



A Critical Evaluation of Social and Eco-Labels Used in the Textile Industry: Their Possible Impact Demonstrated Through Environmental and Social LCA

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A Critical Evaluation of Social and Eco-Labels Used in the Textile Industry: Their
Potential Impact Demonstrated Through Environmental and Social Life Cycle
Assessment

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Abstract

This thesis evaluated and compared social criteria of ecological (eco) and social labels used in the textile and apparel industry. One objective was to demonstrate potential impacts of sustainably labeled apparel. Based on the impact analysis, as well as the label evaluation results, additional criteria were proposed to address gaps and further strengthen the impact of the labels. The research results were used to propose purchase recommendations for consumers.

Information about relevant consumer facing labels was collected through standardsmap.org and ecolabelindex.com. Social criteria were evaluated by the topics and stakeholder groups covered, and by the specificity of the requirements. To assess the potential positive impacts of the social criteria, a social life cycle assessment (S-LCA) was conducted. The baseline assessment was done for conventional cotton blouses produced in India and sold and used in the USA. A second comparative S-LCA analyzed cotton blouses certified with a social label.

An environmental life cycle assessment (E-LCA) was also conducted to measure differences between eco-labeled and conventional apparel. Data collection for the life cycle inventory was mainly carried out through literature review and former LCA studies. Input and output adjustments to the comparative E-LCA were made based on the Global Organic Textile Standard (GOTS) label requirements. This included, among other

requirements, that certain chemicals prohibited by GOTS were not used in the cotton cultivation and textile production.

During research the focus shifted from environmental to social issues and opportunities because there were already several rankings of eco-labels available. Hence this thesis is an attempt to recommend textile labels that improve stakeholders' livelihoods, based on the reduced social risk S-LCA results. This research explores how end consumers could support social developments through the purchase of eco and socially (sustainably) labeled products, specifically garments. Sustainable products might be more expensive but if the positive impacts are better managed and communicated, consumers may demand more of these products.

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Table of Contents

Acknowledgments	v
List of Tables	ix
List of Figures.....	xi
Definition of Terms	xii
I. Introduction	1
Research Significance and Objectives.....	2
Background.....	4
Impact of the Textile and Apparel Industry	4
Private Compliance Programs/Code of Conducts	6
As-Is Apparel Supply Chain Challenges	7
Consumer Behavior	9
Standards and Regulations	11
Voluntary Sustainable Standards (VSS).....	13
Ecological and Social Labels.....	14
Life Cycle Assessment in the Textile Industry.....	17
Research Questions, Hypotheses and Specific Aims	19
Specific Aims	19
II. Methods	21
Label Research and Evaluation	22

Life Cycle Assessment (LCA).....	27
E-LCA Goal and Scope	28
E-LCA Life Cycle Inventory	30
E-LCA Life Cycle Impact Assessment	41
S-LCA.....	43
S-LCA Goal and Scope	44
S-LCA Life Cycle Inventory	45
S-LCA Life Cycle Impact Assessment.....	50
III. Results	52
Label Assessment Results	52
Environmental Impact Assessment Results.....	54
Social Impact Assessment Results	60
IV. Discussion	65
Social Labels by Strength of Criteria	65
Label Criteria and Impact on LCA Results	67
Suggestions for Label Improvement	70
Suggestions for End Consumer	74
Research Limitations	76
Conclusions	77
Appendix 1 Input and Output Sets of E-LCA Life Cycle Inventory.....	80
Appendix 2 Label Evaluation by Subcategories	84

Appendix 3 Original SHDB Social Risks entries for the Indian Textile Sector	88
Appendix 4 Label Criteria and Evaluation of remaining Risks	93
References	99

List of Tables

Table 1	Stakeholder groups and subcategories.	23
Table 2	Electricity mix for India.	31
Table 3	Conventional cotton fiber inventory, ginned at farm, India.	32
Table 4	Final production stage inventory for fifteen cotton blouses.	34
Table 5	Transport dataset from India to the USA.	34
Table 6	Powder detergent inventory.	35
Table 7	Total use phase inventory for fifteen blouses.	36
Table 8	GOTS cotton fiber inventory, ginned at farm India.	39
Table 9	Textile refinement inventory GOTS.	40
Table 10	ReCiPe impact categories.	42
Table 11	SHDB process contribution for one cotton blouse (baseline).	47
Table 12	SHDB process contribution one cotton blouse (labeled).	48
Table 13	Social LCIA impact categories.	50
Table 14	Count of criteria per social theme and label assessed.	53
Table 15	LCIA results for fifteen cotton blouses.	57
Table 16	Impact assessment results >50% for low voltage electricity in India.	60
Table 17	Outputs for Indian cotton fibers, ginned at farm (baseline).	80
Table 18	Nitrogen emissions calculation for organic cotton cultivation.	81
Table 19	Outputs for Indian cotton fibers, ginned, at farm - GOTS.	81

Table 20	Inputs and outputs for cotton yarn production in India.	82
Table 21	Cotton weaving inputs and outputs.	82
Table 22	Cotton textile refinement inputs and outputs (baseline).....	83
Table 23	Remaining risk per label standard and subcategory.....	84
Table 24	Original SHDB social theme risk entry and changed entry.	88
Table 25	Label criteria compared to UNEP/SETAC analysis.....	94

List of Figures

Figure 1	Apparel supply chain example.....	7
Figure 2	Label comparison.....	16
Figure 3	System boundary for assessed cotton blouses.....	29
Figure 4	E-LCA relative results for 1000kg cotton fibers, ginned at farm.	55
Figure 5	E-LCA normalized results for 1000 kg cotton fibers, ginned at farm.	56
Figure 6	E-LCA relative results for fifteen cotton blouses... ..	58
Figure 7	E-LCA normalized results for fifteen blouses.. ..	59
Figure 8	S-LCA normalized potential risks for fifteen cotton blouses (baseline).....	61
Figure 9	S-LCA normalized potential risks by social themes (baseline).. ..	62
Figure 10	Process contribution by sector (baseline).....	63
Figure 11	S-LCA normalized potential risks for fifteen cotton blouses (labeled).. ..	63
Figure 12	S-LCA normalized potential risks by social themes (labeled).....	64

Definition of Terms

Eco-toxicity	The potential for biological, chemical or physical stressors to affect ecosystems
Eutrophication	Environmental impacts of excessively high levels of nutrients, degradable organic pollution, and waste heat. Pollutants lead to oxygen consumption
Living wage	Remuneration for a standard workweek that is sufficient for a decent standard of living. It should cover expenses for essential needs such as food, housing, education, health care, transport, clothing, retirement, and provision for unexpected events
Migrant worker	Worker that moved within their country or across borders to another country for employment. After living one year or more in the region they work they are not considered migrant anymore
Social hotspots	An occurring situation that may be a problem, risk or opportunity, in relation to a social theme of interest
Sustainable labels	Labels that consider both social and environmental aspects

Chapter I.

Introduction

There are several hundred ecological (eco) or social labels on the market. They address a variety of different social and environmental criteria, as well as different product groups and life cycle phases. For the textile and apparel industry, there are approximately 60 labels that could apply. The communicated information on them varies in specificity. It is not always clear to end consumers what the labels cover, what is left out, and which one should be preferred (International Organization for Standardization, 2012). Labels can focus on social or environmental criteria and on both (sustainable labels) (Koszevska, 2015). It is difficult for consumers to know the impact of labels along the textile product life cycle. Environmental life cycle assessment (E-LCA) has been used for years to assess the environmental impacts of textiles and some labels are based on E-LCA results. A couple of these labels have also social or socio-economic requirements. Newer than the E-LCA is the social life cycle assessment approach (S-LCA). One of the goals that can be pursued via S-LCA is to assess the social risks and opportunities for a product or service.

There are ongoing efforts to streamline existing environmental information especially for multi-criteria labels across industries (BIO Intelligence Service, 2012). In the textile industry, a cooperation between the Sustainable Apparel Coalition (SAC) and the European Commission aims at pilot testing the Product Environment Footprint (PEF)

information on labels (Sustainable Apparel Coalition, n.d.-a). The PEF belongs to the *Single Market for Green Products* initiative by the European Commission (European Commission, 2016). The *Single Market for Green Products* initiative focuses on environmental data, but does not include the social aspects of the product supply chain. When the new PEF is in place, the commission expects a reduction of methods and label proliferation, but this will not necessarily be enforceable (European Commission, 2013). There are still many other labels in use, and not all apparel companies have joined or are planning to join the SAC (Gunther, 2016).

Research Significance and Objectives

Globally, the textile industry represents an important employment sector, especially in the Asian region. More than 40 million workers were employed in the Asia-Pacific garment and footwear industry in 2014 alone (International Labour Organization, 2015). It is also a sector for which there are significant social and environmental impacts. Examples are high water and pesticide use in the cotton cultivation and long working hours and low pay in the production process (D'Ambrogio, 2014; WWF, 1999). With a growing world population, it is crucial to reduce the negative social and environmental impacts along the textile supply chain.

Despite the efforts to streamline environmental label information (as mentioned above), currently used labels will not be replaced overnight, if at all. These efforts will not have an impact on social labels. Therefore, it is of importance to better understand the differences and possible impacts of the currently existing labels, especially those with

social criteria. Such labels may still be in use on a significant amount of products for the foreseeable future.

This research was carried out to give end consumers a better understanding of the potential positive impacts that eco- and socially-labeled textile product purchases could have. Recommendations for end consumers on social labels were made based on this researcher's evaluation of the label criteria and corresponding S-LCA results. Label requirements were analyzed and evaluated based on the risk that social issues such as forced or child labor could still be occurring. Further suggestions for label improvement were made based on discovered social hotspots during the S-LCA and evaluation of criteria. The LCA results showed positive differences between regular and labeled products. This could encourage consumers to demand and purchase products with social or sustainable labels. If end consumers were more aware of the impacts of their purchases, demand of sustainable products would hopefully increase to further help minimize social and environmental impacts.

The objectives of my research were:

- To evaluate social labels used in the textile and apparel industry based on the criteria they address
- To demonstrate the impacts of sustainably labeled products through life cycle assessment (LCA)
- To address gaps and impacts of social labels in the textile and apparel industry

- To give suggestions on social labels, for improved consumer apparel purchase decisions

Background

The textile and apparel industry is one of the world's biggest polluters, and even when organic cotton is used to reduce pesticides in apparel products, the water use can still be tremendous (Sweeny, 2015). Earth is a closed system where energy enters and leaves but matter does not leave (Berger, 2001). We should therefore be aware of the products we create and leave behind. Discharges and disposals that are not readily biodegradable might come back to us through drinking water, food and air. For future generations to be able to live in a healthy sustainable world, the textile and apparel industry needs to transition its practices to drastically reduce its adverse social and environmental impacts while staying profitable. End consumers play an important role in increasing demand for sustainable products. Eco and social labels can help to identify such products. Life cycle assessment can quantify social and environmental impacts of products and help to verify sustainable claims. Holistic approaches are needed, which can be challenging in today's complex, global textile supply chains.

Impact of the Textile and Apparel Industry

The textile and apparel industry has immense impact on the environment and on its stakeholders, especially the workforce. Globally, more than 100 billion garments were produced in 2014 (Greenpeace, 2016b). Overall apparel consumption is on the rise; a growing world population and developing countries with increasing income will spend more money on clothing in the future. If 80% of emerging countries rise to Western

clothing consumption levels, CO₂ emissions are estimated to rise 77% by 2025 compared to 2015 (McKinsey&Company, 2016).

A trend that is known as fast-fashion practiced by retailers like Zara and H&M has increased the turnover rate of products in retail stores. Such retailers launch several fashion collections a year at affordable prices with the goal to inspire consumers to buy new clothing more frequently. This trend conflicts with the growing attention to sustainability in the textile supply chain. Fast fashion represents trendiness, while sustainability promotes long-lasting garments with low social and environmental impacts (Vadicherla & Saravanan, 2015).

Over the years many LCAs have shown the environmental impacts of textiles and garments. Companies like Patagonia are known for their efforts to create socially and environmentally conscious products and supply chain processes (The Good Trade, 2016). In recent years, there has been increasing awareness of the necessity to adopt sustainable practices in the textile industry. There are several initiatives within the textile and apparel industry, including the Higg Index developed by the SAC. The Higg Index measures and helps manage social and environmental impacts at the product, facility and brand level (Sustainable Apparel Coalition, n.d.-b). Some fast-fashion retailers are working on reducing negative environmental impacts. For example, H&M, the second biggest retailer in the world, offers an annual prize for new technologies to recycle clothes and has a jeans collection that contains recycled cotton (Reuters, 2015). Zara has a similar initiative called “Closing the Loop Project”, launched in 2015, which mainly focuses on collecting used clothes and donating them to charities, but also searches for efficient solutions to recycle textile products (Inditex, n.d.). The sports brand Adidas introduced DryDye in

2012, a method to dye polyester fabrics without water that saves 25 liters of water per shirt, and uses fewer chemicals and energy. Adidas has also partnered with Parley since 2015 to turn ocean plastics into high-performance sportswear among other innovative approaches (Adidas AG, n.d.).

Private Compliance Programs/Code of Conducts

Usually, apparel companies have their own supplier code of conduct. However, one global apparel brand often represents only a fraction of total production volume of a supplier; therefore, it is not clear if the brands have the power to effectively make suppliers adhere to their codes of conducts (Locke, 2013). Such compliance programs and investigations of work conditions, environmental impacts, health, and safety can vary extensively from company to company. It is also questionable how accurate audits and successful compliance programs really are (Locke, 2013). There has been extensive effort to streamline the auditing processes within the textile and apparel industry especially through the Higg Index. Factories that produce for several brands have to comply with the different codes of conduct. Hence, one tool such as the Higg Index, applied by many brands and retailers could decrease the auditing time and efforts. For social and labor issues, the Social & Labor Convergence Project (SLCP) will directly inform the Higg Factory Social & Labor Module. The SLCP aims at building the first industry-wide framework to assess social and labor conditions, including objective social and labor data that can be used to identify improvement opportunities (Social & Labor Convergence, 2017). Nevertheless, complexity might still be high if not all brands and retailers buying from the same supplier are members of the SAC and instead request compliance with their own code of conduct.

As-Is Apparel Supply Chain Challenges

A representation of a typical apparel supply chain is shown in Figure 1. The textile and apparel industry faces several environmental and social challenges along the supply chain.

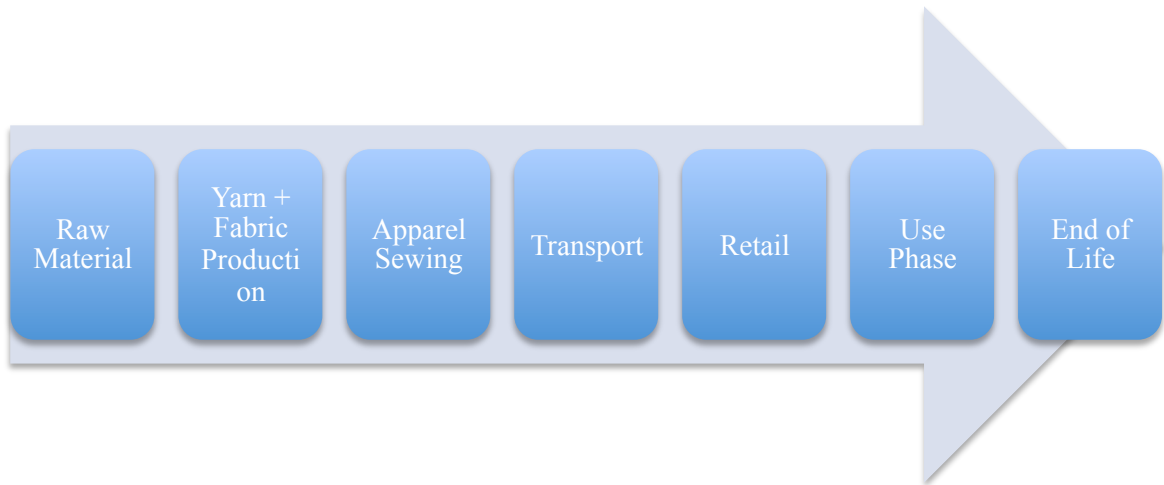


Figure 1. Apparel supply chain example. (Illustration source: author).

