Repair shop/Retailer)	Truck	246	Google maps
	Unknown, Sweden (Repair shop/Retailer)	Unknown, Sweden (User)	Car	50*	

Table D.15: Assumptions for transportation processes for Storage.

	From	To	It is assumed that:
Material			
Finished jeans	Korallen	Repair shop/ Retailer	The distance can be estimated as the average distance from Korallen to all Repair Shops in Sweden.
Auxiliary material			
Well-pap carton	Avisera	Korallen	The production in Sweden takes place in the mid point of Sweden (Torpshammar).
	Korallen	Repair shop/ Retailer	The same applies as for finished jeans.
Paper bag	Avisera	Korallen	The production in Romania takes place in the midpoint of Romania (Făgăraș).
	Korallen	Repair shop/ Retailer	See estimation for finished jeans.

D.4 Use and Reuse

Table D.16 presents the inventory data and the modelling choices in GaBi for Use and Reuse. Assumptions for specific inventory data are presented in table D.17. Furthermore, it should be noted that:

- Emissions are modelled in GaBi where the amount depend on amount of energy use. Thus, emissions are not included in the table.
- Abbreviations for geographical regions can be found in table D.2.
- Paper bag (Reuse Repair Shop) is not included since it is already accounted for in the table D.12.

Table D.16: Inventory data and modelling choices for Use and Reuse.

Material	Amount	Unit	Reference	Database	Dataset
Finished jeans	7,2E-01	kg/f.u.			
Auxiliary material					
Detergent	2,6E-01	kg/f.u.	(Ecolabelling Denmark, 2011)	Thinkstep	GLO, 2020: Detergent (fatty acid sulphonate derivate)
Water					
Washing	1,4E+02	kg/f.u.	(Energimyndigheten, 2011)	Thinkstep	EU-28, 2020: Tap water
Energy					
Electricity (washing)	1,4E+00	kWh/f.u.	(Energimyndigheten, 2011)	Thinkstep	SE, 2020: Electricity grid mix
Electricity (drying)	3,4E+00	kWh/f.u.	(Bosch, 2019)	Thinkstep	SE, 2020: Electricity grid mix
Waste					
Waste water	1,4E+02	kg/f.u.		Thinkstep	EU-28, 2020: Municipal waste water treatment (mix)
Main product					
Worn out jeans	7,2E-01	kg/f.u.			

Table D.17: Assumptions for Use and Reuse data presented in table D.16.

	It is assumed that:
Auxiliary material	
Detergent	Number of washes per jeans and per year is 26 based on the assumptions that number of uses per week is 3 and number of uses before wash is 6 (Laitala et al., 2012)
Water	
Washing	See assumptions for detergent.
Energy	
Electricity (washing)	The jeans are washed at 40 °C (Laitala et al., 2012) Also, see assumption for detergent.
Electricity (drying)	The jeans are tumble dried each time they are washed.
Waste	
Waste water	The same amount as water is used for washing. Also, see assumption for detergent.

The transportation processes for Use and Reuse are presented in table D.18. Means of transportation and transportation routes are assumed for both of the transportation processes presented in the table. Assumptions for specific transportation processes are presented in table D.19. Furthermore, it should be noted that:

- Abbreviations for geographical regions can be found in table D.2.
- Modelling choices for means of transportation can be found in table D.1.
- Transportation of finished jeans and paper bag from storage at Repair Shop/Retailer to user are not included since these processes have already been accounted for in table D.14.

- A value that is marked with an asterisk for the distance denotes that the given transportation distance has been estimated based on an educated guess.

Table D.18: Transportation processes for Use and Reuse.

	From	To	Means of transportation	Distance (km)	Reference distance/location
Auxiliary material					
Detergent	Vadstena, Sweden (Kempartner)	Unknown, Sweden (Shop)	Truck	291	(Kempartner, 2019)/ (Via Michelin, 2019)
	Unknown, Sweden (Shop)	Unknown, Sweden (User)	Car	1	(Amcoff et al., 2015)
Main product					
Worn out/repaired jeans	Unknown, Sweden (User)	Unknown, Sweden (Repair shop/Retailer)	Car	50*	
	Unknown, Sweden (Repair shop/Retailer)	Unknown, Sweden (User)	Car	50*	

Table D.19: Assumptions for transportation for Use and Reuse.

	From	To	It is assumed that:
Auxiliary material			
Detergent	Kempartner	Shop	The distance can be estimated as average distance from assumed supplier to Stockholm, Göteborg and Malmö.
	Shop	User	The user only buys detergent at the shop.

D.5 Repair

Table D.20 presents the inventory data and the modelling choices in GaBi for Repair. Assumptions for specific repair data are presented in table D.21 Furthermore, it should be noted that:

- Emissions are modelled in GaBi where the amount depend on amount of energy use. Thus, emissions are not included in the table.
- Abbreviations for geographical regions can be found in table D.2.
- The second column from the left presents the main components of the materials.
- A value that is marked with an asterik for the amount denotes that the given amount has been estimated based on an educated guess.

Table D.20: Inventory data and modelling choices in GaBi for Repair.

		Amount	Unit	Reference	Database	Dataset
Material						
Worn out jeans		7,2E-01	kg/f.u.	(Denim Authority, 2018)		
Thread	Polyester	1,5E-03	kg/f.u.	Weighing, (Michael Lundin, 2019)	Thinkstep	DE, 2017: Polyester resin unsaturated (UP)
Zipper	Brass	2,80E-04	kg/f.u.	(Michael Lundin, 2019)	Thinkstep	RER, 2017: Brass: 80 % Copper, 20 % Zink
	Polyester (ribbon)	2,80E-05	kg/f.u.	(Michael Lundin, 2019)	Thinkstep	RER, 2017: Polyester (PET) fabric
Denim patch (fabric)		5,1E-03	kg/f.u.	Weighing, (Michael Lundin, 2019)		RER, 2017: Brass: 80 % Copper, 20 % Zink
Button		2,6E-06	kg/f.u.	(Michael Lundin, 2019)	Thinkstep	RER, 2017: Brass: 80 % Copper, 20 % Zink
Glue		7,2E-04*	kg/f.u.		Thinkstep	DE, 2017: PVC adhesive (estimation)
Auxiliary material						
Hangtag	Recycled paper	3,0E-03	kg/f.u.	Weighing	Ecoinvent 3.5	RoW, 2018: Offset printing, per kg printed paper
	Polyester (rope)	1,0E-03	kg/f.u.	Weighing	Thinkstep	DE, 2017: Polyester resin unsaturated (UP)
Detergent		1,0E-02	kg/f.u.	(Ecolabelling Denmark, 2011)	Thinkstep	GLO, 2017: Detergent (fatty acid sulphonate derivate)
Plastic bag		8,8E-03	kg/f.u.	(Avisera, 2019)	Ecoinvent 3.5	RER, 2018: Extrusion, plastic film
Paper bag		9,5E-02	kg/f.u.	(Avisera, 2019)	Ecoinvent 3.5	RER, 2018: Kraft paper production, unbleached
Water						
Washing		5,2E+00	kg/f.u.	(Energimyndigheten, 2011), (Michael Lundin, 2019)	Thinkstep	EU-28, 2020: Tap water
Steaming		1,2E-01	kg/f.u.	(MediaMarkt, 2019), (Michael Lundin, 2019)	Thinkstep	EU-28, 2020: Tap water
Energy						
Electricity (washing)		5,4E-02	kWh/f.u.	(Energimyndigheten, 2011), (Michael Lundin, 2019)	Thinkstep	SE, 2020: Electricity grid mix
Electricity (steaming)		1,1E-01	kWh/f.u.	(MediaMarkt, 2019), (Michael Lundin, 2019)	Thinkstep	SE, 2020: Electricity grid mix
Electricity (sewing)		1,3E-02	kWh/f.u.	(Eon, 2019), (Michael Lundin, 2019)	Thinkstep	SE, 2020: Electricity grid mix
Waste						
Waste water		5,2E+00	kg/f.u.		Thinkstep	EU-28, 2020: Municipal waste water treatment (mix)
Main product						
Repaired jeans		7,2E-01	kg/f.u.	(Denim Authority, 2018)		

Table D.21: Assumption for Repair data presented in table D.20.