For example, at the raw material stage, cotton production has high water usage as well as insecticide and pesticide usage if not organically grown (Meyer, 2014; WWF, n.d.). During the manufacturing processes, a lot of water, chemicals and energy are used to spin fibers and produce fabrics (Greenpeace, 2016b). Chemicals can contaminate freshwater resources. Long transport distances can lead to high emissions and during the retail phase energy use can be high depending on the store conditions.

The use phase of garment can also have a sizable impact on the environment in regards to water and energy use depending on how often the item is washed and tumble-dried. Reuse of apparel prolongs the use cycle but one day these clothes are not wearable anymore. At end-of-life, garment often gets disposed in a landfill. 2014 US data shows

that out of 16.22 million U.S. short tons of municipal solid textile waste 64.5% ended up in a landfill, 19.4% were combusted with energy recovery and 16.2% of the textiles were reported as recycled (U.S. Environmental Protection Agency, 2016a). There was recently a celebrated breakthrough in Sweden regarding the recycling processes of cotton and other cellulosic textiles like viscose (Smith, 2016). Although there are initiatives to recycle textile products, it often cannot be done at an efficient rate, mainly due to the absence of effective recycling technology. This is especially true for mixed fibers garments (Muthu, Li, Hu, & Ze, 2012). For instance, clothes made out of 99% cotton and 1% spandex currently end up in a landfill due to the difficulties in separating the blended materials for recycling (Gould, 2015).

The textile and apparel industry is also confronted with many social issues. Most global apparel brands have outsourced the cost intensive parts of production activities to lower-cost countries. Working conditions are not always healthy and safe. Besides several factory fires, tragedies such as the 2013 Rana Plaza factory collapse in Bangladesh killed more than 1,100 workers. The building was built with substandard material and not according to building codes (Yardley, 2013). Furthermore, countries such as India have a high rate of gender inequality, which is reflected in literacy rates, education and workplace presence (Fair Wear Foundation, 2016). The female workforce in India dropped from 35% in 1990 to 27% in 2013 (United Nations Development Programme, 2015).

Not all countries acknowledge worker rights. India, for example, has not ratified fundamental ILO conventions C087 and C098, which cover “freedom of association and protection of the right to organize” and “right to organize and collective bargaining”

(International Labour Organization, 2017). India grants the right to freedom of association in trade unions through the constitution, but its trade union act, does not compulsory require employers to recognize trade unions (Fair Wear Foundation, 2016). India did sign the fundamental conventions C138 and C182 in 2017, which will enter into force in June 2018. These conventions relate to child protection and cover the minimum age for labor employment (in case of India 14 years) and the prohibition of the worst forms of child labor. This is not specifically related to the textile industry but the overall country. Nevertheless, working conditions affect every worker and the Indian textile industry employed about 45 million workers in 2016 (Fair Wear Foundation, 2016).

Other issues of concern in the textile and apparel industry are excessive working time and low wages. Workers often work long hours to make enough money to cover their basic needs. Initiatives work on implementing a living wage so that workers can make enough money in a 48-hour work week (Clean Clothes Campaign, n.d.). According to the Fairtrade Textile Standard, the reason why social conditions are not improving include, the lack of transparency in complex textile supply chains; audits that are predictable, too infrequent and too short; manipulated data, and failure to incorporate local knowledge (Fairtrade International, 2016b).

Consumer Behavior

Demand for eco-friendly apparel is growing. To keep this trend on the rise, it is important to demonstrate the positive impacts of eco- and socially-labeled apparel to end consumers. This way, end consumers can see the positive impact they make through their garment purchasing choices. As with purchasing power, the consumer is the leading force in deciding how often to wear, wash and maybe line dry instead of tumble dry the

clothes. Several LCA studies show that the use phase can have a tremendous impact on the environmental performance of a garment product during its life cycle (Muthu, 2015).

In 2012, the intent to buy eco-friendly women's casual wear and footwear had doubled in one year, from 21% to 47% and from 23% to 48% respectively (King, 2012). This was a survey result among 1000 health and eco-conscious consumers. According to 57% of consumers, labels or other information on apparel products are the top sources of sustainable product information; the consumers also indicated interest in an apparel sustainability index or rating to better compare shopping options and find sustainable items (RyanPartnershipChicago, 2012). This shows that consumers are looking mainly for information on the products themselves and therefore labeling is an important medium to communicate with the consumers.

Studies also show that when making purchasing decisions, consumers' action do not always align with their expressed intentions. In Germany and Sweden more than 30% of consumers (out of approximately 1000 persons surveyed per country), expressed that they try to think of the environment when they purchase clothing. However, when thinking of their last garment purchase, the most important drivers were price, quality and durability, and the least important ones were environmental and fair trade aspects (Austgulen, Stø, & Jatkar, 2013). The same study concludes that consumers do not exert enough pressure for eco-labeled clothing. Key challenges can be the fear of possible higher prices for socially- and environmentally-sound clothes versus a shrinking purchasing power of EU consumers and their behavior of buying as cheaply and as much as possible (Retail Forum for Sustainability, 2013). Consumers state that they do not

know enough about each eco-label to decide which one is more important or that they do not have the time or energy to search for eco-labeled clothes (Henninger, 2015).

Another reason for not demanding more sustainable clothing might be trust and credibility, as these are important criteria for consumers. They do not want to fall for claims in which the products or processes are not as environmentally friendly as promoted, and avoid “green-washing”. Hence, there might be reluctance to trust eco-friendly claims, if background information is missing. Certifications awarded by well-known third party organizations help to overcome mistrust. Research shows that young consumers tend to buy sustainable textiles, if they think they can make a positive impact and if they had good experience with such purchases in the past; provided that the product is comparable with non-labeled products in function and quality to fulfill consumer needs (Kang, Liu, & Kim, 2013). Depending on consumer preferences, one might prefer a single-criteria label that addresses an issue important to them. The same consumer may not be willing to pay more for a product with a label that addresses several impact issues (Wenban-Smith & UNFSS, 2013).

Standards and Regulations

Standards help to align eco-labeling and provide reliable information to consumers. The International Organization for Standardization (ISO) has developed different standards under the 14020 series to deal with environmental claims and declarations. ISO 14024:1999 refers to multi-criteria, life-cycle labels commonly known as “ecolabelling”. Such type I labels consider the whole product life cycle. Environmentally preferable products should be distinguishable but the environmental labeling should be voluntary. Type I labels are certified by a third party verification.

Another standard is the 14021:2016, which specifies requirements for self-declared claims including graphics and symbols. These are called type II environmental labeling (International Organization for Standardization, 2016) and they require “accurate and verifiable environmental claims that are not misleading” (International Organization for Standardization, 2012).

A third standard, type III environmental declarations are covered under ISO 14025 and can be described as: “quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040 series of standards, but not excluding additional environmental information” (International Organization for Standardization, 2012). This type gained importance in business-to-business commerce and is based on independently verified life cycle assessments. Type II and III labels were not considered in this study. The reason for not considering type II was the missing third party certification. Type III is more prominent between business-to-business, while my focus is on the end consumer. The attempts of certain labels to quantify impacts using life cycle assessment is part of this project, which would not have been necessary for type III labels as those are based on life cycle assessment already.

For guidance on social responsibility the ISO 26000:2010 was created. It provides guidance on principles and practices relating to social responsibility and how to turn them into effective action. Specifically, human rights, labor practices, the environment, fair operating practices, consumer issues, and community involvement and development are addressed. The standard is neither a labeling standard nor does it contain any requirements, therefore it cannot be certified (International Organization for Standardization, 2010).

Voluntary Sustainable Standards (VSS)

The significant proliferation of eco-labels across industries started in the end of the 1980's. A shift from type I labels and organic certification to other label types happened and newly created labels did not always fit the ISO classification (OECD Environment Directorate, 2016).

There are different kinds of sustainable standards:

- National
- International
- Private
- Performance standards
- Different objects of certification (product, production processes or the company/organization itself) (Wenban-Smith & UNFSS, 2013)

While there is no generic definition of sustainability standards, the United Nations Forum on Sustainability Standards (Wenban-Smith & UNFSS, 2013) states the following characteristics of standards as follows:

- Focus on a single aspect of sustainability (for example on greenhouse gas emissions or labour rights), or cover many aspects.
- Focus on the management within one sector (for example forest management, farming), or cover multiple sectors.
- Focus on a single phase of a product's life cycle (for example its energy or water consumption in use) or cover the full life cycle impacts of a product from production to disposal.
- Specify performance thresholds for particular characteristics, or may focus on achieving gradual improvement over time.
- Be associated with public claims or labels, or may be intended only to meet the internal sustainability objectives of a company or organization (p.17).

Ecological and Social Labels

To promote a product or service with an eco and/or social label, certain label specific criteria have to be fulfilled and, usually, a certification has to be obtained through a specific process. Criteria for eco-labels could include chemical and energy use or emissions, whereas criteria for social labels could be wages, working conditions and consumer safety. Such labels are often part of voluntary standards (OECD Environment Directorate, 2016). In this thesis I am focusing on the social requirements of consumer-facing social and sustainable labels that are attached or directly printed on apparel products. In this way, the sustainability claim information is available to the end consumers at the points of sale.

Eco, social and sustainable labels can address different parts of a product life cycle. Organic cotton certification, for example, controls raw material production. The Fair Wear Foundation focuses on social criteria addressing the cut, make, and trim phase of apparel production. There are around 60 eco and social labels, standards and certifications in the textile and apparel industry according to standardsmap.org and around 20 captured by ecolabelindex.com when searching for “textiles” or “textile” (Big Room Inc., 2016; International Trade Centre, 2015). Despite the new EU approach for the PEF, there are industry leaders that foresee that the number of eco-labels on the market will still rise and outperform legislation, meaning that their criteria request higher standards than laws require. Hence it is likely that sustainable brands will rely on eco and social labels to demonstrate their sustainability efforts (Ludvigsen & Zeuthen, 2016). Also, it is argued in the case of the EU Ecolabel that a label should not rely on LCA-indicators alone like the PEF but should also include more robust, verifiable and

enforceable criteria like thresholds relevant to production, use and end-of-life (Morales & Vuerich, 2014).

Despite confusion among consumers due to the proliferation of labels and claims, there was no negative impact on the uptake of labels but an increasing acceptance and commitment from manufacturers and retailers (Wenban-Smith & UNFSS, 2013). Eco-labels should contain impact metrics that are useful, feasible, and robust while a focus should be on the balance of information value and cost (Golden, Vermeer, Clemen, Noyes, & Akella, 2010). As stressed by behavioral scientists, eco-labels should not only provide accurate product information but also generate the intended meaning to the consumers, in order to create a relationship between what the label covers and what consumers do not want to lose (Grolleau, Ibanez, Mzoughi, & Teisl, 2016). The dolphin safe tuna label, for example, was successful in part because of the emotional relationship of Americans to dolphins (Grolleau et al., 2016; Körber, 1998). For social impacts, the relationship could be created through family members or ancestors that worked in factories and their knowledge of the importance of adequate working hours and frequent breaks.

There are several databases that provide information on eco and social labels (ecolabelingindex.com, standardsmap.org) and that describe the purpose of each label (Big Room Inc., 2016; International Trade Centre, 2015). However, the full information on ecolabelingindex.com is not accessible to consumers free of charge. On standardsmap.org, up to four (formerly eight) different labels can be compared, offering a good overview of the criteria addressed by the label (Figure 2). The requirements per

sustainability area seem to be a count of addressed criteria; this means there is no ranking or weighing of the attributes.

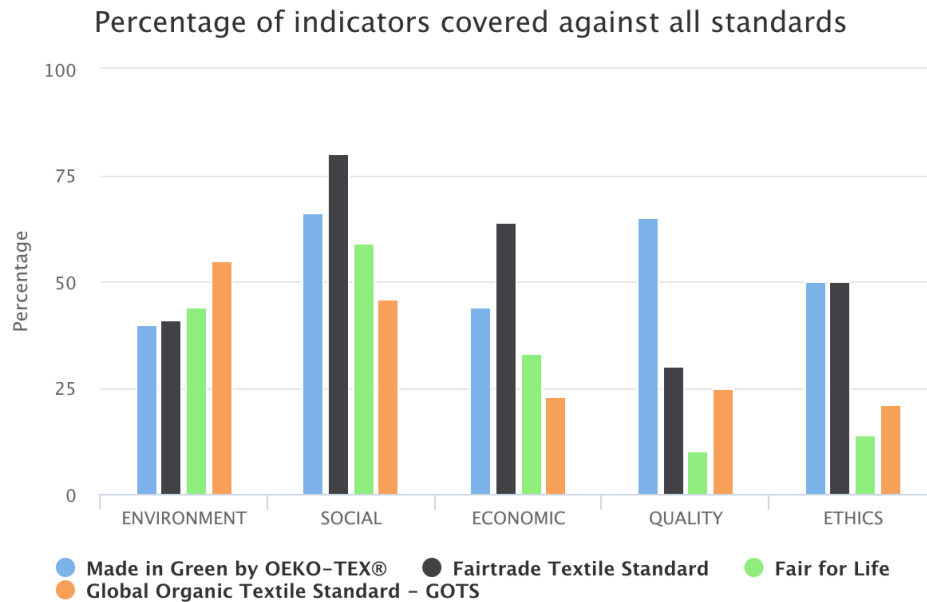


Figure 2. Label comparison. Example from standardsmap.org.

There has been research on improving eco-labels, for example, from Duke University. The resulting suggestions from that research were general with recommendations such as moving from single attributes to multi attributes (Golden, Vermeer, et al., 2010). No specific suggestions on each label regarding which attributes should be combined or considered for improvement could be found.

There has been research in Norway on the barriers to garment eco-label success; one of the findings from a stakeholder survey was that it is too difficult for consumers to identify effective eco-labels, since there are simply too many and they cover different aspects. The labeling initiatives should be better coordinated. Some labels used globally

would be preferred by global companies like H&M but other companies would prefer regional labels that are already well-known by consumers (Austgulen et al., 2013). There has also been research pointing out that there is not enough demand by consumers to produce and promote sustainable textiles, and that the volume of labels is confusing; hence, the market share of sustainable textiles is still smaller than it could be (Retail Forum for Sustainability, 2013).

Giving consumers a better overview of the specifics behind the labels, and which ones have the strongest criteria, could help steer their purchasing decision in a more impactful and sustainable direction. If the significance and meaning of the eco and social labels is not clear, it will likely not play an important role in decision-making. Brands might be able to reduce their own auditing efforts if they buy from factories that process certified materials, such as apparel made from fair trade (organic) cotton. Harmonization of label criteria could lead to a better label comparability and/or a later merger of them, could help to ease the certification process for third party auditors (Wenban-Smith & UNFSS, 2013). A holistic approach over the entire supply chain is important to avoid unintended impacts. Unintended impacts happened, for example, with the subsidy of ethanol as a fuel which led to increased water use, higher corn prices and potential loss of biodiversity due to intensified corn monoculture (Golden, Dooley, et al., 2010).

Life Cycle Assessment in the Textile Industry

E-LCAs are a commonly used method to measure the impacts of textiles. They can identify the overall environmental burden of a material or garment and the result can be used to detect improvement areas. E-LCAs can also depict consequences of changing inputs/materials and hereby help to identify the preferred material option (Baumann &

Tillman, 2004). Several LCAs exist for raw material production (cradle-to-gate) such as cotton and organic cotton; others focus on the whole life cycle (cradle-to-grave). The SAC, for example, uses its material sustainability index (MSI) to provide life cycle assessment based raw material information to product design teams (Sustainable Apparel Coalition, 2016).

Levi Strauss & Co conducted their first life cycle assessments for a core set of apparel products in 2007 that covered the impacts over the entire life cycle (Levi Strauss & Co., 2015). Their study showed that high energy and water usage was predominant in cotton cultivation and consumer care. Other LCA studies confirm the impact of washing temperatures, class of washing machines, drying times, temperatures and frequencies as well as ironing times and temperatures (Muthu, 2015). In general, as with all data, the more detailed the data are, the more exact are the results. Variances among results can be high. Former research showed that the thickness of textile threads is important for an E-LCA to be precise (Van Der Velden, Patel, & Vogtländer, 2014).