	It is assumed that:
Waste	
Waste water	Amount of waste water is the same as amount as water used for washing.

The transportation processes for Repair are presented in table D.22. Means of transportation are assumed for all transportation processes. Assumptions for specific transportation processes are presented in table D.23. Moreover, it should be noted that:

- Abbreviations for geographical regions can be found in table D.2.
- Modelling choices for means of transportation can be found in table D.1.
- Transportation of worn out jeans from Use and Reuse to Repair is not included since this transportation process have already been accounted for in table D.18.
- A value that is marked with an asterikfor the distance denotes that the given transportation distance has been estimated based on an educated guess.

Table D.22: Transportation processes for Repair.

		From	To	Means of transportation	Distance (km)	Refrence distance/location
Material						
Hangtags		Herning, Denmark (A-TEX)	Göteborg, Sweden (Repair Shop)	Truck	284	(Via Michelin, 2019)/ (A-TEX, 2019)
	Recycled paper	Unknown, Unknown	Herning, Denmark (A-TEX)	Truck	100*	(A-TEX, 2019)
	Polyester (rope)	Unknown, Unknown	Herning, Denmark (A-TEX)	Truck	100*	(A-TEX, 2019)
Thread		Borås, Sweden (Rudholm och Haak)	Göteborg, Sweden (Repair Shop)	Truck	62	(Via Michelin, 2019)/ (Rudholm, 2019)
Zipper		Borås, Sweden (YKK)	Göteborg, Sweden (Repair Shop)	Truck	62	(Via Michelin, 2019)/ (YKK, 2019)
	Brass	Unknown, Unknown	Borås, Sweden (YKK)	Truck	500*	(YKK, 2019)
	Polyester (ribbon)	Unknown, Unknown	Borås, Sweden (YKK)	Truck	500*	(YKK, 2019)
Denim patch (fabric)		Ras Jebel, Tunisia (Denim Authority)	Göteborg, Sweden (Repair Shop)	Truck	2 004	(Via Michelin, 2019)/ (Michael Lundin, 2019)
				Ship	752	(Sea-Distances, 2019) / (Michael Lundin, 2019)
Button		Wuppertal, Germany (Berning)	Göteborg, Sweden (Repair Shop)	Truck	1008	(Via Michelin, 2019)/ (Berning, 2019b)
Glue		Unknown, Unknown	Göteborg, Sweden (Repair Shop)	Truck	100*	(Michael Lundin, 2019)
Auxiliary material						
Detergent		Vadstena, Sweden (Kempartner)	Unknown, Sweden (Shop)	Truck	291	(Via Michelin, 2019)/ (Kempartner, 2019)
		Unknown, Sweden (Shop)	Göteborg, Sweden (Nudie Repair Shop)	Car	1	(Amcoff et al., 2015) / (Michael Lundin, 2019)
Plastic bag (Online)		Unknown, Bulgaria (Avisera)	Borås, Sweden (Korallen)	Truck	2 597	(Via Michelin, 2019)/ (Avisera, 2019)
		Borås, Sweden (Korallen)	Unknown, Sweden (User/Reuser)	Truck	500*	(Korallen, 2019)
Paper bag (Repair Shop)		Unknown, Romania (Avisera)	Borås, Sweden (Korallen)	Truck	2 279	(Via Michelin, 2019)/ (Avisera, 2019), (Korallen, 2019)
		Borås, Sweden (Korallen)	Unknown, Sweden (Repair shop/Retailer)	Truck	246	Google maps/ (Korallen, 2019)
		Unknown, Sweden (Repair shop/Retailer)	Unknown, Sweden (User/Reuser)	Car	50*	
Main product						
Repaired jeans		Göteborg, Sweden (Repair Shop)	Unknown, Sweden (User/Reuser)	Car	50*	(Michael Lundin, 2019)

Table D.23: Assumptions for transportation processes for Repair.

	From	To	It is assumed that:
Auxiliary material			
Detergent	Kempartner	Shop	See detergent in table D.19
	Shop	Repair Shop	The repair shop only buys detergent at the shop.
Plastic bag (Online)	Avisera	Korallen	The production in Bulgaria is located in the midpoint of Bulgaria (Dunavtsi).
Paper bag (Repair Shop)	Avisera	Korallen	See paper bag in table D.19
	Korallen	Repair shop/ Retailer	See paper bag in table D.19

D.6 Incineration

Table D.24 presents the inventory data and modelling choices in GaBi for Incineration. Moreover, it should be noted that:

- Emissions are modelled in GaBi where the amount depend on amount of energy use. Thus, emissions are not included in the table.
- Abbreviations for geographical regions can be found in table D.2.

Table D.24: Inventory data and modelling choices in GaBi for End-of-Life Treatment.

	Amount	Unit	Reference	Database	Dataset
Material					
Worn out jeans	7,2E-01	kg/f.u.	(Denim Authority, 2018)	Thinkstep	SE, 2020: Textile (animal and plant based) in waste incineration plant

The transportation processes for Incineration are presented in table D.25. Means of transportation is assumed and the distance is based on an educated guess and is therefore denoted with "*". Furthermore, it should be noted that:

- Abbreviations for geographical regions can be found in table D.2.
- Modelling choices for means of transportation can be found in table D.1.

Table D.25: Transportation processes for Incineration.

	From	To	Means of transportation	Distance (km)	Reference distance/location
Material					
Worn out jeans	Unknown, Sweden (User)	Unknown, Sweden (Incineration plant)	Truck	100*	

D.7 Allocation Calculations

D.7.1 Allocated Water Use at the Warehouse (Korallen)

The allocated water used at Korallen was calculated according to equation D.1, where $V_{water\ for\ jeans\ storage,\ Korallen}$ is the volume of water used for storing Nudie Jeans at Korallen and $n_{jeans,\ Korallen}$ is the number of stored Nudie Jeans at Korallen. Note that the allocation procedure does not distinguish between Lean Dean Lost Legend jeans and other jeans models.

$$V_{allocated\ water,\ Korallen} = \frac{V_{water\ for\ jeans\ storage,\ Korallen}}{n_{jeans,\ Korallen}} \tag{D.1}$$

The water used for storing the jeans at Korallen, $V_{water\ for\ jeans\ storage,\ Korallen}$ was calculated according to equation D.2 where $V_{tot.\ water,\ Korallen}$ is the total water consumption per year and $n_{weeks\ for\ jeans\ storage}$ is the assumed number of weeks that the jeans are stored at Korallen.

$$V_{water\ for\ jeans\ storage,\ Korallen} = V_{tot.\ water,\ Korallen} \cdot \frac{n_{weeks\ for\ jeans\ storage}}{n_{weeks\ per\ year}} \tag{D.2}$$

Equation D.3 presents the calculation for determining the number of Nudie Jeans stored at Korallen, where $A_{storage}$ is the area of the storage facility, $X_{storage\ used\ by\ Nudie}$ is the fraction of the storage facility used by Nudie, $X_{stored\ Nudie\ Jeans}$ is the assumed fraction of the Nudie Jeans' storage containing jeans and $n_{jeans\ per\ arear,\ Korallen}$ is the assumed number of jeans being stored per square meter of Nudie Jeans' storage.

$$n_{jeans,\ Korallen} = A_{Korallen} \cdot X_{Nudie,\ Korallen} \cdot X_{jeans,\ Korallen} \cdot n_{jeans\ per\ area,\ Korallen} \tag{D.3}$$

D.7.2 Allocated Energy Use at the Warehouse (Korallen), Repair Shops and Retailers

The allocated energy consumption for one pair of Nudie Jeans, $E_{allocated,\ Korallen}$, was calculated according to the equation D.4 where $E_{jeans\ storage,\ Korallen}$ is the energy used for storing Nudie Jeans and $n_{jeans,\ Korallen}$ is the number of stored Nudie Jeans, which is calculated according to equation D.3 above.

$$E_{allocated,\ Korallen} = \frac{E_{jeans\ storage,\ Korallen}}{n_{jeans,\ Korallen}} \tag{D.4}$$

$E_{jeans\ storage,\ Korallen}$, is calculated according to equation D.5, where $E_{tot,\ Korallen}$ is the total energy consumption per year and $n_{weeks\ for\ jeans\ storage}$ is the assumed number of weeks that the jeans are stored.

$$E_{jeans\ storage,\ Korallen} = E_{tot,\ Korallen} \frac{n_{weeks\ for\ jeans\ storage}}{n_{weeks\ per\ year}} \tag{D.5}$$

The allocated energy consumption for the storage are assumed to be the same at the Repair Shops and retailers. The allocated value was calculated according to equation D.6 where the suffix, shop, is used for to both Repair Shop and retailer and the number of jeans stored at the shop is assumed. In the equation, $E_{jeans\ storage,\ shop}$ is the energy used for storing Nudie Jeans in the shops and $n_{jeans,\ shop}$ is the number of stored Nudie Jeans.

$$E_{allocated,\ shop} = \frac{E_{jeans\ storage,\ shop}}{n_{jeans,\ shop}} \tag{D.6}$$

$E_{jeans\ storage,\ shop}$, is calculated according to equation D.7 where $E_{tot,\ shop}$ is the total energy consumption area and year, A_{shop} is the assumed area of a shop, $n_{weeks\ for\ jeans\ storage}$ is the assumed number of weeks that the jeans are stored and $n_{weeks\ per\ year}$ is set to 52 weeks. Note that the jeans are assumed to be stored for the same number of weeks at the Repair Shops and retailers as for Korallen.

$$E_{jeans\ storage,\ shop} = E_{tot,\ shop} \cdot A_{shop} \frac{n_{weeks\ for\ jeans\ storage}}{n_{weeks\ per\ year}} \tag{D.7}$$

D.7.3 Allocated Amount of Detergents and Water for the Washing Procedure during Use and Reuse

The allocated amount of detergent used per jeans and year was calculated according to equation D.8 where $m_{detergent\ per\ wash}$ is the mass detergent used per wash, m_{year}

is the mass of one pair of jeans and $n_{washes\ per\ year}$ is the number of times that the jeans are washed each year.

$$m_{allocated\ detergent} = m_{detergent\ per\ wash} \cdot m_{jeans} \cdot n_{washes\ per\ year} \tag{D.8}$$

$n_{washes\ per\ year}$ is calculated according to equation D.9, where $n_{uses\ per\ year}$ is the assumed number of times that the jeans are worn per year and $n_{uses\ per\ wash}$ is the number of times that the jeans are worn before being washed.

$$n_{washes\ per\ year} = \frac{n_{uses\ per\ year}}{n_{uses\ before\ wash}} \tag{D.9}$$

The allocated amount of water used for the washing one pair of jeans during a year is calculated according to equation D.10 where $V_{water\ per\ washed\ jeans}$ is the volume of water needed to wash one pair of jeans and $V_{washes\ per\ year}$ is presented above.

$$V_{allocated\ water,\ washing} = V_{water\ per\ washed\ jeans} \cdot n_{washes\ per\ year} \tag{D.10}$$

$V_{water\ per\ washed\ jeans}$ was calculated according to equation D.11 where m_{jeans} is the mass for one pair of jeans, $V_{water\ per\ wash}$ is the volume of water required for one wash and $m_{clothing\ per\ wash}$ is the mass of clothing washed per wash.

$$V_{water\ per\ washed\ jeans} = m_{jeans} \cdot \frac{V_{water\ per\ wash}}{m_{clothing\ per\ wash}} \tag{D.11}$$

For modelling in GaBi, the material inputs where scaled so that they apply to the estimated use time by multiplying equation D.8 and D.10 with t_{use}.

D.7.4 Allocated Energy Use for the Washing Procedure

Equation D.12 presents the allocated energy used for washing, where $E_{per\ washed\ jeans}$ is the energy needed to wash one pair of jeans and $E_{washes\ per\ year}$ is presented above.

$$E_{allocated,\ washing} = E_{per\ washed\ jeans} \cdot n_{washes\ per\ year} \tag{D.12}$$

$V_{energy\ per\ washed\ jeans}$ was calculated according to equation D.13 where m_{jeans} is the mass of one pair of jeans, $V_{energy\ per\ wash}$ is the volume of water required for one wash and $m_{clothing\ per\ wash}$ is the mass of clothing washed each wash.

$$E_{per\ washed\ jeans} = m_{jeans} \cdot \frac{V_{energy\ per\ wash}}{m_{clothing\ per\ wash}} \tag{D.13}$$

Allocated energy for tumble drying one pair of jeans during a year's use is allocated according to equation D.14, where $E_{per\ dried\ jeans}$ is the energy needed to tumble dry one pair of jeans and $n_{dries\ per\ year}$ is the number of times that the jeans are tumble dried. It is assumed that the jeans are dried the same number of times that they are washed, see equation D.9.

$$E_{allocated,\ drying} = E_{per\ dried\ jeans} \cdot n_{dries\ per\ year} \tag{D.14}$$

$E_{per\ dried\ jeans}$ was calculated according to equation D.15 where m_{jeans} is the mass of one pair of jeans, $E_{per\ dry}$ is the energy required for one tumble dry and $m_{clothing\ per\ dry}$ is the mass of clothing dried each tumble dry cycle.

$$E_{per\ washed\ jeans} = m_{jeans} \cdot \frac{E_{per\ tumble\ dry}}{m_{clothing\ per\ wash}} \tag{D.15}$$

In order to model the energy input in GaBi so that it applies to the use time, equations D.12 and D.14 were multiplied with t_{use}.

D.7.5 Allocated Amount of Water used for Steaming

Water used for steaming the jeans is calculated according to equation D.10, where $m_{steam\ per\ second}$ is the mass of steam used per second of steaming, $t_{steaming}$ is the time it takes to steam one pair of jeans and ρ_{water} is the density of water.

$$V_{allocated\ water,\ steaming} = \frac{m_{steam\ per\ second} \cdot t_{steaming}}{\rho_{water}} \tag{D.16}$$

D.7.6 Allocated Amount of Paper and Plastic Bags used for Repaired Jeans

Allocated amounts of paper and plastic bags were calculated according to equation D.17 and D.18 respectively. In the equation $m_{paper\ bag}$ and $m_{plastic\ bag}$ is the mass of the paper and plastic bags respectively. Furthermore, $n_{reuse,\ online}$ and $t_{reuse,\ shop}$ is the number of jeans per year being sold online and in Repair Shops. Lastly, $n_{reused\ jeans}$ is the total number of reused jeans being sold each year.

$$m_{allocated\ plastic\ bag} = m_{plastic\ bag} \cdot \frac{n_{reuse,\ online}}{n_{tot.\ reused\ jeans}} \tag{D.17}$$

$$m_{allocated\ paper\ bag} = m_{plastic\ bag} \cdot \frac{n_{reuse,\ shop}}{n_{tot.\ reused\ jeans}} \tag{D.18}$$

D.8 Characterisation Results

This appendix shows all of the characterisation results from each studied impact category with respect to both the linear and the circular case.

Table D.26: Results for all of the studied impact categories expressed in table form. Results depicted in barcharts can be found the Results and Discussion chapter.