Social LCAs are evolving in the textile sector. Reducing social impacts is gaining importance in the sector and first S-LCAs conducted with input/output modeling exist. Social hotspots with at risk worker hours can be identified and used as a basis for improvement. A case study in the Italian textile industry identified among others child labor as a very important problem in Mongolia (Lenzo, Traverso, Salomone, & Ioppolo, 2017). Another S-LCA conducted for the Swedish textile sector found that low wage was the most significant issue (Roos, Zamani, Sandin, Peters, & Svanström, 2016).

Research Questions, Hypotheses and Specific Aims

These challenges lead to a focus on the following research questions:

1. Can social labels be ranked by the strength of their criteria?
2. Can LCAs help demonstrate and support the underlying meaning and impact of ecologically- and socially-labeled apparel to end consumers?
3. What is the effect of social label criteria on S-LCA results?
4. Can a S-LCA confirm the evaluated strength of social labels?
5. How could social and eco-labels in the textile industry be improved?
6. Could recommendations to consumers be made based on the S-LCA results?

I hypothesize that social labels could be ranked by the strength of their criteria and that conducting a S-LCA will support the evaluated results. The strength of the criteria is defined for this thesis as a decrease of the potential social risks along the apparel supply chain when label requirements are applied. I further hypothesize that social and environmental LCAs can demonstrate the positive impact of social and eco-labels and could be used as a driver to increase demand for socially/eco-labeled products.

Specific Aims

To address these questions and hypothesis, I performed several steps:

1. Researched the most relevant social/sustainable labels used in the textile and apparel industry to develop a matrix showing the criteria addressed
2. Ranked labels by the most comprehensive and effective criteria
3. Collected data for a non-labeled apparel and measured environmental and social impact through LCA.
4. Adjusted LCAs to criteria that comply with a strong eco and social label.

5. Compared results and suggested improvements for stages/criteria not covered through labels.
6. Made suggestions to consumers why to buy eco- and socially-labeled apparel

Chapter II.

Methods

My overall research design evaluated eco, social and sustainable labels currently used in the textile and apparel industry and identified their impact through life cycle assessment. Based on the evaluated label criteria a suggestion of which ones to prefer was proposed. The framework used to evaluate the social label criteria was the UNEP/SETAC Guidelines for S-LCA and the methodological sheets for subcategories (UNEP & SETAC, 2009, 2013). For the environmental criteria, it was decided to use the most robust globally used label, which is according to a former ranking done by Greenpeace and Eco Top Ten the Global Organic Textile Standard (GOTS)(EcoTopTen, 2013; Greenpeace, 2016a). Overall the IVN Best label was declared the strongest, but as GOTS is used globally it was decided to use GOTS. It should also be noted that GOTS covers only textile products made from at least 70% certified organic natural fibers (Global Standard gGmbH, 2017).

The impact of eco and social labels was demonstrated with measurement and comparison of a non-labeled product versus a labeled product through Life Cycle Assessment (LCA). To conduct the E-LCAs, openLCA software version 1.6.1 was used with the ecoinvent database version 2.2. Several E-LCAs and other literature were consulted for different textile processing and inventory information needed. SimaPro

software with the Social Hotspots Database (SHDB) was used to run the S-LCAs. S-LCA is relatively new compared to E-LCA and few S-LCAs for textile were available.

Label Research and Evaluation

First, the most relevant textile and apparel labels were determined through a revision based on the information provided by standardsmap.org and ecolabelindex.com. Data about the labels were collected from these two sites and from the label websites and/or issuing organizations. Label standards that included the criteria to be fulfilled for certification and if applicable, guiding documents were downloaded from the respective websites. The criteria used included: addressed life cycle stages, multi-criteria addressed, social and environmental aspects, stakeholder involvement, and region of use. The data were put into an Excel matrix and was analyzed in regards to which social criteria were covered and which not. Based on the first analysis it was decided to include the following label standards for in-depth evaluation: Fairtrade Textile Standard, Cradle to Cradle, Fair Wear Foundation, GOTS, STeP, and Fair for Life. Labels were chosen that had a social focus or at least significant social criteria, when used globally or at least in major apparel selling regions such as North America and Europe. Fairtrade Textile Standard was chosen as an example specific for the textile industry, Cradle to Cradle as a life cycle assessment example. GOTS was chosen as it has strong environmental criteria, but also has social requirements. Fair Wear Foundation was chosen as a purely social standard for a specific supply chain stage (cut, make, trim). STeP was chosen as another textile specific mainly socially focused label that is combined with the environmentally focused Standard100 by OEKO-TEX certification in the Made in Green label. Fair for Life is another Fairtrade

example used in the textile industry but not exclusively. The elected labels are third-party certified.

Table 1. Stakeholder groups and subcategories.

Stakeholder Group	Subcategories
Stakeholder "worker"	Freedom of association and collective bargaining
	Child labor
	Fair salary
	Working hours
	Forced labor
	Equal opportunities/discrimination
	Health and safety
	Social benefits/social security
Stakeholder "consumer"	Health and safety
	Feedback mechanism
	Consumer privacy
	Transparency
	End of life responsibility
Stakeholder "local community"	Access to material resources
	Access to immaterial resources
	Delocalization and migration
	Cultural heritage
	Safe and healthy living conditions
	Respect of indigenous rights
	Community engagement
	Local employment
	Secure living conditions
Stakeholder "society"	Public commitments to sustainability issues
	Contribution to economic development
	Prevention and mitigation of armed conflicts
	Technology development
	Corruption
Value chain actors* (not including consumers)	Fair competition
	Promoting social responsibility
	Supplier relationships
	Respect of intellectual property rights

(UNEP/SETAC, 2009).

The methodological sheets used as a reference during label evaluation, support users in the application of S-LCA. They do not present a complete set of criteria that must be met, and can be seen as work in progress, that will evolve with more practical experience in S-LCA (UNEP & SETAC, 2013). As not all label requirements could be matched with criteria from the methodological sheets, new relevant criteria were added to the subcategories. These new criteria were also considered when carrying out the S-LCA to assess risk levels. Stakeholder groups considered were workers, consumer, local community, society, and value chain actors. Assessed subcategories for the stakeholder groups can be seen in Table 1.

Some assumptions regarding the labels had to be made. First, it is assumed that the criteria required for the label certification are fulfilled. More specifically, if the weekly working hours should not exceed 48 hours than it is assumed for this paper that it is adhered to this requirement. Second, some of the labels have different levels of certification and when possible, the midlevel was chosen, for example, Cradle to Cradle has five levels of certification, starting with basic, bronze, silver, gold, and platinum. Therefore, criteria needed for the silver level certification were evaluated. Which label level, company size or other decisions were made can be seen in appendix 4. Furthermore, some standards include criteria that should be met after a few years to give a direction for further development. Such requirements were evaluated as not having significant impact. For criteria with no specific compliance date it was assumed that it had to be met at certification audit date. And last, sometimes set requirements referred also to specific ILO conventions. For such cases the ILO convention was read and used

for clarification but the written requirement from the label standard was taken as basis for evaluation.

Each label standard was assigned a different color. Newly added criteria were entered in different colors matching the label color it originated from. An excerpt of the Excel sheet with the criteria and evaluation per label can be found in appendix 4.

Several of the criteria require complying with the national legislation. That might seem like a reasonable solution for label standards with global application. However, this requirement alone bears the risk that the country national laws be weaker than international instruments, and might not be considered safe under US or European law. For example, wastewater treatment, the GOTS and STeP add their own thresholds that need to be followed in addition to the national legislation. The Fairtrade Textile Standard requires one adhere to national legislation or regional and sector-specific practices if these set higher requirements than Fairtrade (Fairtrade International, 2016a). The label evaluation was solely based on label requirements and neither legislation nor regional or sector-specific customs were researched when a label referred to them. Criteria with only reference to national legislation are considered as having no impact.

The strength of social label criteria were often based on general definitions, an example being that living wage is most likely higher than minimum wage if not the same amount (Society for Human Resource Management, 2012). In other cases the strength was ranked higher when in addition to the criterion, supporting documentation was required, for example, in the case of wage payment. Was there written evidence that the workers were paid?

The Cradle to Cradle silver label was not ranked, because it requires a self-audit on which results, improvement strategies have to be developed. This approach is fitted to each company and has few specific requirements; therefore, it was not suitable to be generally analyzed. Nevertheless, the label was analyzed based on questions from the B corporation impact assessment self-audit tool as requested by the Cradle to Cradle Standard.

To determine social criteria that were not covered by the baseline blouse assessment, S-LCA results were considered to see where and which social issue could occur in the textile and apparel sector. Also, for the evaluation of life cycle stages the general processes most apparel products flow through such as raw material production, textile production and processing, apparel production, and transport were considered. Retail, product use and end-of-life phase were briefly researched for social impacts and opportunities. Those life cycle stages plus the design phase were not available in the SHDB and were also not seen as being critical.

After evaluation the attempt to rank the social labels was done by the range of social issues covered and by the depth and detail of the requirements. Sometimes it was challenging to decide if a narrow requirement would be stronger than a broad request. It was attempted to evaluate the level of the remaining risk. Assessing the remaining risk after criteria fulfillment per stakeholder category led to another Excel file that was used to make an overall assessment of the total label criteria strength. The results by lowest risk count can be seen in the results section in Table 14. The count of the criteria in the label standards does not necessarily equal the count of assessed requirements as sometimes criteria were split or combined depending on the significance and information

provided. Additionally, in some cases not all label standard requirements were taken into account. This was mainly due to non-applicability, for example, when the label had extensive environmental requirements, which were only considered on a basic level for this paper.

This Excel sheet was then used as a base of information for the second S-LCA that presented social risks and opportunities for a socially-labeled apparel product. Explanations to changes made in the SHDB can be found in the S-LCA Life Cycle Inventory section of this paper and the Excel sheet can be found in appendix 3.

Life Cycle Assessment (LCA)

Environmental LCA (E-LCA) is used to quantify environmental impacts of a product or service during its lifetime and social LCA (S-LCA) is used to evaluate social impacts on affected stakeholder groups (Benoît Norris, Norris, & Aulision-Cavan, 2015). To measure the environmental impact of cotton blouses, an E-LCA was performed and to measure the social impacts and opportunities, an S-LCA was conducted. Life Cycle Costing (LCC) to complete the three pillars of sustainability was not carried out due to time constraints as well as the social focus of this paper.

LCA studies consist of four phases. First, goal and scope are defined, including the system boundaries. Second, the life cycle inventory (LCI) data with all relevant inputs and outputs for the assessed product or service are collected. Then the life cycle impact assessment (LCIA) takes place, and the final phase is the interpretation of the results in order to suggest recommendations or support decision-making (International Organization for Standardization, 2006). It is important and recommended to include all

life cycle stages and their economic, social, and environmental impacts to avoid burden shifting from one area to another and not reducing the overall negative impact (United Nations Environment Programme, 2017). There is a risk of double counting environmental impacts when using E-LCA and S-LCA; this was taken into account in the discussion section of this paper (UNEP & SETAC, 2009).

E-LCA Goal and Scope

The goal of this study was to compare the whole life cycle of blouses made from conventional cotton and without specific environmental requirements to GOTS labeled ones. Blouses made from conventional cotton served as the baseline case. The cotton cultivation and production was assumed to happen in India. India was chosen as it is the second biggest cotton producer (Bremen Cotton Exchange, 2017) and with 66.9% share, the biggest organic cotton producer in the world (Textile Exchange, 2016). Furthermore, the Maharashtra region was selected, as both conventional and organic cotton is cultivated there. The baseline LCA results were compared to a second E-LCA where the inventory data had been adjusted according to measures based on GOTS eco-label criteria, version 5.0.

The scope of this LCA project was a cradle-to-grave study and included stages of cotton blouses from raw material production till end-of-life. The functional unit was fifteen woven blouses (size S) made in India out of 100% cotton, which weigh in total 2 kg and are used for 2 seasons (1 year), worn 60 times each in total and washed 30 times without tumble drying. The blouses do not have a print or buttons and fulfill the function of clothing a woman, not necessarily to keep her specifically warm or be of enduring lifetime, the blouse is seen as a fashion item to present a certain lifestyle.

The system boundary for this study with the assessed life cycle stages can be found in Figure 3 with a rough overview of inputs and outputs. For the baseline case, pesticide input was considered in the cotton cultivation. Not considered for inputs were production of capital goods, human labor, retail phase, and packaging.

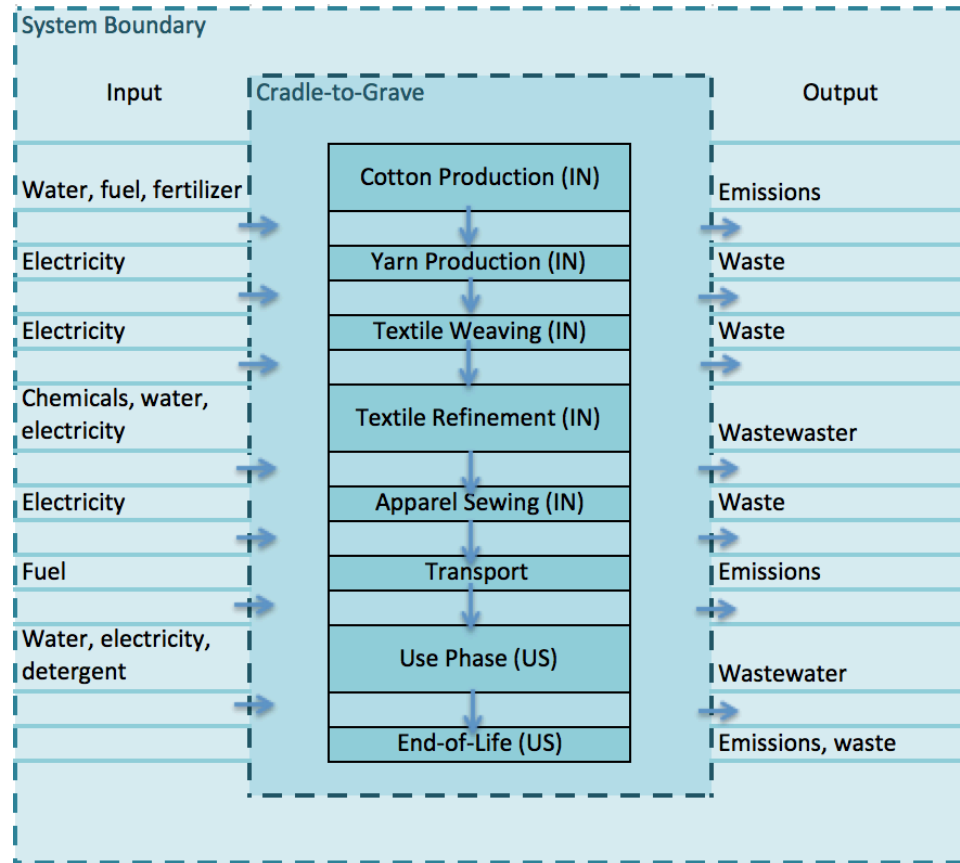


Figure 3. System boundary for assessed cotton blouses. Main input and outputs are shown for a cradle-to-grave garments life cycle. (Illustration source: author).

The retail storage and sale phase was omitted, as this was not feasible to model due to missing and high variability of in-store data. Also, the comparison case with an eco-labeled garment does not consider the criteria related to that phase. It is assumed that the blouses were directly shipped to the end customer. The impact analysis was carried

out without cut-off, which means all material and energy flow data were considered even when they had a very small impact contribution. To have no cut-off was decided after a first comparison of the two cases, as there was a significant difference in the outcome when setting a cut-off at 1%.