	Global Warming Potential excl. Biogenic Carbon (kg CO2) eq./f.u.)		Acidification Potential (kg SO2 eq./f.u.)		Eutrophication Potential (kg Phosphate eq./f.u.)	
	Linear	**Circular**	**Linear**	**Circular**	**Linear**	**Circular**
Production of Fabric	2,4E+00	6,0E-01	5,6E-03	1,4E-03	1,8E-03	4,5E-04
Production of Jeans	4,5E-01	1,1E-01	2,1E-03	5,1E-04	1,1E-03	2,8E-04
Storage	7,4E-01	1,9E-01	2,0E-03	4,9E-04	4,1E-04	1,0E-04
Use/Reuse	4,8E-01	4,8E-01	2,0E-03	2,0E-03	1,2E-03	1,2E-03
Repair	0,0E+00	6,8E-02	0,0E+00	3,6E-04	0,0E+00	2,0E-04
Incineration	2,0E-02	4,9E-03	4,6E-04	1,2E-04	1,1E-04	2,7E-05
Transports	6,3E-01	4,6E-01	2,1E-03	8,0E-04	5,2E-04	1,9E-04
Total	4,7E+00	1,9E+00	1,4E-02	5,7E-03	5,1E-03	2,4E-03

	Particulate Matter (kg PM2.5 eq./f.u.)		Ozone Layer Depletion Potential (kg R11 eq./f.u.)		Photochemical Ozone Creation Potential (kg Ethene eq./f.u.)	
	Linear	**Circular**	**Linear**	**Circular**	**Linear**	**Circular**
Production of Fabric	4,0E-04	1,0E-04	5,4E-10	1,4E-10	2,9E-04	7,3E-05
Production of Jeans	3,7E-04	9,2E-05	2,4E-08	6,0E-09	9,0E-04	2,2E-04
Storage	1,3E-04	3,2E-05	4,8E-09	1,2E-09	1,6E-04	4,1E-05
Use/Reuse	8,7E-05	8,7E-05	9,6E-12	9,6E-12	1,6E-04	1,6E-04
Repair	0,0E+00	5,4E-05	0,0E+00	5,3E-09	0,0E+00	3,2E-05
Incineration	1,1E-05	2,7E-06	2,7E-14	6,7E-15	2,7E-05	6,7E-06
Transports	1,5E-04	5,2E-05	7,7E-15	2,2E-15	3,9E-05	-1,1E-06
Total	1,1E-03	4,2E-04	3,0E-08	1,3E-08	1,6E-03	5,4E-04

	Ionizing Radiation (kBq U235 eq./f.u.)		Abiotic Depletion (kg Sb eq./f.u.)		Human Toxicity Potential (kg DCB eq./f.u.)	
	Linear	**Circular**	**Linear**	**Circular**	**Linear**	**Circular**
Production of Fabric	1,6E-01	4,1E-02	1,4E-06	3,6E-07	1,9E-01	4,8E-02
Production of Jeans	2,6E-02	6,5E-03	7,0E-06	1,8E-06	3,4E-01	8,6E-02
Storage	2,7E-01	6,7E-02	2,8E-07	6,9E-08	8,6E-02	2,1E-02
Use/Reuse	7,2E-01	7,2E-01	1,1E-06	1,1E-06	5,3E-02	5,3E-02
Repair	0,0E+00	2,7E-02	0,0E+00	1,6E-07	0,0E+00	3,7E-02
Incineration	2,0E-03	5,1E-04	1,8E-08	4,5E-09	2,4E-03	6,1E-04
Transports	7,7E-04	2,3E-04	1,6E-08	4,9E-09	1,5E-02	8,5E-03
Total	1,2E+00	8,7E-01	9,8E-06	3,4E-06	6,9E-01	2,6E-01

	Terrestric Ecotoxicity Potential (kg DCB eq./f.u.)		Marine Aquatic Ecotoxicity Potential (kg DCB eq./f.u.)		Freshwater Aquatic Ecotoxicity Potential (kg DCB eq./f.u.)	
	Linear	**Circular**	**Linear**	**Circular**	**Linear**	**Circular**
Production of Fabric	9,4E-04	2,4E-04	2,7E+02	6,8E+01	9,7E-03	2,4E-03
Production of Jeans	6,6E-03	1,6E-03	3,1E+02	7,8E+01	8,2E-02	2,1E-02
Storage	2,5E-03	6,3E-04	3,0E+02	7,4E+01	2,3E-02	5,7E-03
Use/Reuse	2,5E-03	2,5E-03	3,4E+02	3,4E+02	1,1E-02	1,1E-02
Repair	0,0E+00	1,8E-03	0,0E+00	6,5E+01	0,0E+00	2,2E-02
Incineration	4,1E-04	1,0E-04	7,7E-01	1,9E-01	3,5E-05	8,7E-06
Transports	2,4E-04	8,2E-05	3,9E+00	1,1E+00	1,5E-03	4,5E-04
Total	1,3E-02	6,9E-03	1,2E+03	6,3E+02	1,3E-01	6,2E-02

E

Appendix: Data Collection Forms

E.1 Candiani

Table E.1: Basic information collected in the data collection form sent to the Candiani (fabric producer) in 2018.

Basic information	
Company name	Candiani
Factory/Facility name	Candiani S.p.A.
Type of production	Fabric manufacturing
Product ID	RR 2716 Old Crispy & RR 7216 Sioux Preshrunk
Location of the facility (city and country)	Robecchetto con Induno (MI) - Italy
Production time (when the factory is open for production) in number of hours per year	

Table E.2: Questions related to production, materials, chemicals, solid waste data, water usage, waste water treatment, which where included in the data collection form sent to Candiani (fabric producer) in 2018.

Production data
Is fabric (textile) the only type of product produced at the facility?
If no, what other products are produced at the facility and how large share of the total production is represented by fabric production?
What was the total production of fabric (all produced fabrics) at the facility in 2017?
What was the total production of the specific fabric RR 2716 Old Crispy at the facility in 2017?
What was the total production of the specific fabric RR 7216 Sioux Preshrunk at the facility in 2017?
Is the finished product RR 2716 Old Crispy stored at the facility before shipped of? If yes, how long?
Material data - RR 2716 Old Crispy
What is the final weight of the finished product RR 2716 Old Crispy?
What is the content of different materials in the fabric RR 2716 Old Crispy, split into percentage by weight?
Material 1: Cotton
What was the total amount of purchased cotton in 2017?
Please estimate how much of the raw cotton that is spilled each year.
How much raw cotton is used for the production of the fabric RR 2716 Old Crispy?
Where is the cotton used in the production of the fabric RR 2716 Old Crispy cultivated?
Is the cotton used for the production of the fabric RR 2716 Old Crispy cultivated in organic or non-organic conditions?
In what kind of vehicle is the cotton transported to the facility?
For how long time is the cotton stored at the facility before usage?
Material 2: Elastane
How much elastane is used for the production of the fabric RR 2716 Old Crispy?
What type of elastane is used for the production of the fabric RR 2716 Old Crispy?
From which country/company is the elastane purchased?
Chemical Data
What was the total use of chemicals at the facility during 2017?
Which chemicals are used in the production of the fabric RR 2716 Old Crispy?
How are the chemicals handled after use?
Solid Waste Data
Please estimate the total amount of solid spillage generated at the facility each year, from raw materials to complete finished product.
What do the spillage, in the largest extent, contain of?
How is the spillage handled?
Water usage data
What was the total water usage at the facility in 2017?
What is the primary source of water at the facility?
How is the water used at the facility? Choose the alternative that suits the best, please specify the answer.
Water usage - Spinning
Is any water used in the spinning process? If yes, how much water is required in the process?
Water usage - Warping
Is any water used in the warping process? If yes, how much water is required in the process?
Water usage - Dyeing
Is any water used in the dyeing process? If yes, how much water is required in the process?
Water usage - Sizing
Is any water used in the sizing process? If yes, how much water is required in the process?
Water usage - Other processes
Is any water used in any other processes? If yes, which processes and how much water is required in the processes?
Water treatment
Please select the option that best applies to the facility regarding how the water is treated after being used
Is the water recycled at the facility? If yes, Please specify between which processes recycling is occurring and the total amount of recycled water.

Table E.3: Questions related to energy and transportation, which where included in the data collection form sent to Candiani (fabric producer) in 2018.

Energy Data
What was the total use of electricity at the facility in 2017?
What is the energy source of the electricity?
What was the total use of other types of fuels at the facility in 2017?
Is the facility heated? If yes, how much energy goes to heating the facility?
What type of energy is used for heating?
Energy Data - Process Specific
If known, please state how much electricity that goes to the spinning process each year
If known, please state how much electricity that goes to the warping process each year
If known, please state how much electricity that goes to the dyeing process each year
If known, please state how much electricity that goes to the sizing process each year
If known, please state how much electricity that goes to the weaving process each year
Transportation Data
Transportation - Storage of cotton to Spinning
Is any transportation occurring between the storage of cotton and the spinning process? If yes please state,
Type of transportation
The transport distance
Transportation - Spinning to Warping
Is any transportation occurring between the spinning and the warping process? If yes please state,
Type of transportation
The transport distance
Transportation - Warping to Dyeing
Is any transportation occurring between the warping and dyeing process? If yes please state,
Type of transportation
The transport distance
Transportation - Dyeing to Sizing
Is any transportation occurring between the dyeing and sizing process? If yes please state,
Type of transportation
The transport distance
Transportation - Sizing to Weaving
Is any transportation occurring between the sizing and weaving process? If yes please state,
Type of transportation
The transport distance
Transportation - Weaving to Finishing
Is any transportation occurring between the weaving and finishing process? If yes please state,
Type of transportation
The transport distance
Transportation - Finishing to Storage
Is any transportation occurring between the finishing process and storage of finished fabric? If yes please state,
Type of transportation
The transport distance
Transportation - Shipping of from the facility
In what kind of vehicle is the finished product RR 2716 Old Crispy transported from your facility?