E-LCA Life Cycle Inventory

During the inventory phase, data for all environmentally relevant flows are collected and the environmental loads are calculated in relation to the functional unit (Baumann & Tillman, 2004). Input and output data for the relevant blouse production processes from cradle-to-grave were mainly collected through literature review or calculated based on former E-LCAs. For accurate results, it is essential for LCAs to have detailed and spatial data. The textile industry has energy intensive processes, therefore the electricity mix for India was modeled based on current electricity mix data for India that was taken from an energy outlook for 2015 (International Energy Agency, 2015; Steinberger, Friot, Jolliet, & Erkman, 2009). Main power generation was from coal (60%), hydropower (15%), wind and natural gas (both at 8%), and smaller fractions came from oil (3%), nuclear (2%) and solar (1%). 3% electricity coming from other undefined sources was assumed to be generated from biogas. The coal ratio was divided into lignite and hard coal according to coal statistics of India (Coal Controller's Organisation, 2017), leading to 56.15% hard coal and 3.85% lignite powering. The complete electricity mix inventory is shown in Table 2.

Table 2. Electricity mix for India.

Flow	Category	Amount	Unit
F ₂ electricity, oil, at power plant - CZ	oil/power plants	0.03000	kWh
F ₂ electricity, hard coal, at power plant - CN	hard coal/power plants	0.56148	kWh
F ₂ electricity, nuclear, at power plant pressure wat...	nuclear power/power plants	0.02000	kWh
F ₂ electricity, natural gas, at power plant - CENTREL	natural gas/power plants	0.08000	kWh
F ₂ electricity, production mix photovoltaic, at plant...	photovoltaic/power plants	0.01000	kWh
F ₂ electricity, hydropower, at reservoir power plant...	hydro power/power plants	0.15000	kWh
F ₂ electricity, at cogen with biogas engine, allocati...	biomass/cogeneration	0.03000	kWh
F ₂ electricity, lignite, at power plant - CZ	lignite/power plants	0.03851	kWh
F ₂ electricity, at wind power plant 600kW - CH	wind power/power plants	0.08000	kWh

(International Energy Agency, 2015).

For cotton production, yarn manufacturing, weaving, and refinement of textiles, the process data entries from the ecoinvent database were used as a basis but adjusted to India specific data where possible. Textile refinement contains bleaching, washing, dyeing and drying processes (Kujanpää & Nors, 2014). The ecoinvent datasets consider emissions to air, soil or water, land occupation or transformation, and extraction of resources where applicable (Ecoinvent, n.d.). Screenshots of the input and output sets can be found in Appendix 1.

Cotton generates seeds and fibers as co-products; it was assumed that there is no difference in ratio between cotton fiber and seed cotton depending on the country. Hence the economic allocation for cotton (organic and conventional) was assumed for India to be the same as for US cotton with allocation factor 87.2% to fiber according to the ecoinvent database. The cotton yield data for the China ecoinvent dataset was used for India with 1,299 kg of cotton fiber and 2,299 kg of seed cotton per hectare as this was similar to outcomes of a yield study on Indian seed cotton with 2,157 kg per hectare (ha)

(Forster et al., 2013). Gin waste was considered as no burden to the system as in other studies, and irrigation input data were adjusted in ecoinvent according to a Maharashtra study with 500m³/ha (Textile Exchange, 2014). The ginned cotton fiber inventory for the Indian baseline includes tillage, hoeing, sowing, fertilizer and pesticide use, irrigating, water and energy use (Table 3). Outputs related to the inventory are shown in Appendix 1.

Table 3. Conventional cotton fiber inventory, ginned at farm, India.

Inputs			
Flow	Category	Amount	Unit
F hoeing - CH	agricultural means of prod...	0.00077	ha
F tillage, ploughing - CH	agricultural means of prod...	0.00077	ha
F fertilising, by broadcaster - CH	agricultural means of prod...	0.00232	ha
F sowing - CH	agricultural means of prod...	0.00077	ha
F tillage, currying, by weeder - CH	agricultural means of prod...	0.00155	ha
F application of plant protection products, by field...	agricultural means of prod...	0.01545	ha
F tillage, harrowing, by spring tine harrow - CH	agricultural means of prod...	0.00077	ha
F baling - CH	agricultural means of prod...	0.00500	Item(s)
F packaging box production unit - RER	paper & cardboard/cardbo...	3.40000E-10	Item(s)
F pesticide unspecified, at regional storehouse - RER	agricultural means of prod...	0.00232	kg
F triple superphosphate, as P2O5, at regional stor...	agricultural means of prod...	0.07727	kg
F glyphosate, at regional storehouse - RER	agricultural means of prod...	0.00232	kg
F chemicals organic, at plant - GLO	chemicals/organics	1.93180E-5	kg
F pyrethroid-compounds, at regional storehouse - RER	agricultural means of prod...	0.00047	kg
F potassium chloride, as K2O, at regional storeho...	agricultural means of prod...	0.12363	kg
F parathion, at regional storehouse - RER	agricultural means of prod...	0.00047	kg
F organophosphorus-compounds, at regional stor...	agricultural means of prod...	0.00047	kg
F ammonia, liquid, at regional storehouse - RER	chemicals/inorganics	0.10045	kg
F ammonium nitrate, as N, at regional storehouse...	agricultural means of prod...	0.05023	kg
F urea, as N, at regional storehouse - RER	chemicals/organics	0.05023	kg
F Carbon dioxide, in air	Resource/in air	1.65000	kg
F cotton seed, at regional storehouse - US	agricultural means of prod...	0.01640	kg
F electricity, low voltage, production UCTE, at gri...	electricity/production mix	0.54306	kWh
F Transformation, to arable	Resource/land	7.72730	m2
F Transformation, from arable	Resource/land	7.72730	m2
F Occupation, arable	Resource/land	7.72730	m2*a
F Water, well, in ground	Resource/in water	5.04350	m3
F Water, river	Resource/in water	1.77200	m3
F irrigating - US	agricultural means of prod...	0.38500	m3
F Energy, gross calorific value, in biomass	Resource/biotic	18.56300	MJ
F transport, lorry 3.5-16t, fleet average - RER	transport systems/road	0.24285	t*km
F operation, van < 3,5t - RER	transport systems/road	0.01507	v*km






Adapted from China cotton fiber inventory data in ecoinvent (Ecoinvent, 2010).

Process data that were not available in ecoinvent were mainly collected through literature review, though some data stemmed from independent measurements such as weight of the blouses, and sizes for packaging. At the cutting stage, a 13% textile loss was considered as stated by Ensait (Beton et al., 2014). The loss was represented by the dataset “disposal, paper, 11.2% water, to sanitary landfill”, which was adapted from the original ecoinvent dataset for cotton yarn. Short fibers as a possible by-product of fabric production were not considered as done in the ecoinvent dataset.

Highly variable energy consumption data were found for the cutting and sewing stage, so it was decided to use available data for a cotton t-shirt which added up to 1.962 MJ or 0.545 kWh (Sule, 2012). Packaging was included and it was assumed that each blouse was packed separately in low-density polyethylene film (LDPE) and all fifteen blouses together in one corrugated board box. Measures taken were 12"X 13.5"X 0.03" and width for the cardboard box was measured as 3". For the LDPE film, 9.72 cubic inches equaled 145.8 cubic inches for the fifteen blouses, which was first divided by 46,656 to convert to 0.003125 cubic yard. The weight of loose LDPE was 35 lbs. per cubic yard (U.S. Environmental Protection Agency, 2016b). 35 lbs. equal 15.8757 kg. For the ecoinvent dataset, the weight was needed in kg; hence 0.003125 cubic yard was multiplied by 15.8757 kg to receive the weight of 0.04961 kg. For the volume to weight conversion for one packaging box, the weight of 106 lbs. per cubic yard for old corrugated paper containers was used (U.S. Environmental Protection Agency, 2016b). The calculation was done as described above except that for the box sides 2.42 cubic inches were added and for the bottom and top of the box, 2.16 cubic inches were added.




The box weight was calculated as 0.01475 kg. Table 4 shows the inventory for the cutting and sewing stage to produce and pack the blouses.

Table 4. Final production stage inventory for fifteen cotton blouses.

Flow	Category	Amount	Unit
F ₂ electricity, low voltage, at grid - IN		8.17500	 kWh
F ₂ disposal, paper, 11.2% water, to san...	waste management/...	0.26000	 kg
F ₂ textile refined, cotton, at plant - IN		2.26000	 kg
F ₂ packaging film, LDPE, at plant - RER	plastics/processing	0.04961	 kg
F ₂ packaging, corrugated board, mixed...	paper & cardboard/...	0.01475	 kg

For transportation from production plant in India (Nagpur, Maharashtra) to the USA (Boston, MA), data were modeled for the typical truck-sea-truck transportation route according to distances from the EcoTransIT website. The truck route within India was 854.6 km, the ocean-shipping route was 14,788.59 km, and it was 10 km from the port in Boston to the end consumer in downtown Boston (Table 5).

Table 5. Transport dataset from India to the USA.

Flow	Category	Amount	Unit
F ₂ transport, lorry 3.5-7.5t, EURO4 - RER	transport syste...	1*10	 kg*km
F ₂ transport, transoceanic freight ship - OCE	transport syste...	1*14789	 kg*km
F ₂ transport, lorry >32t, EURO3 - RER	transport syste...	1*869	 kg*km

For the transport within India a truck >32 tons was used, and for the transport within the USA a smaller truck was used.

For the consumer use phase, thirty washes and an expected lifetime of two seasons were assumed, which was similar to data of a former LCA that set 25 washes and one year lifetime (Beton et al., 2014). Detergent was used but no fabric softener or stain

remover. The average detergent amount of 82.75 grams was used as given by Schenck (Cotton Incorporated, 2017). The detergent itself was modeled based on an adaption for 1 kg powder detergent in ecoinvent (Table 6) based on Saouter and van Hof (Beton et al., 2014). Packaging for the detergent was not modeled. This inventory was not seen as critical, as it was the same for both assessed cases.

Table 6. Powder detergent inventory.

Flow	Category	Amount	Unit
F ₁₀ ethoxylated alcohols (AE11), palm oil, at plant - RER	washing agents/tensides	0.02100	kg
F ₁₀ ethoxylated alcohols (AE7), coconut oil, at plant - RER	washing agents/tensides	0.04300	kg
F ₁₀ alkylbenzene sulfonate, linear, petrochemical, at plant - RER	washing agents/tensides	0.08300	kg
F ₁₀ acetic acid, 98% in H2O, at plant - RER	chemicals/organics	0.05500	kg
F ₁₀ layered sodium silicate, SKS-6, powder, at plant - RER	washing agents/builders	0.03200	kg
F ₁₀ zeolite, powder, at plant - RER	washing agents/builders	0.21500	kg
F ₁₀ sodium percarbonate, powder, at plant - RER	washing agents/bleaches	0.18100	kg
F ₁₀ sodium perborate, monohydrate, powder, at plant - RER	washing agents/bleaches	0.09300	kg
F ₁₀ sodium perborate, tetrahydrate, powder, at plant - RER	washing agents/bleaches	0.12200	kg
F ₁₀ sodium sulphate, powder, production mix, at plant - RER	chemicals/inorganics	0.00400	kg
F ₁₀ water, completely softened, at plant - RER	water supply/production	0.15100	kg

(Beton et al., 2014).

Energy and water usage during the use phase were based on the Energy Star washing machine Samsung WF45M5500A (Samsung, 2017). The US electricity mix dataset in ecoinvent 2.2 was from 2004; therefore an updated one was modeled for Massachusetts, as natural gas is currently the leading energy source and not hard coal anymore (U.S. Energy Information Administration, 2017). The washing machine uses 0.83 kWh per load washed in cold water according to the user manual. The water usage was estimated from the Energy Star website where the annual water use is stated as 3,850 gallons based on 295 loads, which lead to 13.05 gallons per load respectively 49.4 liters (Energy Star, 2016). Calculations were done with assumption of 65% load capacity based

on former LCAs (Beton et al., 2014). 11.97 wash loads are needed to wash 60 kg of clothes (2kg times 30 washes). It was assumed that the blouses were washed with other garments together. Hence no rounding up to an even number was done in regards to the wash loads. The 4.5 cubic feet washing machine has a load capacity of approximately 17 lbs. or 7.711 kg and 65% hereof are 11.05 lbs. or 5.012 kg. 60 kg divided by 5.012 lead to 11.97 loads. Total kWh usage for all washes was 9.9358, total water usage 591.363 liters, or respectively the same amount in kg, and total amount of detergent used was 0.9906 kg. The inventory in OpenLCA was modeled with unrounded numbers (Table 7). The use phase modeling in this paper included three “best case” scenarios: washing at cold temperature, using an Energy Star appliance, and air-drying (Cotton Incorporated, 2012). Manufacturing of the washing machine was not taken into consideration.

Table 7. Total use phase inventory for fifteen blouses.

Flow	Category	Amount	Unit
F _{blouses} at destination - (IN) US		2.00000	kg
F _{tap water} , at user - RER	water supply/pro...	591.36299	kg
F _{electricity} , low voltage, at grid MA US		9.93586	kWh
F _{detergent} - Saouter and van Hof		0.99059	kg

Outputs

Flow	Category	Amount	Unit
F _{use phase blouses} - (IN) US		2.00000	kg
F _{Detergents} , unspecified	Emission to water/unspecified	0.99059	kg

For end-of-life, disposal of 64.5% of the blouses at a landfill, recycling of 16.2% of the blouses and incineration of 19.4% of them were attempted to be modeled based on the above-mentioned EPA report. As there was no textile recycling process available inecoinvent, it was decided to proportionally increase the ratio of landfill to 76.88% and incineration to 23.12%.

The comparative E-LCA was done with data according to criteria from the GOTS label based on blouses made out of 100% organic cotton. For processes where the GOTS label does not have requirements such as use phase, the same process data as for the baseline case was used. GOTS refers to organic fiber production that meets any standard approved in the International Federation of Organic Agriculture Movements (IFOAM) Family of Standards. For this thesis, the “IFOAM Standard for Organic Production and Processing” version 2.0 was used. GOTS certified products contain organic cotton, and since organic cotton yield is often lower than conventional yield, the yield was set at 82% of the conventional cotton production (Beton et al., 2014). Land use for the ecoinvent model was adjusted accordingly.

There is no chemical pesticide use allowed, in this case, it was assumed that the pest was controlled by appropriate choice of cotton species and variety as well as appropriate crop rotation and local pest predators that were not modeled in this E-LCA. Poultry manure as organic fertilizers was applied for organic cotton cultivation instead of mineral fertilizer. Average nutrient suggestions rank between 100 - 120 kg/ha for nitrogen, 50 – 60 kg/ha for phosphorous and 40 -50 kg/ha for potassium; fertilizer dosage depends on the soil composition, cotton yield variety and previous crop (Eyhorn, Ratter, & Ramakrishnan, 2005). The manure amount applied was set at 13.79 t per hectare to not

exceed the suggested 120 kg/ha nitrogen, almost five tons less than done by smallholder farmers in a former study in the Indian Madhya Pradesh region (Forster et al., 2013). This was quite high compared to a global average organic cotton studies, where on average 44 kg of nitrogen were applied and for a specific case in the Maharashtra region even less (Textile Exchange, 2014). There was a high variability of applied fertilizer depending on the region. Total nitrogen application through fertilizer accounted for 120 kg per hectare in the first comparative assessment in this study.

Organic farming methods conserve and minimize loss of topsoil through minimal tillage, contour plowing, and other practices (International Federation of Organic Agriculture Movements, 2014). To reflect this in the E-LCA tillage activities in the originalecoinvent data were reduced. Specifically, “tillage, ploughing” and “tillage, currying” were removed from the dataset. Usage of genetically engineered organisms and nanomaterial was prohibited. Table 8 illustrates an inventory for an attempted organic cotton cultivation that would be acceptable by GOTS standard.

Table 8. GOTS cotton fiber inventory, ginned at farm India.