E.2 Denim Authority

Table E.4: Basic information collected in the data collection sent to the Denim Authority (jeans producer) in 2018.

Basic information	
Company name	Denim Authority
Factory/Facility name	Denim Authority
Type of production	Textile / Denim
Product ID	112582 Lean Dean
Laundry	Lost Legend
Location of the facility (city and country)	Ras Jebel, Tunisia
Production time (when the factory is open for production) in number of hours per year	

Table E.5: Questions related to production, materials, chemicals and solid waste, which where included in the data collection form sent to Denim Authority (jeans producer) in 2018.

Production Data
Are jeans the only type of product produced at the facility? If no, what other products are produced at the facility? and, how large share (number of products or % of total weight) of the total production (of all produced products) is represented by jeans production?
What was the total production of jeans (all produced jeans) at the facility in 2017, in
- number of jeans
- kg/tons of jeans
What was the total production of the specific product 112582 Lean Dean Lost Legend at the facility in 2017, in
- number of Lean Dean Lost Legend
- kg/tons of Lean Dean Lost Legend
Material data - 112582 Lean Dean Lost Legend
What is the final weight of the finished product 112582 Lean Dean Lost Legend?
What is the content of different materials in the product 112582 Lean Dean Lost Legend, split into percentage by weight?
Material 1: Denim Fabric
What was the total amount of purchased denim fabric in 2017?
Please estimate how much of the denim fabric that is spilled each year
What happens to the spillage?
How much denim fabric is used for the production of one pair of 112852 Lean Dean Lost Legend?
In what kind of vehicle is the fabric transported to the facility?
Material 2: Zippers and other metallic articles
What type of material is used in the zippers of the pant 112852 Lean Dean Lost Legend?
From which country/company is the zipper purchased?
What type of material is used in the button and other metallic details in the pant 112852 Lean Dean Lost Legend?
From which country/company is the article purchased?
Other materials or substances
If other materials are used, except from the above mentioned, please specify the material and where it is purchased
Chemical data
What was the total use of chemicals at the facility during 2017?
Which chemicals are used in the laundry process of the product 112582 Lean Dean Lost Legend?
Please specify name and amount (including unit) of each chemical
How are the chemicals handled after use?
Solid Waste Data
Please estimate the total amount of solid spillage generated at the facility each year, from raw materials to complete finished product
What do the spillage, in the largest extent, contain of?
How is the spillage handled?

Table E.6: Questions related to water usage, waste water treatment, energy, storage and packaging and transportation, which where included in the data collection form sent to Denim Authority (jeans producer) in 2018.

Water usage data	
What was the total water usage at the facility in 2017?	
What is the primary source of water at the facility?	
How is the water used at the facility? Choose the alternative that suits the best, please specify the answer	
Water usage - Laundry process	
What was the total water use for the laundry process at the facility in 2017?	
Are all jeans that are produced at the facility washed? If No, how many of the produced pants are washed? (percentage of all produced pants)	
Waste water treatment	
Please select the option that best applies to the facility regarding how water is treated after being used	
Is the water recycled at the facility? If yes, Please specify between which processes recycling is occurring and the total amount of recycled water	
Energy Data	
What was the total use of electricity at the facility in 2017?	
What is the source of the electricity?	
What was the total use of other types of fuels at the facility in 2017?	
Is the facility heated? If yes, how much energy goes to heating the facility?	
What type of energy is used for heating? Electricity or other type of energy, please specify	
Energy Data - Process Specific	
If known, please state how much electricity that goes to the cutting process each year	
If known, please state how much electricity that goes to the sewing process each year	
If known, please state how much electricity that goes to the laundry process each year	
Storage and Packaging	
Is the product 112582 Lean Dean Lost Legend stored at the facility? If yes, estimate how long time it is stored at the storage facility	
Is the product 112582 Lean Dean Lost Legend packaged before shipped of? If yes, describe how the product is packaged in terms of,	
How many products are packaged in the same packaging?	
What type of packaging material is used?	
Estimate the weight (kg) of the packaging material that is used	
Transportation Data	
Transportation - Storage of fabric to Cutting	
Is any transportation occurring between the storage of fabric and the cutting process? If yes please state,	
	Type of transportation
	The transport distance
Transportation - Cutting to Sewing	
Is any transportation occurring between the cutting and sewing process? If yes please state,	
	Type of transportation
	The transport distance
Transportation - Sewing to Laundry	
Is any transportation occurring between the sewing and laundry process? If yes please state,	
	Type of transportation
	The transport distance
Transportation - Laundry to Packaging	
Is any transportation occurring between the laundry process and the packaging? If yes please state,	
	Type of transportation
	The transport distance
Transportation - Packaging to Storage	
Is any transportation occurring between the packaging and storage of finished product? If yes please state,	
	Type of transportation
	The transport distance
Transportation - Shipping from the facility	
In what kind of vehicle is the finished product 112582 Lean Dean Lost Legend transported from your facility?	

Table E.7: Questions included in the complementary data collection form sent to Denim Authority (jeans producer) in 2019.

Chemicals and Water Use
One of the laundry chemicals you submitted in last year's questionnaire was "PVA". Do you mean Poly Vinyl Alcohol or do you mean Potassium Permanganate?
- If neither, what chemical are you referring to?
The chemicals Resine 3D: Nofelding NFS + Nearfinish 10X NF, Dirty: Orange LG-L were given the following percentages: 5 %, 5 % and 0.05 %, respectively. Are these weight-percentages based on the total amount of water used in the laundry process?
How much "Stone" is used?
Are we right to assume that Stone is the same as Washing Pumice?
Regarding the chemical Neutralisation Agent: META - what is its chemical formula?
- If you don't know, is it right to assume that the purpose of this chemical is to neutralise the effects of the PP Spray?
Regarding the chemical Soaping Agent: NEARESERVE DSW – what is its chemical formula?
Regarding the chemical Dirty: ORANGE LG-L – what is its chemical formula?
Waste Management
How much paper waste do you generate at the facility per year?
How much plastic waste do you generate at the facility per year?
How much waste water (in m3) do you generate at the facility per year?
Is it correct to assume a rough estimate of: total amount of water usage = total amount of waste water?
Energy
When you say fuel - do you mean diesel fuel?
Regarding the fuel,
- What supplier do you buy it from?
- Where is the supplier located (country and city)?
When you submitted the total use of electricity at the facility in 2017, you entered the unit "kwatt". Did you meam kilo watt hours (kWh)?
Packaging Material
Which supplier produces the material?
- In which country is the supplier located?
- In which city is the supplier located?
How is the material transported from the supplier to Denim Authority?
Laundry Chemicals
Which supplier produces the material?
- In which country is the supplier located?
- In which city is the supplier located?
How is the material transported from the supplier to Denim Authority?

E.3 Data Collection Form: Korallen

Table E.8: Questions included in the data collection form sent to Korallen (warehouse) in 2019.