Inputs			
Flow	Category	Amount	Unit
F hoeing - CH	agricultural means of producti...	0.00094	ha
F fertilising, by broadcaster - CH	agricultural means of producti...	0.00282	ha
F sowing - CH	agricultural means of producti...	0.00094	ha
F tillage, harrowing, by spring tine harrow - CH	agricultural means of producti...	0.00094	ha
F baling - CH	agricultural means of producti...	0.00500	Item(s)
F packaging box production unit - RER	paper & cardboard/cardboard...	3.40000E-10	Item(s)
F Carbon dioxide, in air	Resource/in air	1.65000	kg
F compost, at plant - CH	agricultural means of producti...	0.00000	kg
F poultry manure, dried, at regional storehouse - CH	agricultural means of producti...	12.94915	kg
F cotton seed, at regional storehouse - US	agricultural means of producti...	0.01640	kg
F electricity, low voltage, production UCTE, at grid...	electricity/production mix	0.54306	kWh
F Transformation, to arable, organic	Resource/land	9.42354	m2
F Transformation, from arable	Resource/land	9.42354	m2
F Occupation, arable, organic	Resource/land	9.42354	m2*a
F irrigating - US	agricultural means of producti...	0.46951	m3
F Water, well, in ground	Resource/in water	6.15061	m3
F Water, river	Resource/in water	2.16098	m3
F Energy, gross calorific value, in biomass	Resource/biotic	18.56300	MJ
F transport, lorry 3.5-16t, fleet average - RER	transport systems/road	0.24285	t*km
F operation, van < 3,5t - RER	transport systems/road	0.01507	v*km

Outputs related to the inventory had to be calculated. Nitrogen emissions NH_3 (ammonia), N_2O (nitrous oxide), and NO_3 (nitrate) for the cotton production stage were calculated based on chicken slurry as fertilizer with nitrogen content of 0.87% (Brentrup, Kuesters, Lammel, & Kuhlmann, 2000). NO (nitric oxide) emissions were modeled as 43% of total N-fertilizer input (Textile Exchange, 2014). Carbon sequestration in the soil, as well as gin waste, were not considered due to uncertainties as was done in other LCAs (Cotton Incorporated, 2017). Soil erosion calculation was also omitted for this study, as soil protection measures are often practiced by organic cotton farmers and hence the risk of erosion is significantly reduced (Textile Exchange, 2014). Other emissions arising from organic cotton cultivation and ginning not yet calculated were modeled according to average data from a former study on organic cotton (Textile Exchange, 2014). That study also states that the toxicity assessment of heavy metals is especially uncertain and that

there is no evidence that organic soil contains less heavy metal than conventional soil.

The outputs related to the cotton fiber inventory are shown in Appendix 1.

The same yarn production and weaving process data were used as for the baseline life cycle case, as the main input was electricity and no, by GOTS prohibited substances were used. Adjustments were made for the textile refinement process; the adjusted inventory is shown in Table 9. According to the GOTS standard, carboxymethyl cellulose is allowed as an auxiliary washing agent but the surfactant fatty alcohol sulfate mix was replaced by fatty alcohol sulfate made of coconut oil. Moreover, since linear alkylbenzene sulfonate (LAS) is prohibited as a surfactant, it was replaced with soap for this study. Bleaching was omitted as no oxygen based bleaches as requested by GOTS standard were found in ecoinvent. The sodium chloride amount was kept the same as in the original ecoinvent refinement dataset used for the baseline case.

Table 9. Textile refinement inventory GOTS.

Inputs			
Flow	Category	Amount	Unit
F ₂ heat, natural gas, at industrial furnace >100kW...	natural gas/heating sy...	5.39050	MJ
F ₂ treatment, sewage, to wastewater treatment, cla...	waste management/w...	0.13800	m ³
F ₂ chemicals organic, at plant - GLO	chemicals/organics	0.13000	kg
F ₂ tap water, at user - RER	water supply/production	138.00000	kg
F ₂ electricity, low voltage, at grid - IN		1.10917	kWh
F ₂ heat, light fuel oil, at industrial furnace 1MW - RER	oil/heating systems	30.54600	MJ
F ₂ chemical plant, organics - RER	chemicals/organics	1.00000...	Item(s)
F ₂ transport, lorry >16t, fleet average - RER	transport systems/road	0.25000	t*km
F ₂ carboxymethyl cellulose, powder, at plant - RER	washing agents/auxili...	0.01000	kg
F ₂ fatty alcohol sulfate, coconut oil, at plant - RER	washing agents/tensides	0.01000	kg
F ₂ soap, at plant - RER	washing agents/tensides	0.01000	kg
F ₂ sodium chloride, powder, at plant - RER	chemicals/inorganics	0.54700	kg

The refinement ecoinvent data were adjusted based on GOTS requirements.

The final production stage inventory was also kept the same as the baseline case except the cardboard packaging; a corrugated board from recycled fiber was used instead of one from mixed fibers. The GOTS requires packaging material for retail trade to be from pre- or post-consumer waste (Global Standard gGmbH, 2017). For the comparison case, no changes were made with respect to the transport, use phase, and end-of-life inventory datasets.

E-LCA Life Cycle Impact Assessment

Life cycle impact assessment (LCIA) intends to draw a picture of the environmental consequences related to the environmental burden stemming from the prior conducted inventory collection (Baumann & Tillman, 2004). For clarity, comprehensibility and readability inventory result parameters are grouped through the LCIA (Baumann & Tillman, 2004). For this study, the LCIA was carried out with ReCiPe midpoint (H) method created by RIVM, CML, Pre Consultants and Radboud Universiteit Nijmegen. ReCiPe transforms the LCI results into indicator scores. Results can be presented as eighteen robust midpoint indicators or grouped into three easy to understand endpoints namely damage to human health, ecosystems and resource availability (ReCiPe, n.d.).

To have a more precise overview it was chosen to present results at midpoint level and in “hierarchist” (H) perspective. The “hierarchist” perspective represents the medium-term perspective, such as global warming potential for 100 years (GWP100), and is often used as the default model (ReCiPe, 2012; Textile Exchange, 2014). The eighteen different impact categories used in ReCiPe as midpoint indicators can be seen in Table 10 with their respective unit of measure. To carry out the impact assessment the

collected inventory data were put into openLCA for each relevant process within the blouse life cycle. All impacts for the whole life cycle were accumulated and assessed.

Table 10. ReCiPe impact categories.

Impact category	Unit
Agricultural Land Occupation	m ² a
Climate Change	kg CO ₂ eq
Fossil Depletion	kg oil eq
Freshwater Ecotoxicity	kg 1,4-DB eq
Freshwater Eutrophication	kg P eq
Human Toxicity	kg 1,4-DB eq
Ionising Radiation	kg U235 eq
Marine Ecotoxicity	kg 1,4-DB eq
Marine Eutrophication	kg N eq
Metal Depletion	kg Fe eq
Natural Land Transformation	m ²
Ozone Depletion	kg CFC-11 eq
Particulate Matter Formation	kg PM10 eq
Photochemical Oxidant Formation	kg NMVOC
Terrestrial Acidification	kg SO ₂ eq
Terrestrial Ecotoxicity	kg 1,4-DB eq
Urban Land Occupation	m ² a
Water Depletion	m ³

(ReCiPe, n.d.).

The calculation of the environmental impacts per category is called characterization; the characterization results were normalized to relate them to a reference value (Baumann & Tillman, 2004). For this project, it was chosen to use the “world ReCiPe midpoint (H) 2000” normalization and weighing set. The reason for using world data was that the processes took place in India and USA with international transportation hence the relation to world data seems the best option. The normalization factors were revised in 2010 (ReCiPe, 2010).

After the first assessment for the baseline case and the GOTS comparison, a sensitivity analysis with less fertilizer was performed for the cotton-growing phase, as the nitrogen content of the first organic cotton LCA was high compared to some other organic studies including one in the Maharashtra region (Textile Exchange, 2014). Manure management and application should not lead to land degradation or water pollution (International Federation of Organic Agriculture Movements, 2014). Oversupply of nutrients could hinder uptake of calcium, magnesia, iron, and zinc (Eyhorn et al., 2005). For this analysis manure applied was reduced to 6.9 t/ha with nitrogen content of 60 kg/ha. The adjustments gave a better picture of the environmental impacts that fertilizer management in cotton cultivation can have.

S-LCA

S-LCA can be used to complement an E-LCA and focuses on positive and negative social and socio-economic impacts of products along the supply chain. All life cycle stages from cradle-to-grave can be assessed. S-LCA follows the ISO 14040 framework and the ISO 14044 requirements but some aspects differ compared to E-LCA. S-LCA provides that subcategories per stakeholder group should be considered, stakeholders are encouraged to contribute information on impacts, performance reference points are used, and subjective data may be the most appropriate type to use (UNEP & SETAC, 2009). “Social impacts are not determined by the elementary flows of the LCA but rather by the behaviors of the stakeholders involved” (Pesonen & Benoît Norris, 2014), this is the reason why their input and opinion in the assessment should be included when possible and relevant (UNEP & SETAC, 2009). In addition, regional specificity can be very important in S-LCA due to societal, political, and cultural differences (Benoît

Norris et al., 2015). As mentioned, to conduct the S-LCA the SHDB entries were used in SimaPro to assess sector and country-specific risks in the textile/apparel supply chain. The SHDB system is based on the Global Trade Analysis Project (GTAP) Version 7 and contains input/output sets for 113 regions and 57 different sectors (Benoît Norris, 2014).

S-LCA Goal and Scope

Aligned with the E-LCA the goal of the S-LCA baseline case was to assess social impacts of cotton blouses produced in India for non-certified and sustainably labeled apparel. Through the country and sector-specific data in the social hotspots database, areas of high risk became visible. Social hotspots that were identified from the baseline case assessment were considered when evaluating the social labels that would best address these hotspots. Afterwards, a second S-LCA was carried out for the same type of product but with adjusted data based on social label requirements. For this case, the SHDB entries were adapted to reflect the changed social impacts based on the prior conducted label assessment in Excel. Aforementioned stakeholder groups and subcategories were considered for the label assessment as suggested by UNEP/SETAC (Table 1). The S-LCA results were used to show the effect of the social/sustainable labels but also to identify areas of improvement for the labels regarding life cycle stages and/or stakeholders. The main focus of the label criteria was on workers in the production stage but other stakeholders like society, local community and consumers were also considered.

The scope of the study included the life cycle stages from raw material cultivation in India to end-of-life of the products in the US. The design phase of the products was not considered. It is assumed that designing of the products happened in the US and there

were no considerable social risks during the design process. There is no data available for the use phase and for the end-of-life in the SHDB, therefore, research was conducted to assess risks and opportunities. It was then decided to omit these two phases, as there is no significant social risk in the use phase other than the ones related to energy and water consumption, which are considered in the E-LCA. Recycling and waste management of clothes can be labor intensive (Zamani, 2014) but due to missing data no social risk evaluation was performed. Health risks that might stem from chemicals during the use phase or at end-of-life were assessed through the E-LCA.

The functional unit was fifteen blouses at a 2002 purchasing value of 93 USD. For the baseline case, data present in the SHDB was used as is. The activity variable used was working hours similar to the SHDB.

S-LCA Life Cycle Inventory

For the baseline S-LCA, the entries of the SHDB for “plant based fibers”, “textiles”, “wearing apparel”, “transport” and “water transport” from India were used. The hotspots assessment was made for the textile sector and apparel finishing in general. SHDB entries are aligned with GTAP and for “plant based fibers” the datasets include: cotton, flax, hemp, sisal and other vegetable materials used in textiles; for “textiles” the datasets include: textiles and man-made fibers and for “wearing apparel” they include clothing, dressing and dyeing of fur (Benoît Norris, 2014; Center for Global Trade Analysis, 2013). Impacts in the SHDB are assessed in dollar value of 2002 hence a transition from mass to deflated monetary value was necessary. The assessed purchasing value of 93.5 USD was based on a United Nations statistics where export value of woven shirts made in India was averaged based on the number of items at 7.8 USD for 2013

(Lopez-Acevedo & Robertson, 2016). 7.8 USD per blouse converted to 2002 value amounts to 6.2 USD (Areppim AG, 2017). Here 50% of the value was attributed to each “textiles” and “wearing apparel”.

In the SHDB, no distinction is made between apparel created from cotton or other materials hence “plant based fibers/IN” was added as a process to have an evaluation closer to cotton as raw material input. The “plant based fibers” amount of 0.07 (rounded) USD 2002 per blouse was derived from values in the “wearing apparel” dataset that belonged to the categories of crops, leather products, and wool/silkworm cocoons. These categories were not relevant for this study. Moreover, plant based fibers from India and other countries were taken out of the “wearing apparel” dataset and added to the separate entry of “plant based fibers/IN”. The sum of these factors represents 1.10% of the “wearing apparel” entries. The amount of 3.1 USD 2002 for “wearing apparel” was adjusted to $3.1 - 0.07 = 3.03$ (rounded) USD 2002 and values dedicated to materials not relevant for this study as mentioned above were set to 0 in the “wearing apparel” SHDB entry.

Transport activity values were fully taken from the India datasets as the longest truck transport takes place there and ocean shipping originates from there as well. Water transport cost was estimated at 0.01 USD and road transport at 0.25 USD per ton-mile, based on shipment cost per ton-mile in 1995 USD adapted from Ballou (Rodrigue, 1998). Converted to kg/km the costs were $0.25/1000/1.609344 = 0.000155$ USD for road transport and $0.01/1000/1.609344 = 6.21373E-06$ USD for water transport. Multiplied by the distance 854.6 km the kg cost for road transport was 0.133 and 0.092 in 1995 USD. Inflated to 2002 transportation costs added up to 0.25 USD per kg of apparel with 0.15

USD for the road distance and 0.1 USD for the sea shipment. Per blouse, this equals 0.02 USD 2002 for truck and 0.013 USD 2002 for sea shipment. The described inputs for one cotton blouse (baseline case) can be seen in Table 11.

Table 11. SHDB process contribution for one cotton blouse (baseline).

Outputs to technosphere: Products and co-products		Amount	Unit	Quantity	Allocation	Waste type	
Cotton blouses baseline IN		6.23333	USD 2002	Currency	100 %		
Add							
Outputs to technosphere: Avoided products		Amount	Unit	Distribution	SD2 or 2SD	Min	
Add							
Inputs							
Inputs from nature		Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min
Add							
Inputs from technosphere: materials/fuels		Amount	Unit	Distribution	SD2 or 2SD	Min	
Cotton wearing apparel/IN		3.0320542	USD 2002	Undefined			
Plant based fibers/IN		0.0679458	USD 2002	Undefined			
Transport nec/IN		0.02	USD 2002	Undefined			
Water transport/IN		0.01333	USD 2002	Undefined			
Textiles/IN		3.1	USD 2002	Undefined			

For the second S-LCA the SHDB risk entries were adjusted for the outputs that were covered by Fairtrade Textile requirements. First, the original SHDB processes were copied and then the social risks adjusted where necessary. Possible risks were assessed as high, medium, and low based on the earlier criteria evaluation likewise estimated at three levels namely high, moderate, and low. Monetary amounts were left the same as for the baseline case. As the Fairtrade criteria are applicable for the textile production stage and the final apparel cut, trim, make phase, social issue outputs were adjusted accordingly in both the “textiles/IN” and “wearing apparel/IN”. The Fairtrade Textile Standard does not apply to the cotton production phase. It does require that Fairtrade certified cotton or other responsible fibers be used (Fairtrade International, 2016a). The “plant based fibers/IN” entries were adjusted according to the Fairtrade Standard for Small Producer

Organization (Fairtrade International, 2011). The transport processes were not adjusted as they had very little social impact overall and because the labels do not cover transport. Process contributions for the labeled blouse case are illustrated in Table 12. All applicable social themes and the risk assessment changes in the SHDB for the textile sector can be seen in Appendix 3.

Table 12. SHDB process contribution one cotton blouse (labeled).

Outputs to technosphere: Products and co-products		Amount	Unit	Quantity	Allocation	Waste type	
Cotton blouses labeled IN		6.23333	USD 2002	Currency	100 %		
Add							
Outputs to technosphere: Avoided products		Amount	Unit	Distribution	SD2 or 2SD	Min	
Add							
Inputs							
Inputs from nature		Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min
Add							
Inputs from technosphere: materials/fuels		Amount	Unit	Distribution	SD2 or 2SD	Min	
C wearing apparel/IN labeled		3.0320542	USD 2002	Undefined			
C plant based fibers/IN labeled		0.0679458	USD 2002	Undefined			
Transport nec/IN		0.02	USD 2002	Undefined			
Water transport/IN		0.01333	USD 2002	Undefined			
C Textiles/IN labeled		3.1	USD 2002	Undefined			

The risk of wages being lower than minimum wage or \$2 per day were both set to medium as wage level paid is not exactly known. The Fairtrade Standard requests to pay living wages based on their Anker methodology approach but companies have up to six years time to reach the living wage level (Fairtrade International, 2017). Forced labor risks were estimated to be low due to the major requirement by the Fairtrade label to not engage in, support or tolerate forced labor. The risk of child labor was set to low due to the criterion that children are neither employed directly or indirectly through sub-contracting. Risk of excessive working time was estimated to be low, as on a regular basis not more than 8 hours per day and 48 per week should be worked. As freedom of

association rights was granted through label certification the remaining risk was set to low.