Material
Hur mycket kläder lagras i lokalen?
Hur stora är lagerlokalerna?
Hur stor är hela fastigheten?
Hur stor del av lokalerna går till Nudie?
Hur stor är andelen jeans lagras sett till den totala mängden lagrade kläder?
Hur stor andel Lean Dean Lost Legend jeans lagras sett till den totala mängden lagrade jeans?
Vilka packningsmaterial används för att paketera jeans innan de transpoteras till återförsäljare och Nudie Jeans repair shops?
Hur mycket väger respektive packingsmaterial för jeans?
Energi
Hur stor var lokalens totala elförbrukningen under 2018 (inklusive uppvärmning och tvätteri)?
Använder ni andra typer av energikällor? Om ja, vilka energikällor och hur stor var konsumptionen av respektive energikälla för 2018?
Vatten
Hur mycket vatten konsumerades under 2018?
Tvätteri
Hur mycket tvättmedel konsumerades 2018?
Hur långt och med vilket fordon transporteras tvätt mellan lagret och tvätteriet?

E.4 Data Collection Form: Project Manager for the Repair and Reuse Concept

Table E.9 showcases a part of the questionnaire that was sent to Michael Lundin, Project Manager for the Repair and Reuse concept at Nudie Jeans. The table only shows questions regarding the back pockets. However, all components of the Repair system were inquired about in the exact same fashion as the back pockets. Therefore, all processes that are presented in table C.1 were also included in the questionnaire.

Table E.9: An extract from the questionnaire, containing questions about identifying and quantifying of material and energy inputs regarding Back Pockets within the Repair system.

Back Pockets Which materials are required and what are their quantities?			
	Name of Material	**Amount**	**Unit**
Material 1:	Denim patches / Pocket lining	7	g
Material 2:	Glue	1	g
Material 3:	Polyester Threads	0,0542	g/m
	Yes/No	**If Yes, how long?**	**Units**
Is the sowing machine used?	Yes	2-5	min

F

Sensitivity Analysis on Number of Reuses

This appendix showcases the Contribution Analysis combined with a Sensitivity Analysis in terms of number of reuses for all studied impact categories. For each category, a linear case and four circular cases are displayed. These can be identified in the x-axis of the stacked barcharts.

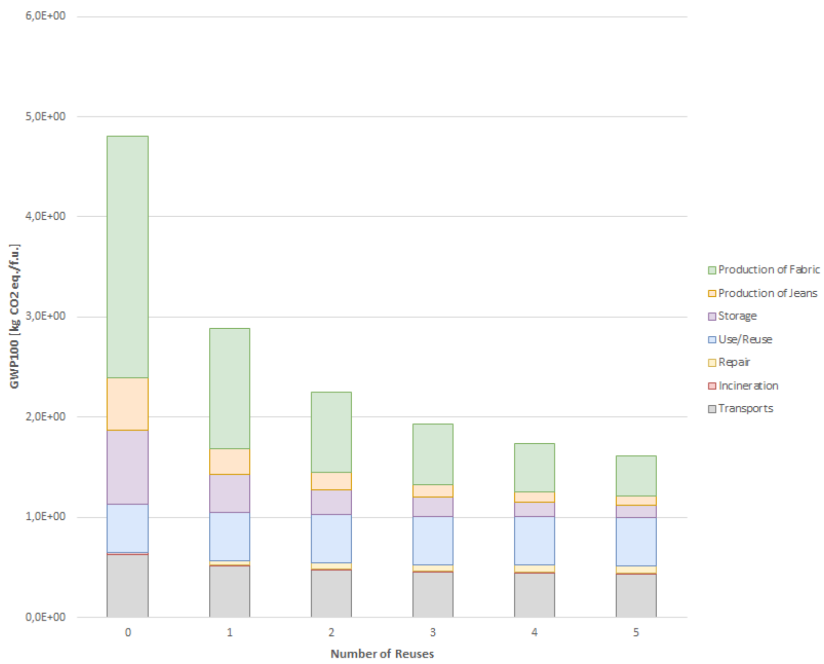

Figure F.1: Stacked barcharts depicting the characterisation results of Global Warming Potential (GWP100), per functional unit, for the process steps involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.

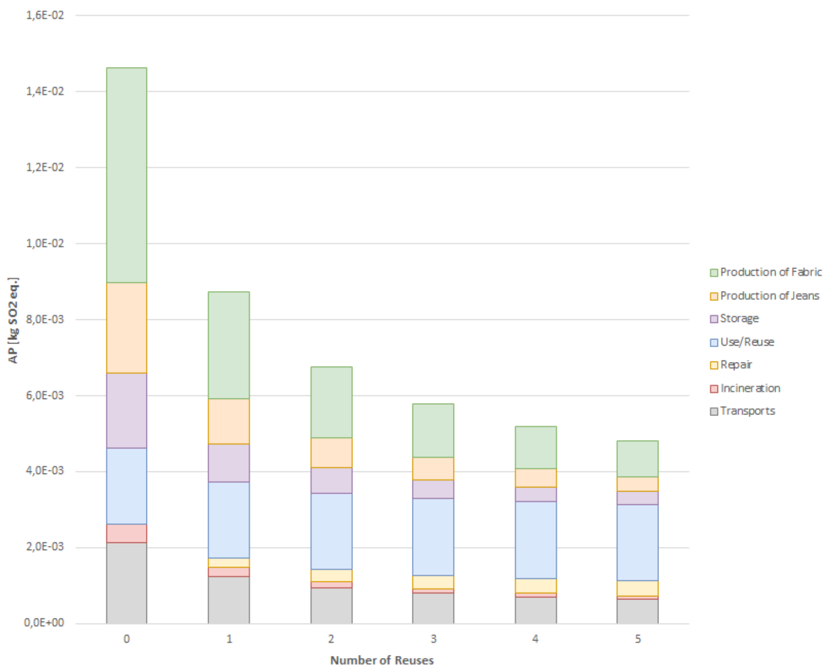

Figure F.2: Stacked barcharts depicting the characterisation results of Acidification Potential (AP), per functional unit, for the process steps involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.

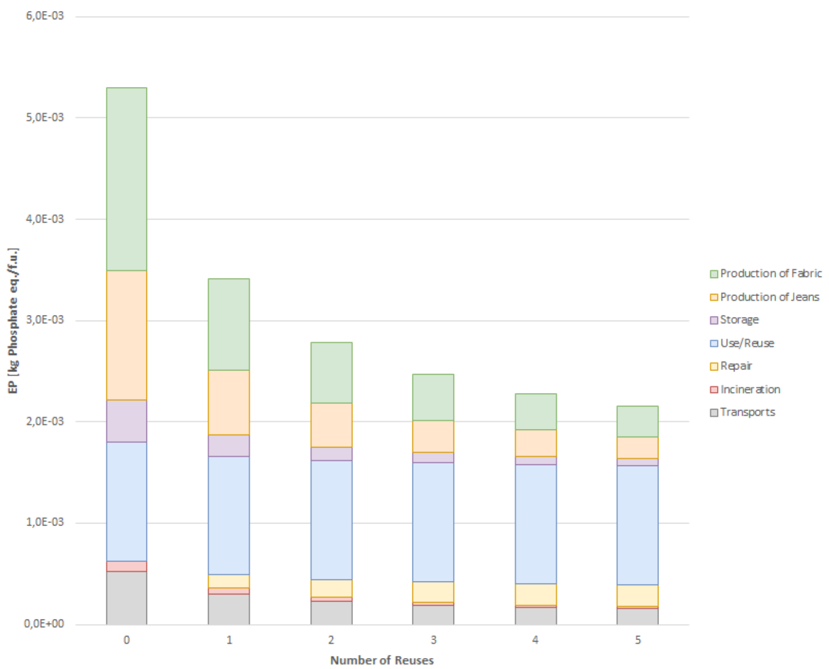

Figure F.3: Stacked barcharts depicting the characterisation results of Eutrophication Potential (EP), per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.