Pay and treatment should be equal; hence indicators related to unfair treatment and gender equity were reduced. Indicators for fatal and non-fatal injuries as well as risk of loss of life due to exposure to carcinogens or particulates was reduced to low risk. Reasons were applied protective gear and general measures taken to avoid accidents including safe machinery and workplaces. Additionally, organic cotton production protects workers' health due to overall reduced toxin exposure that could lead to several health consequences from asthma to cancer (Textile Exchange, 2017). The Fairtrade Textile Standard prohibits use of carcinogenic and highly toxic substances in post-harvest, dyeing, production processes, storage and transportation, which further decreases health risks for workers (Fairtrade International, 2016a). Risk for no access to improved drinking water and sanitation was set to low and medium. The label requirements refer to the workplace and the SHDB to the country and sector but still the risk was lowered as the workers at least have for some time of the day access to good quality drinking water and clean sanitary facilities. The risk of unpaid annual leave was left at medium risk. Annual leave by law should be twelve days if the worker has worked 240 days (Fair Wear Foundation, 2016). The Fairtrade standard requires compliance with national legislation and set an additional criterion for an increase of up to two weeks of paid vacation, but as this is a development requirement due in three years the impact was left a medium risk.

S-LCA Life Cycle Impact Assessment

To assess the social impacts of the inventory the “Social LCIA method 2 V2.00” was used. The method groups impact into five categories; Labor rights & decent work, health & safety, human rights, governance, and community infrastructure. To further detail the impacts they are divided into social themes or impact categories. The labor rights and decent work category has nine social themes, namely child labor, forced labor, excessive working time, wage assessment, poverty, migrant labor, freedom of association etc., unemployment, and labor laws.

Table 13. Social LCIA impact categories.

Impact category	Reference Unit
Child Labor	Child Labor medium risk hours equivalent
Collective Bargaining etc.	Collective Bargaining etc. medium risk hours equivalent
Corruption	Corruption medium risk hours equivalent
Drinking Water	Drinking Water medium risk hours equivalent
Excessive Working Time	Excessive Working Time medium risk hours equivalent
Forced Labor	Forced Labor medium risk hours equivalent
Gender Equity	Gender Equity medium risk hours equivalent
High Conflict	High Conflict medium risk hours equivalent
Hospital Beds	Hospital Beds medium risk hours equivalent
Improved Sanitation	Improved Sanitation medium risk hours equivalent
Inadequate Social Benefits	Inadequate Social Benefits medium risk hours equivalent
Indigenous Rights	Indigenous Rights medium risk hours equivalent
Injuries & Fatalities	Injuries & Fatalities medium risk hours equivalent
Legal System	Legal System medium risk hours equivalent
Migrant Labor	Migrant Labor medium risk hours equivalent
Poverty Wage 1	Poverty Wage 1 medium risk hours equivalent
Poverty Wage 2	Poverty Wage 2 medium risk hours equivalent
Toxics & Hazards	Toxics & Hazards medium risk hours equivalent

(Benoît Norris et al., 2015).

The health & safety category has two themes; “injuries and fatalities” as well as “toxics and hazards”, to the human rights category belong the themes named “indigenous rights”, “high conflicts”, “gender equity”, and “human health issues”. Two themes called “legal systems” and “corruption” are part of the governance category and the community infrastructure category is detailed into five themes, namely accessible “hospital beds”, “drinking water”, “sanitation”, “children out of school”, and “smallholder versus commercial farms” (Benoît Norris et al., 2015). Collective bargaining and the right to strike are part of the freedom of association theme. All assessed social impact categories and their reference unit can be seen in Table 13.

Risks identified are expressed in worker hours affected and are assessed as either low, medium, high or very high risk. For the S-LCA, there might be some underestimation of impacts as the main activity variable for allocation is “working hours” and processes with high social concerns might contribute only a small portion of the total worker hours needed to produce the assessed end product (Grubert, 2016). Therefore, to calculate the total risk hours, low risks are multiplied by 0.1, medium risks by 1, high risks by 5 and very high risks by 10. The factors are applied to weigh the risk hours and express the results in medium risk hours equivalent. Some social issues that are considered most important are risk of forced and child labor in sector, risk of fatal and non-fatal injuries in sector and overall risk of gender inequity in country. Most important risks are multiplied by 1.5 to further weigh the results (Benoît Norris et al., 2015).

Chapter III.

Results

The results of the label evaluation are presented in a compacted table format. An Excel sheet with an excerpt of label criteria and evaluation of the same can be found in Appendix 4. For the E-LCA, the results of the cotton cultivation are presented first as most changes for the comparative E-LCA occurred here and a sensitivity analysis was carried out. Afterwards, the results for the whole life cycle of the fifteen blouses are introduced. Results for the two S-LCAs conclude this chapter.

Label Assessment Results

The label evaluation showed that the Fairtrade Textile Standard had the most comprehensive criteria. It was often more detailed and specific to the textile industry than other labels. Results were sorted by social theme and count of low and medium risk criteria per label standard. High-risk criteria were omitted as those would not lead to an improvement or a change in the SHDB. Table 14 shows due to space constraints only the number of remaining low risk criteria. All subcategories suggested by UNEP/SETAC are shown in the table but some added subcategories that were derived from the label criteria evaluation are only shown in the appendix due to space constraints.

Table 14. Count of criteria per social theme and label assessed.

	Fairtrade Textile	GOTS	Fair Wear (FWF)	STeP	Fair for Life
Subcategories	low risk	low risk	low risk	low risk	low risk
Freedom of association and collective bargaining	6	2	3	3	3
Child labor	3	5	3	7	2
Fair salary	6	2	2	4	3
Working hours	3	2	3	2	2
Forced labor	4	4	2	5	5
Equal opportunities / discrimination	5	5	2	7	4
Health and safety worker	14	9	2	9	11
Social benefits / social security	4	1	1	2	3
Commitment to Voluntary Sustainability Standards (VSS) / Labels	3	1	0	1	3
Capacity building	4	0	0	3	0
Worker rights	1	0	0	1	1
Feedback mechanism	0	0	0	1	0
Consumer privacy	0	1	0	0	0
Transparency	2	2	1	2	3
Access to material resources	1	2	0	1	0
Delocalization and migration	0	0	0	0	1
Safe and healthy living conditions	1	1	0	0	0
Local employment	0	0	0	0	1
Public commitments to sustainability issues	0	0	0	1	1
Corruption	0	1	0	1	0
Fair competition	0	0	0	1	0
Promoting social responsibility	1	0	0	1	0
Supplier relationships	10	3	0	2	10

Social label criteria that led to low remaining social risk for stakeholders when applied. Results are based on the authors' evaluation.

The complete list with medium and low remaining risks count is shown in Appendix 2. The Fairtrade Textile label had compared to the other labels the most criteria that led to low remaining risks in the categories of “health and safety for workers” and “supplier relationships”. The Fairtrade Textile Standard had also robust requirements in the subcategories of freedom of association and collective bargaining, fair salary, and equal opportunities. No criterion was found to decrease risk of corruption or conflicts.

Environmental Impact Assessment Results

The baseline case assessed conventionally cultivated cotton fibers and the results are shown as “cotton fibers, baseline India”. The comparative case named “cotton fibers, GOTS” represents a case of organic cotton cultivation using the GOTS label as an example for criteria adherence. The sensitivity analysis was incorporated as “cotton fibers, GOTS new” scenario. Other eco-labels were not evaluated as mentioned above.

Relative results present the scenario with the highest environmental impact at 100% and the other scenarios are shown in relation. Relative results of “cotton fibers, GOTS new” showed the positive impact of organic fertilizer reductions. Results in Figure 4 show that only in the category “agricultural land occupation” the adjusted organic cotton cultivation (sensitivity analysis) inventory had the highest impact together with the other organic cotton case.

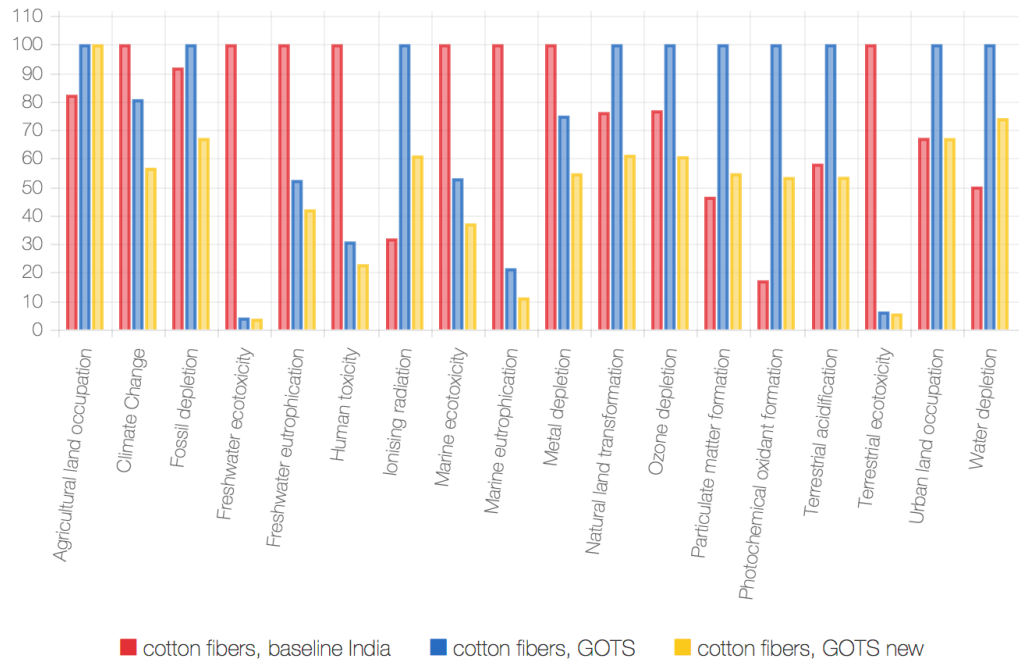


Figure 4. E-LCA relative results for 1000kg cotton fibers, ginned at farm. Calculated in OpenLCA.

Overall, from the relative results it is not clear which cotton cultivation had the highest environmental impact. The baseline case had the highest impact in eight impact categories and the first GOTS inventory had the highest impact in ten different impact categories. Normalized and weighted against world data, results showed that the possible overall highest impacts occurred from the baseline case in freshwater and marine eutrophication. Both of these impacts are classified as damage to ecosystems. Terrestrial acidification and freshwater eutrophication level caused by the original GOTS cotton inventory had the third and fourth highest impact. Highest level in regards to human health damage had the baseline case in the human toxicity category and the first GOTS case in particulate matter formation. Normalized results for all midpoint impact categories are

shown in Figure 5. Clear differences between the three options were visible in most categories.

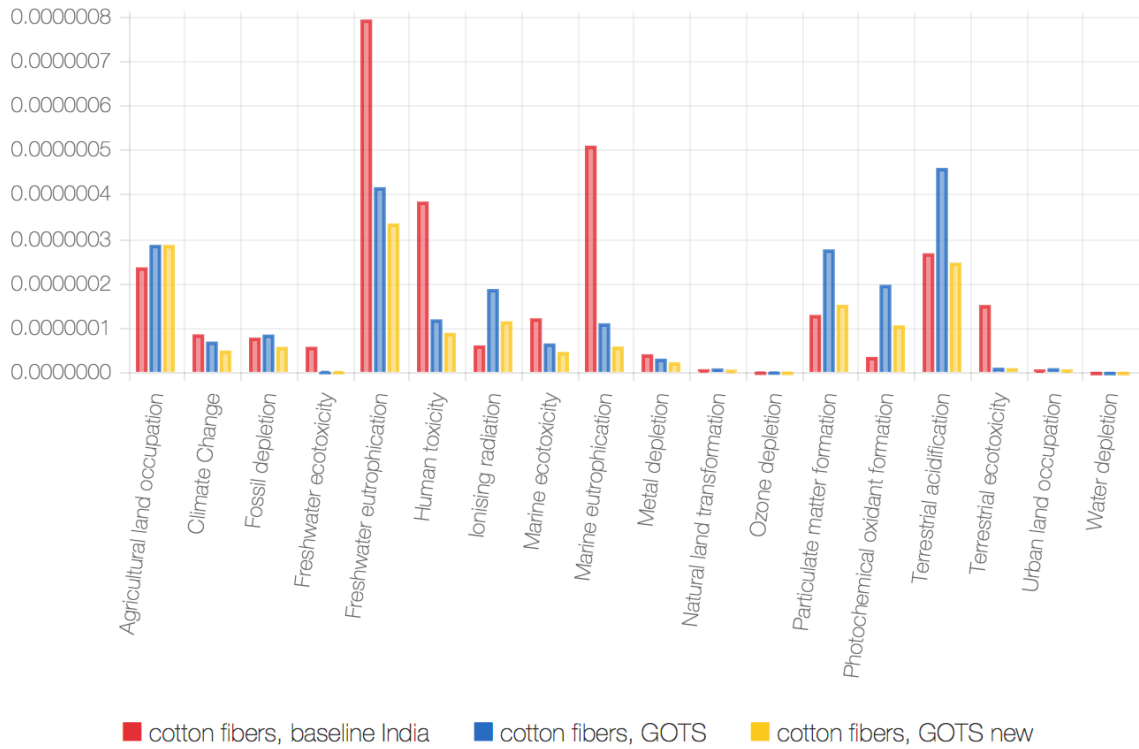


Figure 5. E-LCA normalized results for 1000 kg cotton fibers, ginned at farm. Calculated in OpenLCA.

Impact results for the whole cotton blouse life cycle were not as clearly different as for cotton cultivation. The assessment of the blouses was done for the functional unit of 2 kg (fifteen blouses).

Table 15. LCIA results for fifteen cotton blouses.

Impact category	Cotton blouses, baseline India	Cotton blouses, GOTS India sensitivity analysis	Unit
Agricultural Land Occupation	2.19443E+01	2.63399E+01	m ² a
Climate Change	9.09293E+01	8.67152E+01	kg CO ₂ eq
Fossil Depletion	2.12382E+01	2.07817E+01	kg oil eq
Freshwater Ecotoxicity	5.05066E-03	1.46575E-03	kg 1,4-DB eq
Freshwater Eutrophication	2.37823E-02	2.16969E-02	kg P eq
Human Toxicity	4.09893E+00	3.55848E+00	kg 1,4-DB eq
Ionising Radiation	9.03992E+00	1.01369E+01	kg U235 eq
Marine Ecotoxicity	4.78898E-02	4.50244E-02	kg 1,4-DB eq
Marine Eutrophication	8.42709E-02	3.19716E-02	kg N eq
Metal Depletion	2.09442E+00	1.96863E+00	kg Fe eq
Natural Land Transformation	1.42022E-02	1.62679E-02	m ²
Ozone Depletion	3.59554E-06	3.48844E-06	kg CFC-11 eq
Particulate Matter Formation	2.01091E-01	2.05976E-01	kg PM10 eq
Photochemical Oxidant Formation	2.88934E-01	3.42772E-01	kg NMVOC
Terrestrial Acidification	7.21694E-01	7.08960E-01	kg SO ₂ eq
Terrestrial Ecotoxicity	2.22328E-02	8.33334E-03	kg 1,4-DB eq
Urban Land Occupation	5.99085E-01	5.97309E-01	m ² a
Water Depletion	1.67104E+02	1.82471E+02	m ³

The results were calculated in OpenLCA. They are expressed in absolute values.