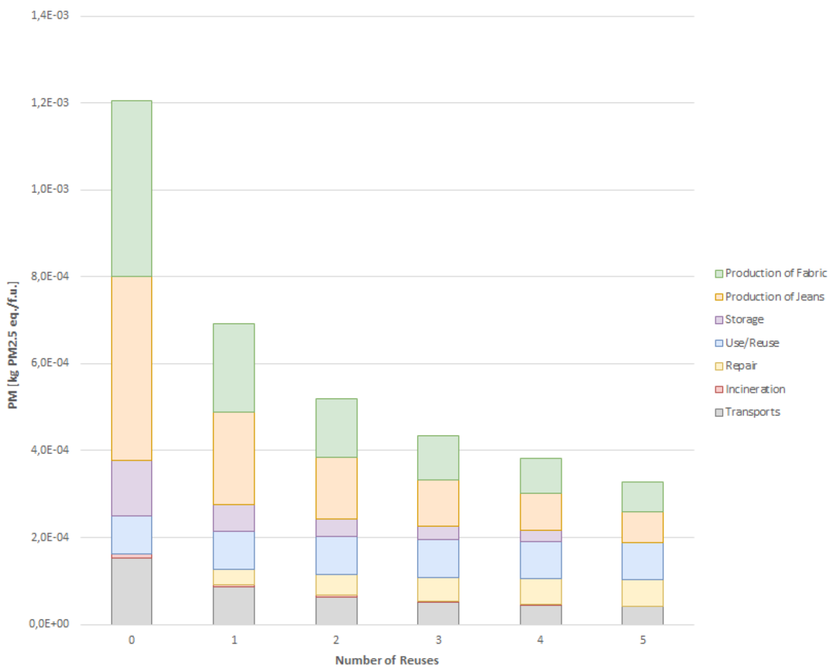

Figure F.4: Stacked barcharts depicting the characterisation results of Particulate Matter (PM), per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.

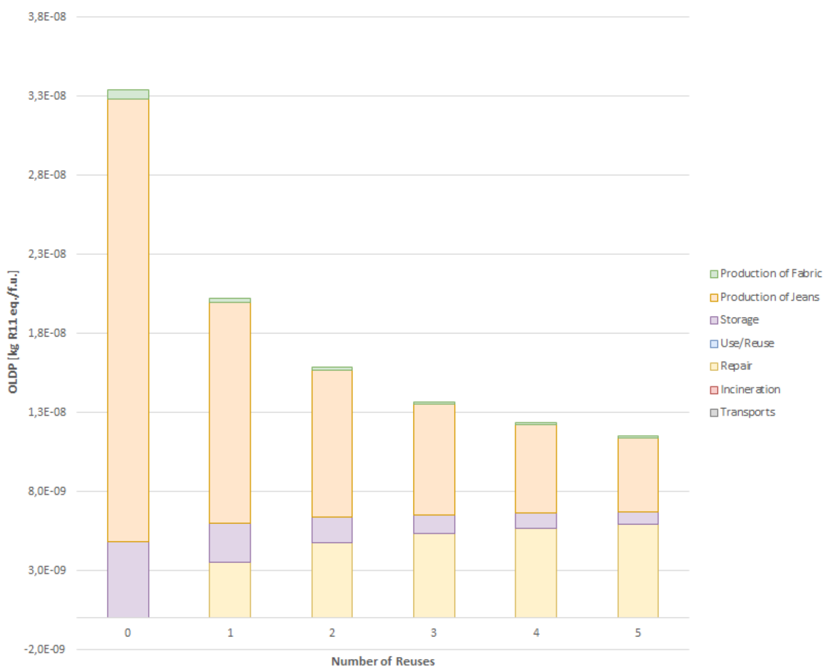

Figure F.5: Stacked barcharts depicting the characterisation results of Ozone Layer Deplwtion Potential (OLDP), per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.

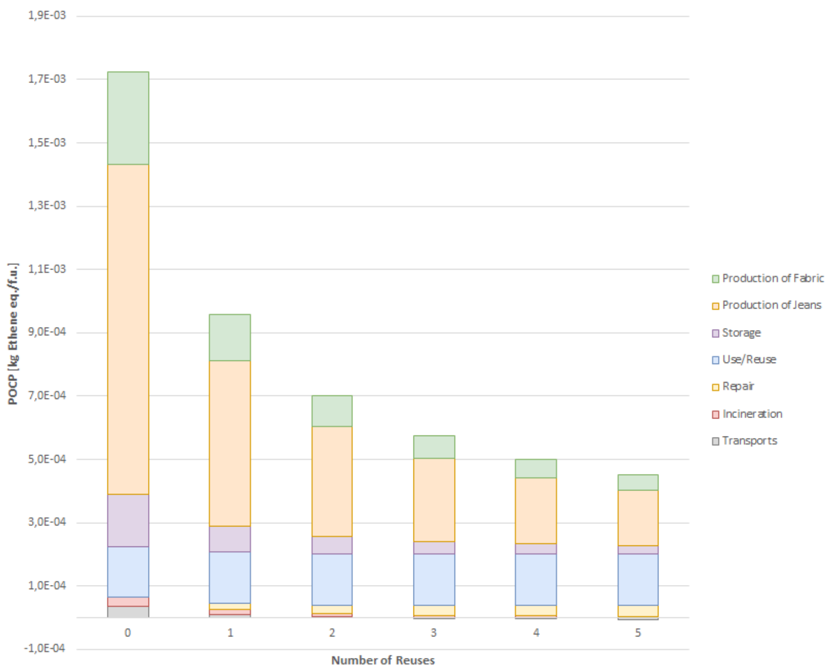

Figure F.6: Stacked barcharts depicting the characterisation results of POCP in terms of the functional unit, for the process steps involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.

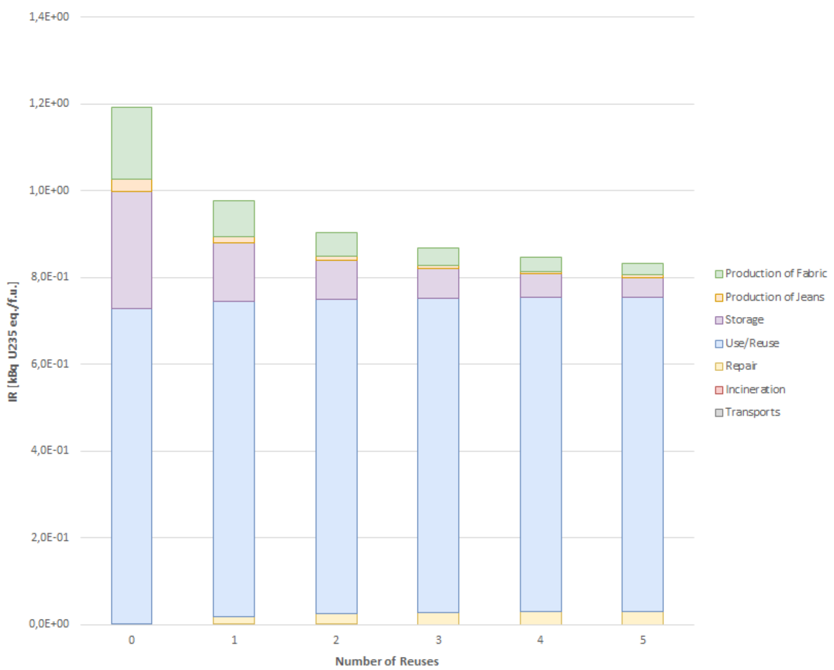

Figure F.7: Stacked barcharts depicting the characterisation results of Ionisation Radiation (IR) in terms of the functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.

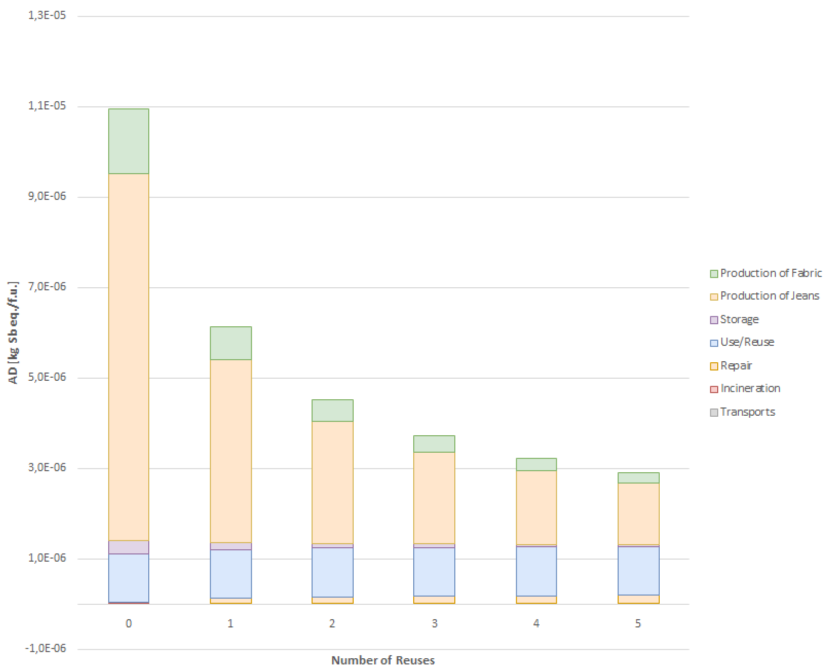

Figure F.8: Stacked barcharts depicting the characterisation results of Abiotic Depletion (AD), per the functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.