LCIA results are shown for the baseline case and the comparative case based on the cotton cultivation from the sensitivity analysis (Table 15). The fertilizer amount in the sensitivity case was closer to cotton cultivation in the Maharashtra region therefore it was used for the cotton blouses life cycle assessment. Relative results show that impacts were fairly close together for all categories except freshwater ecotoxicity, marine eutrophication, and terrestrial ecotoxicity where impacts were significantly lower for the organic cotton blouse example (Figure 6).

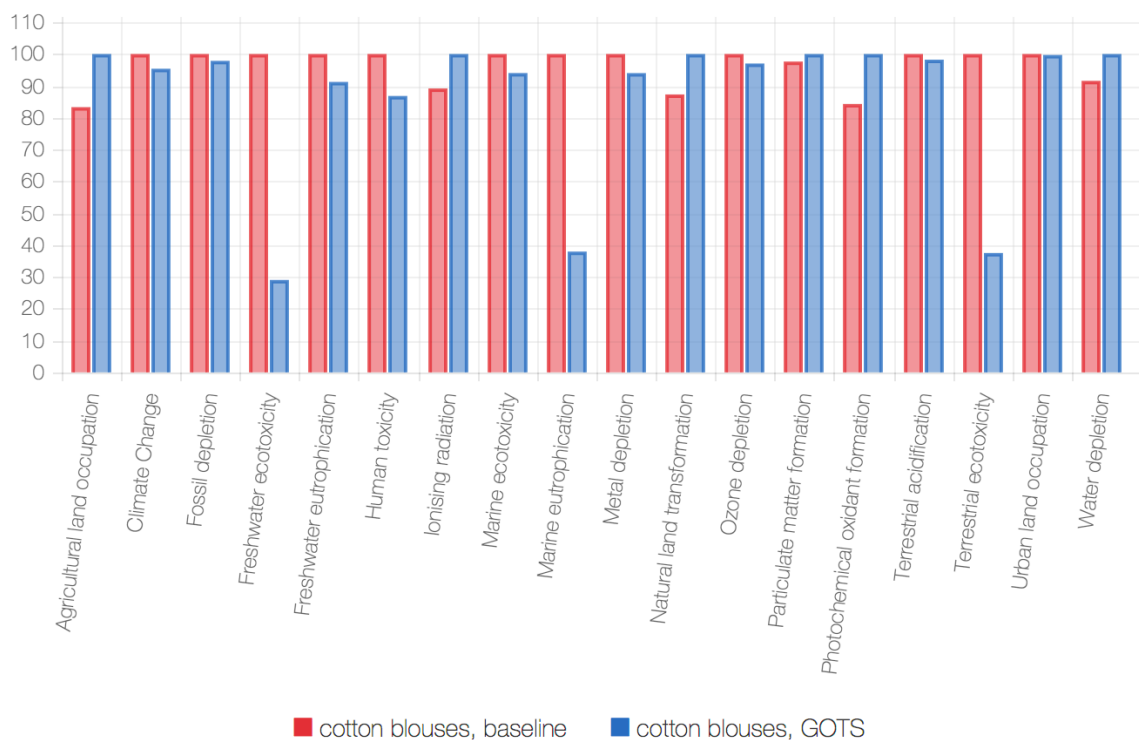


Figure 6. E-LCA relative results for fifteen cotton blouses. Calculated in OpenLCA.

The cotton blouses impact assessment data were normalized with world data, as were the cotton cultivation results. Environmental impact results for both assessed variants were comparatively close together. Results for the baseline case were higher in the four impact categories with the most impact: freshwater eutrophication, human toxicity, marine ecotoxicity, and terrestrial acidification (Figure 7). For the cotton blouses life cycle assessment the freshwater eutrophication had the highest impact, which was also the highest impact category during the cotton cultivation assessment.

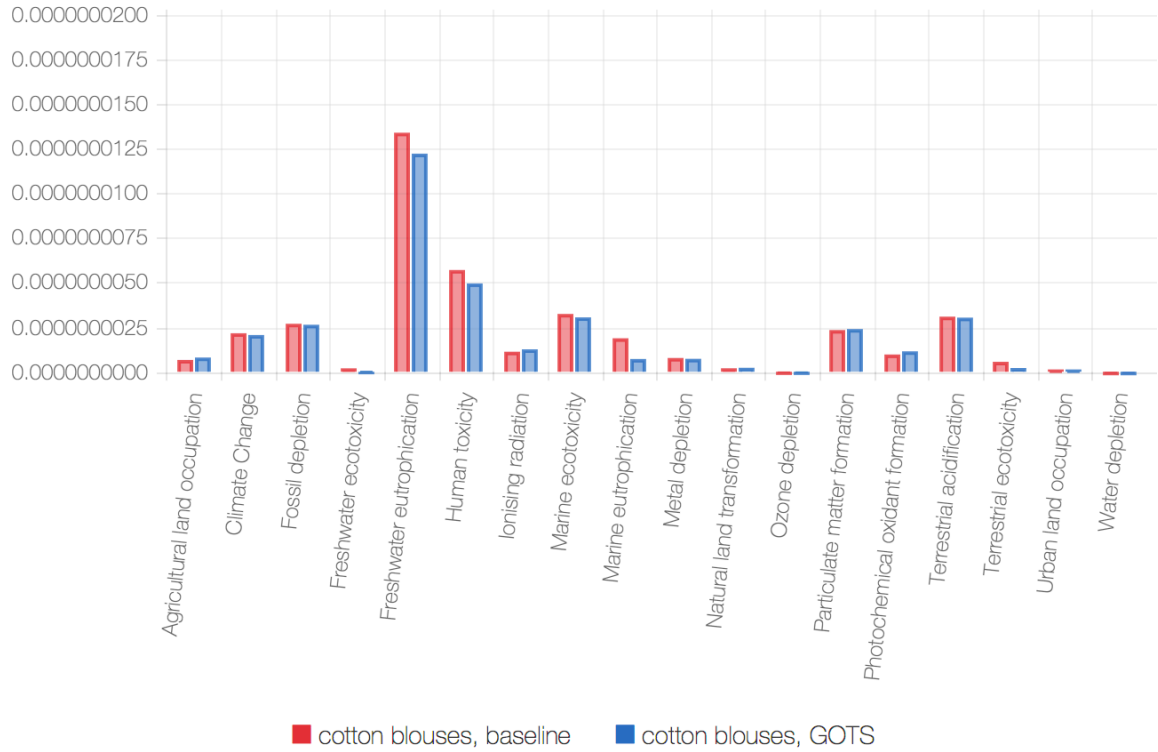


Figure 7. E-LCA normalized results for fifteen blouses. Calculated in OpenLCA.

As mentioned before, the textile and apparel industry is energy intensive. For the processing of yarn, textile, and apparel, high amounts of energy were used which led to relatively low overall impact of the cotton fiber cultivation. Indian low voltage electricity contributes in nine impact categories between 54.63% and 72.77% to the overall impact of the whole life cycle, as shown for the baseline cotton blouses in Table 16.

Table 16. Impact assessment results >50% for low voltage electricity in India from OpenLCA.

Impact assessment results			
Process		P electricity, low voltage, at grid - IN	
Contribution	Impact category	Upstream incl. direct	Unit
72.77%	Urban land occupation	0.43598	m2a
71.30%	Photochemical oxidant formation	0.20601	kg NMVOC
70.30%	Particulate matter formation	0.14137	kg PM10 eq
63.46%	Climate Change	57.70514	kg CO2 eq
62.93%	Human toxicity	2.57949	kg 1,4-DB eq
62.70%	Terrestrial acidification	0.45252	kg SO2 eq
57.21%	Fossil depletion	12.14997	kg oil eq
55.70%	Freshwater eutrophication	0.01325	kg P eq
54.63%	Metal depletion	1.14411	kg Fe eq

Social Impact Assessment Results

For the baseline case no changes were made in regards to inventory related outputs. The results shown are for the assessment of fifteen blouses with the value of 93.5 USD. As mentioned in the social impact assessment section the results are presented in “medium at risk hours equivalent”.

The normalized results of the baseline cotton blouses assessment show that overall the working hours at risk were potentially highest in the textile production, specifically in the area of labor rights and decent work. The social category of labor rights & decent work was, in general, the highest at risk category. In this category total worker hours at risk were 13,300 whereof around 7,720 hours appeared in the textile sector. The wearing apparel sector had the second highest impact after textiles. The textile sector showed in all other four categories the highest risk results, which are in declining order: Health & safety, human rights, governance, and community Infrastructure. The health & safety category had with around 6,180 at risk worker hours

about half of the risk hours as the labor rights & decent work category. The wearing apparel sector had overall the second highest impact with the same declining order as the textile sector. Relatively low at risk results were disclosed for “plant based fibers”, which represents the cotton cultivation. The lowest impacts in all categories had the transportation sector. The community infrastructure category had the lowest at risk hours with a total of 1,430. All normalized results for the baseline case by social category are presented in Figure 8.

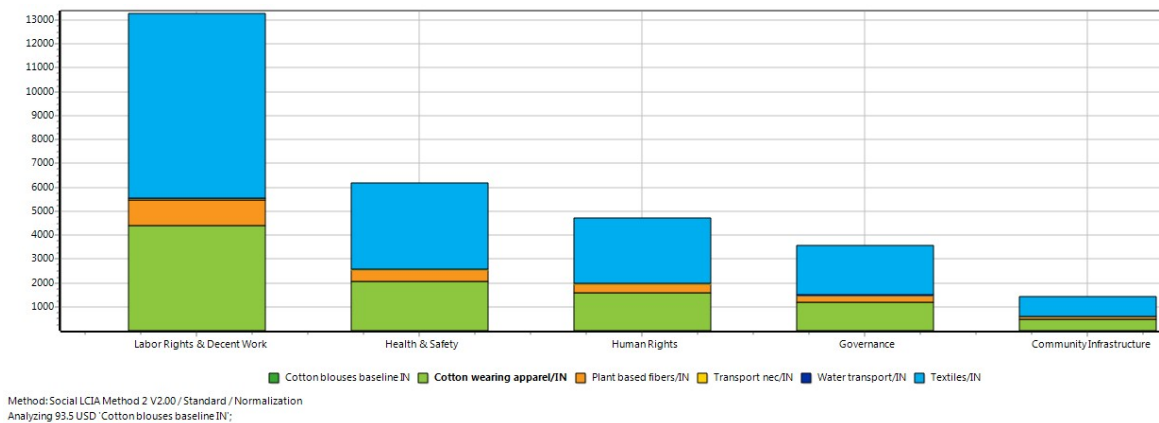


Figure 8. S-LCA normalized potential risks for fifteen cotton blouses (baseline). Calculated in SimaPro.

To get a more detailed picture the social categories were split into social themes. Regarding the health & safety social category, potential risks for injuries and fatalities were highest among all social themes both for the textile and wearing apparel sector. Results were with 4,720 at risk hours double as high as for the five themes that had the second highest risk potential. The textile sector accounted with 2,740 hours for almost 60% of the injuries and fatalities risk. Forced labor and migrant labor, two other social themes from the health & safety category marked with each 2,370 at risk hours the

second highest impacts. The assessment for migrant labor was based on the risk that migrant workers might get treated unfairly (Benoît Norris et al., 2015). Gender equity, high conflict and corruption were the three other themes that had the second highest at risk worker hours as forced and migrant labor. Gender equity and high conflicts belong to the human rights category and assess if there are high conflict zones in the sector or inequalities among genders in the country and specifically in the sector based on representation in the workforce (Benoît Norris et al., 2015). Results for all social themes can be seen in Figure 9; no data were available for indigenous rights and the risk of no access to hospital beds was very low.

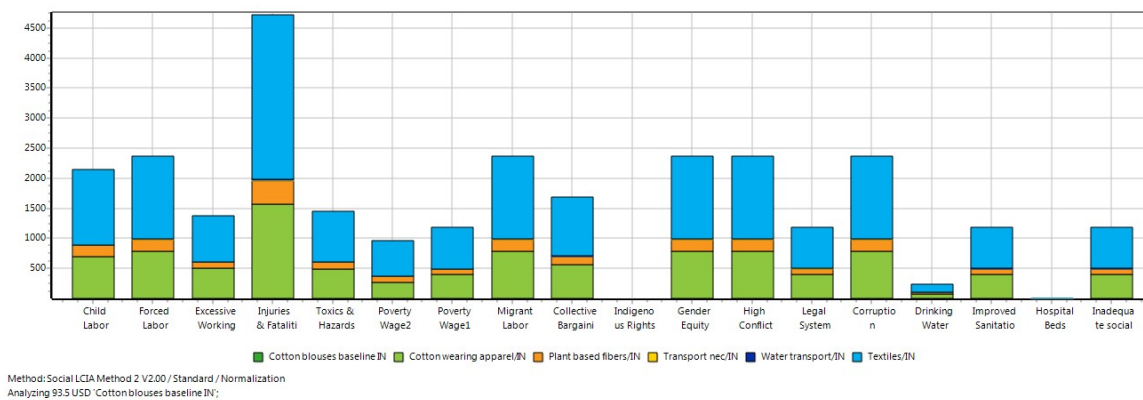


Figure 9. S-LCA normalized potential risks by social themes (baseline). Calculated in SimaPro.

Looking at the overall process contribution the “plant based fibers/IN” had by far the highest share. Total risk hours amount to 15,000. Other sectors contribute around 3,000 hours or less. Figure 10 illustrates the process contribution for the baseline case with 0.1% cut off. The cut off was applied to show only sectors with significant process contribution; otherwise, the chart would have been confusing due to a large number of contributors.

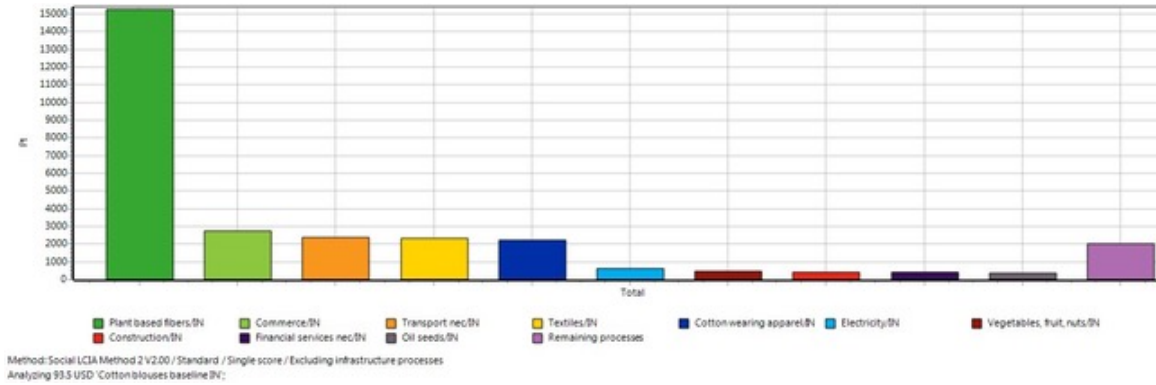


Figure 10. Process contribution by sector (baseline). Calculated in SimaPro.

For the second S-LCA, the impact analysis results show impacts after adjusting the potential social issues in the SHDB. Worker hours at risk were overall lower than for the baseline case. The total at risk hours were still the highest for the labor rights & decent work category, but it decreased to 11,300 hours. For health & safety, at risk hours were reduced to around 5,300 hours. Worker hours at risk were again the highest in all categories for the textile sector and second highest in the apparel sector. Total possible impacts by social category are shown in Figure 11.