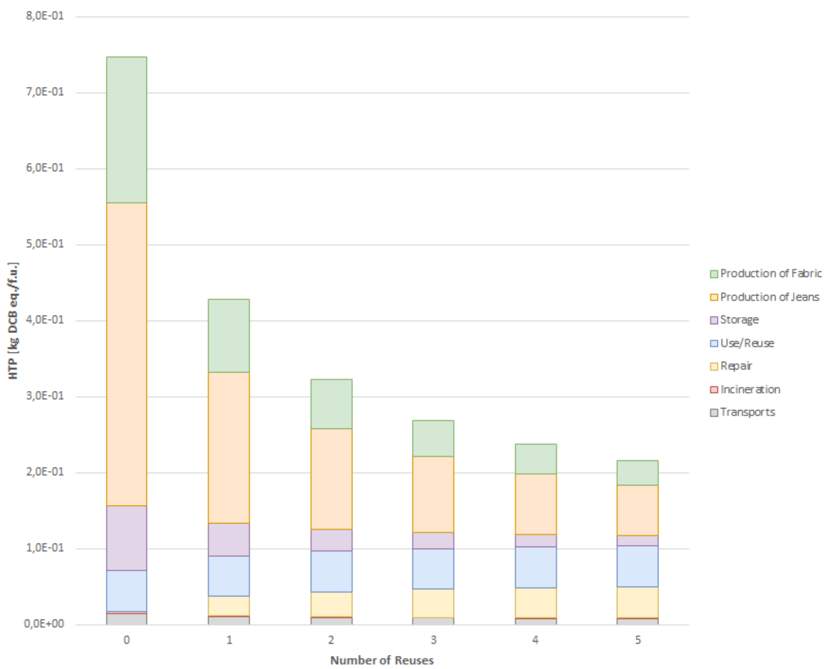

Figure F.9: Stacked barcharts depicting the characterisation results of Human Toxicity Potential (HTP), per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.

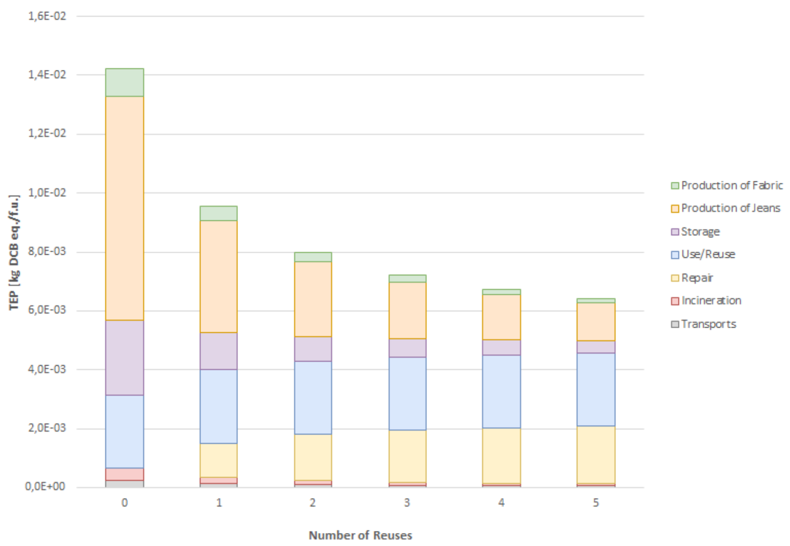

Figure F.10: Stacked barcharts depicting the characterisation results of Terrestrial Ecotoxicity Potential (TEP), per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.

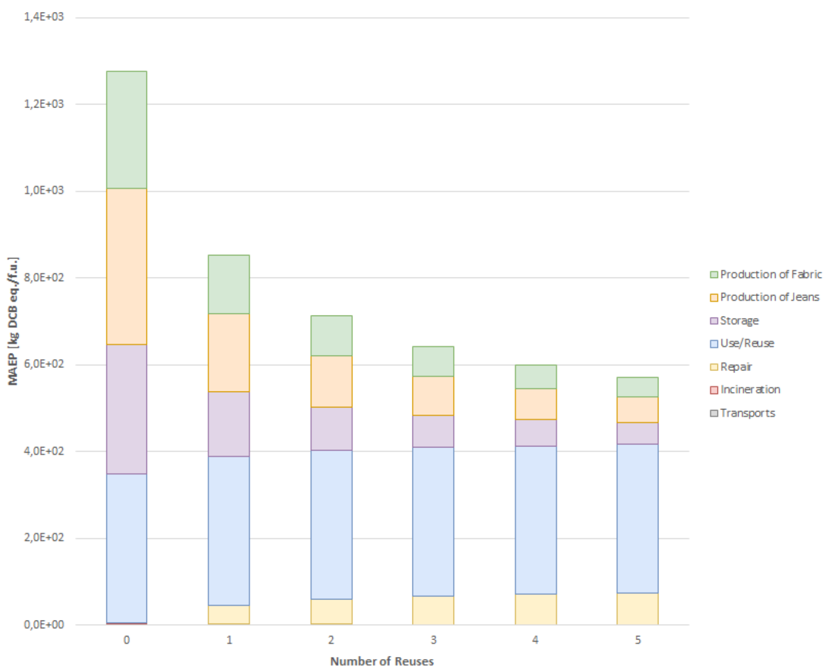

Figure F.11: Stacked barcharts depicting the characterisation results of Marine Equatic Ecotoxicity Potential (MAEP), per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.

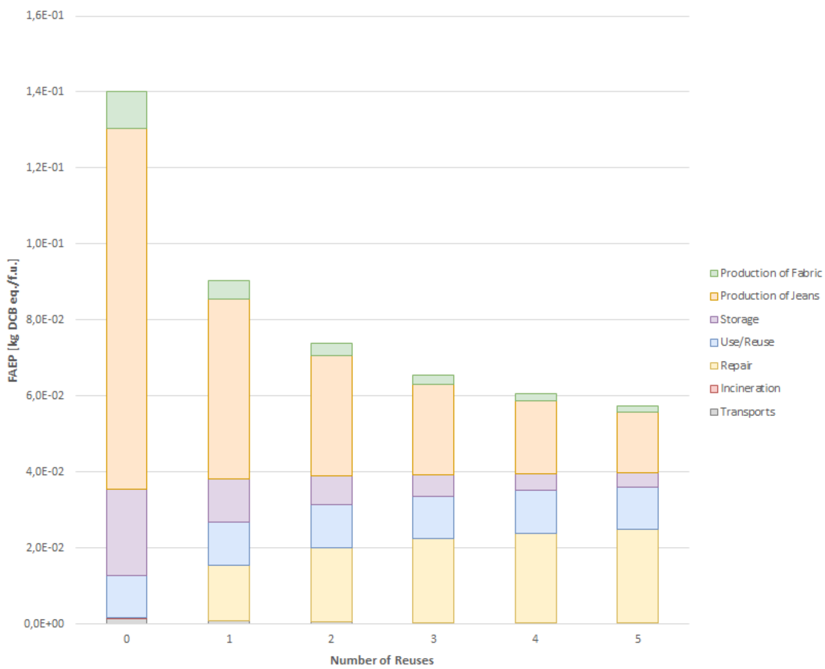

Figure F.12: Stacked barcharts depicting the characterisation results of Freshwater Aquatic Ecotoxicity Potential (FAEP), per functional unit, for the activities involved in the life cycle of a pair of LDLL jeans. A linear case, with zero reuses, and four circular cases, involving one to five reuses, are displayed.