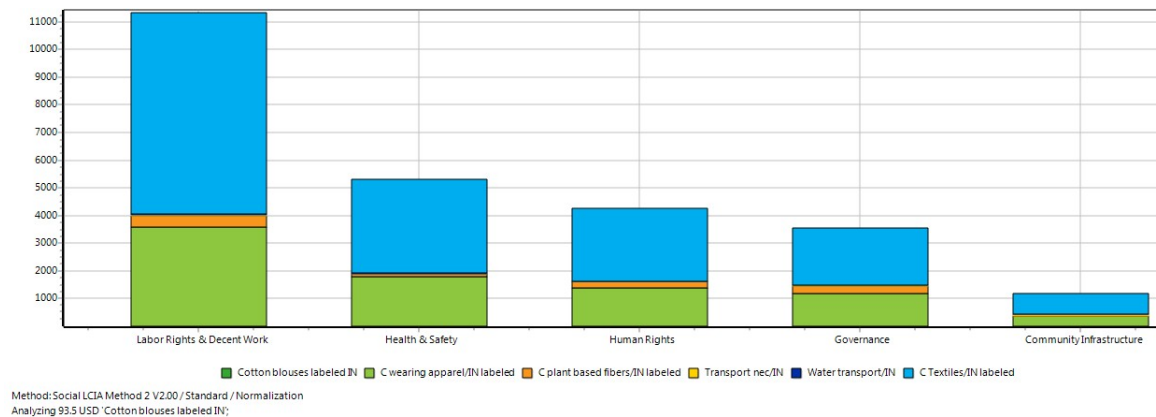


Figure 11. S-LCA normalized potential risks for fifteen cotton blouses (labeled). Calculated in SimaPro.

Looking at the individual social themes, the total risk for injuries & fatalities decreased to 3,780 hours. It was still the social issue with the highest overall risk; 2,490 hours were allocated to the textile sector, 1,210 to the apparel sector, 48 hours to the plant based fibers production and around 24 hours to the transport sector.

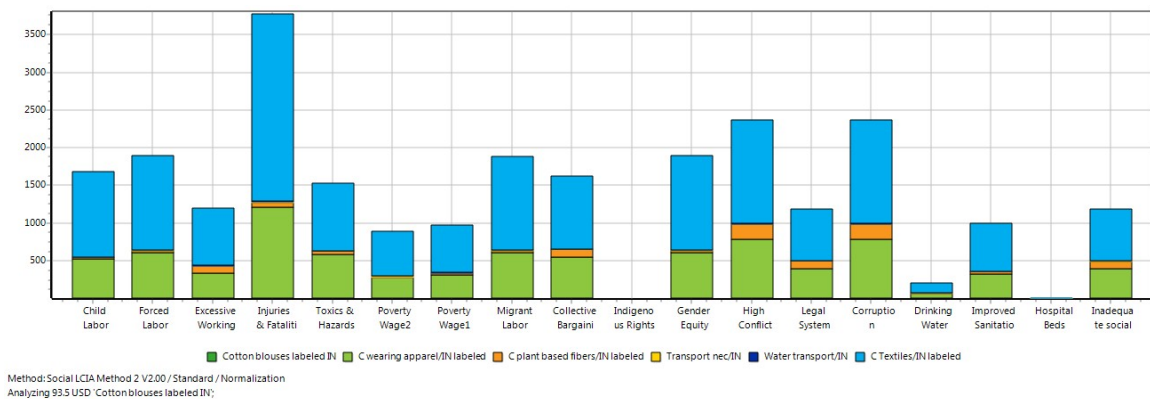


Figure 12. S-LCA normalized potential risks by social themes (labeled). Calculated in SimaPro.

The second highest impacts were attributed to high conflict zones and possible corruption with each 2,370 at risk hours. These two results have not changed compared to the baseline case. Gender equity, forced labor and migrant labor at risk hours were reduced to around 1,890. The risk for social themes child labor, excessive working hours, and improved sanitation decreased also. All assessed social themes and the normalized impact results are shown in Figure 12.

Chapter IV.

Discussion

Sustainable labels can play an important role in the future of a sustainable textile and apparel industry. Consumers also play a critical role in increasing demand for socially- and ecologically-produced and processed clothing. In this study, six social and sustainable labels were evaluated based on their criteria. The results of the label evaluation and the S-LCA indicate that no fixed ranking of the social labels can be done. However, both the E-LCA and S-LCA showed positive impacts achieved through sustainable labels.

Social Labels by Strength of Criteria

In response to the first research question, - can social labels be ranked by the strength of their criteria? The results indicate that no fixed ranking of the evaluated labels can be suggested. One reason is that results partly depend on the country where the criteria were applied. The label evaluation was done generally, meaning not country-specific. The S-LCA performed with data from the SHDB was India-specific. The strength of stakeholder protection against negative social impacts can vary by country. One label might be strong in one country but not in another, depending on where the most critical issues of the country or sector lay. Furthermore, some labels rely on national

legislation. However, this could weaken the purpose of these labels in countries where worker rights and social benefits are not widely protected by the government and/or other organizations. Also, the goal of a label standard should be to aim higher than the national legislation, specifically in countries where laws are not strong or not enforced.

Another reason that made a fixed ranking difficult was criteria of qualitative nature where evaluation depended on interpretation. Some of the standards included additional documents to help with interpretation of the criteria. Nevertheless, the evaluation of the label criteria indicated that certain labels could be preferred over others based on the strength and specificity of the requirements. As mentioned in the results section, this study perceived the Fairtrade Textile Standard as the label with the strongest and most textile relevant requirements. Nevertheless, after the social label evaluation and the S-LCA, no explicit ranking of the social labels could be proposed. The Fair Wear Foundation protects the most critical worker rights in the apparel cut, make, and trim stage. This is not as comprehensive as other labels but does not mean that labels with fewer criteria cannot make a considerable impact in the area they apply to.

Social labels, in general, cover the most pressing issues in the supply chain. Mainly they protect workers by supporting the rights for collective bargaining, fair salary, equal opportunity, and health and safety. Additionally, the Fairtrade and the STeP Standard encourage and require development of regular training for the workers. Several criteria pertain to training requirements ranging from labor rights, skill development to adequate training for female workers.

One aspect that was hard to measure during evaluation of the social label criteria was the involvement of workers or other directly impacted stakeholder groups in the

setting of the label criteria. Instead of adhering to strict numbers of minimum or living wage, criteria should rather involve workers to be interviewed. Criteria such as "the lowest paid workers consider their wages meet their (basic) needs" as suggested by the UNEP/SETAC gave the assessment a perspective closer to the parties affected, given that a representative number of lowest paid workers was interviewed.

Among the criteria for the Fairtrade Textile Standard, there is one that stipulates that if the product cannot be sold as fair-trade, all references to Fairtrade need to be removed. These products are sold without a Fairtrade premium. In such cases, the producer does not get a premium although his products are Fairtrade produced and he might not be better off than any other small-scale producer financially. Hence, it would be helpful to increase demand for Fairtrade products to avoid such situation and support fair payments to producers.

Besides the label criteria, a third-party certification process adds assurance and robustness to the validity of claims made through the labels. FLOCERT is the approved certifier for Fairtrade International, where the Textile Standard belongs. FLOCERT audits companies against the Fairtrade Textile Standard and if the standards' requirements are met, the certified company is allowed to show the Fairtrade mark on their products (Flocert, n.d.).

Label Criteria and Impact on LCA Results

In this section research questions 2 to 4 are answered and discussed. 2 - Can LCAs help demonstrate and support the underlying meaning and impact of ecologically- and socially-labeled apparel to end consumers? In both cases for the E-LCA and S-LCA,

results indicated overall reduced environmental and social impacts. The positive impacts of social labels can be shown through S-LCA but overall risks could be different in another country than India. Therefore the S-LCA performed in another country based on the same social label might have different results. Nevertheless, as mentioned above, social labels cover the most common social issues and would reduce social impact, especially in countries with social hotspots. It is concluded that the LCA results could be used to demonstrate positive impacts of socially- and ecologically-labeled apparel products to end consumers. This could be done per country and sector, based on the origin of the products. The positive impact could be further communicated to end consumers by additional label information accompanying the existing social and eco-label.

During the research for the organic cotton cultivation, it became clear that there are tremendous differences within India and sometimes within the same region regarding the amount of fertilizer applied and other cultivation activities such as irrigation. As this can have a high impact on the emissions assessment results, other LCAs might show significantly different outcomes. As the results show, the first attempt of modeling organic cotton cultivation has a very high impact due to the high fertilizer amount. It is probably not safe to say that the organic production will always have a lower impact than conventional production. As mentioned in the inventory section, the baseline case for India was based on average data; here it should be noticed that probably in a region where the organic fertilizer use is high due to given agricultural circumstances, it would also be high for conventional production.

A recent long-term trial showed that in Maharashtra, India, after a six-year period the organic cotton yield was higher than the conventional cotton yield by up to 227 kg per hectare (Forster et al., 2013). If such results could be confirmed through more trials it could lead to a significant change in the overall environmental impact of organic cotton. Especially, since the land occupation was the only category where the sensitivity case had the highest impact.

As seen in the results section, energy usage was high in the apparel production. Energy usage accounts for significant impact in the E-LCA. In the GOTS documents, no criterion was found that encourages the use of renewable energy. Using more renewable energy could most likely have reduced the environmental impact. An LCA study from China concludes lower lifetime emissions, energy, and water use for non-fossil electricity generation (Aden, Marty, & Muller, 2010). Encouraging producers to use more renewable energy by adding such requirement to label criteria would help to reduce the footprint.

3 - What is the effect of social label criteria on S-LCA results? Social label criteria applied to the SHDB outputs per sector reduced the possible risk of social issues occurring. This is of course only true for criteria that matched the SHDB entries and where the label evaluation concluded low or medium risks and the SHDB original entries had a high or very high possible risk. Label criteria that were considered to have no significant impact or were at the same risk level as the SHDB output were left as is. S-LCA is not seen as an outlet for product comparison (Benoît Norris, 2014). A comparison between the evaluated labels was not conducted. Due to the fact that often one indicator in the SHDB was available for several label criteria, the S-LCA results of several

evaluated labels might have been quite similar. This study compared non-labeled cotton blouses with Fairtrade cotton blouses rather than two specific blouses not to determine the better option, but to demonstrate overall impact of label requirements.

4 - Can an S-LCA confirm the evaluated strength of social labels? The S-LCA risk assessment through the SHDB is not as granular as the label requirements. Therefore, the results can only be an indication of possible risk mitigation. Both label and SHDB had a significant amount of criteria that did not match and many label requirements were not applied to reduce social risks in the SHDB. On the other hand, the SHDB was measuring several indicators, for example, related to all kinds of diseases and potential death or loss of life that could not be directly linked to label criteria. Risks for potential diseases were reduced based on requirements that Fairtrade uses organic cotton, prohibits harmful chemicals, and requests protective gear in the production process. These positive health benefits are generated through both environmental and social label requirements.

Even if the results of the risk adjustments applied in the SHDB could not give a very specific overall result they still confirm the strength of social labels. Reduction of at risk hours is obvious in the results. Enhancements of label criteria based on the results could further improve label strength.

Suggestions for Label Improvement

To answer the fifth research question, - how could social and eco-labels in the textile industry be improved? Areas with a substantial amount of worker hours at risk should be considered with priority. This refers to at risk worker hours in the SHDB results after the label criteria were applied. The assessed labels were mainly focused on the workers and supplier relationships.

The Fairtrade label had already a considerable number of requirements to protect worker health and safety and to promote safe and healthy work environments; therefore no further criterion suggestions are made. Nevertheless, the injuries and fatalities still had the highest at risks results. As seen in the results section, the process contribution of the raw material phase “plant based fibers” had the highest process impact. Fairtrade has its own standard for the small producer organizations and cotton production. This thesis suggests further work on securing the workplaces for farm workers and adding criteria for continuous improvements in the health and safety category. Label standards should ensure proper training of workers to prevent accidents but should also include human rights topics.

Forced labor and migrant labor risks did decrease with the label criteria assessment; however, they still had significant impacts. Requirements related to migrant labor were part of the equal opportunities subcategory. The Fairtrade Textile Standard does include interests of migrant and temporary workers as part of the compliance committee tasks. Nevertheless, in countries with high risks that migrant workers get treated unfairly, criteria should be added specifically to protect them. To further eliminate the risk of forced labor a criterion similar to the one requested by the STeP Standard is suggested. It should be made sure that workers can move around freely after work. In India, sometimes workers are kept in compounds (Fair Wear Foundation, 2016).

Some label standards had requirements based on or referring to the ILO conventions. Here, it is important to note that not all countries have ratified such conventions. For India, the right to collective bargaining was not at highest risk but still considerable. As Indian employers do not need to recognize trade unions, label standards

should always cover such fundamental rights through a label criterion and not refer solely to national legislation. This could have a considerable positive effect on workers' labor conditions.

It is recommended to further include other stakeholders along with workers as suggested by the UNEP/SETAC guidelines. Based on the S-LCA results for India, the social issues of corruption and high conflict zones were significant. No applicable criterion to reduce such social impact was found in the Fairtrade Textile Standard. Therefore, an anti-corruption requirement and measures to reconcile or avoid conflicts would be suggested. Furthermore, engagement in the local community could be another added criterion. This is not necessarily based on the results of the S-LCA, as the risks in social issues belonging to the local community were not significant, but local engagement might help also to mitigate potential conflicts. If the community is engaged and the factory/company provides benefits for the local community, stronger bonds can be built. Engagement should include protection of local cultural heritage.

To holistically include all possible impacts, the whole life cycle should be considered. The Fairtrade Textile Standard does focus on post-harvest through packaging and storage of garments, but the standard does not include directly the raw material and the trading phase. For these phases, it refers to other Fairtrade standards that apply and need to be adhered to instead. The end-of-life stage is probably difficult to include in the label requirements but worthwhile to consider. Labels could suggest “reuse”, “recycle” or “take back” activities if not done already. An indication to “please recycle” should be used only if the garment is made out of materials that can be recycled with current technology. Such guidance could improve consumer engagement. Furthermore, cross-

functional cooperation with the designing brand could be useful as recyclability with current technology highly depends on fabric contents, and the designers select the fabrics used. If a mix of different materials is used in textiles, the recycling might be more difficult or impossible. Here, it is suggested to follow the Cradle to Cradle approach that aims for a closed-loop system.

The rising demand for fair-traded products should increase production under fair conditions; nevertheless, in the short term there may be negative impacts for workers not working in a certified production facility. In general, impact claims of sustainability standards should be handled with caution, as it can be difficult to prove a related positive impact; sometimes it takes years for a measurable impact or the correlation is not easy confirmable (Wenban-Smith & UNFSS, 2013). It is not necessarily the best option to harmonize or merge labels. In some cases, it might be beneficial to have a high and a low standard instead of one that is harmonized with too many criteria for one company to comply with, or too few for another to find it appealing (Wenban-Smith & UNFSS, 2013).

To strengthen trust in eco-labels, a barcode similar to respect-code or the MADE-BY approach could show the exact data about where the product comes from and how it was made (Koszewska, 2015). Avery Dennison in collaboration with EVERYTHING works on digitizing a minimum of 10 billion apparel and footwear products through 2019. Each product has a unique, serialized label that can reveal information on where and how it was manufactured, including end-of-life feature on how to “upcycle” or where to recycle nearby (Avery Dennison, 2016). This adds transparency to the product.

Suggestions for End Consumer

The last research question to be answered is - Could recommendations be made based on the S-LCA results to end consumers? It is not expected that the end consumer knows all of the details about the complex supply chains where the purchased clothes came from. Nevertheless, many consumers are aware, through the media, of tragedies like the mentioned Rana Plaza collapse. End consumers are the ones who spend significant amounts of money on apparel and could drive brands into more social and environmental responsibility by demanding it. Where apparel has been produced in countries with weak environmental laws and social protection, consumers should look for sustainably labeled products. Based on the analysis of label criteria and the results of the LCAs, a combination of the GOTS and Fairtrade Textile Standard label suggests that a garment is sustainable.

If textile products are not certified with an eco or social label, the customer could request more information about the products from the brand. This might be relevant only for future purchases as while shopping often the price tag counts and decisions are made under time pressure. Information requests show an active interest in sustainable products and can strengthen relationships between consumer and brands. Of course, the companies themselves should also actively seek end consumer opinions and encourage more sustainable behavior by providing actions that could be taken. Promoting sustainably labeled products, take-back initiatives, and fostering open communication about sustainability actions could encourage consumers. Consumers further could be encouraged by receiving statistics that show the positive impact of opting for sustainable products (United Nations Environment Programme, 2017).

Relevant information for better decision-making may not always be communicated to the consumer through a label at the point of sale. Sustainability information should be provided to the consumer through different communication methods so that technical barriers are avoided and consumers with different information channels can be informed. With today's connectivity, consumers, especially young ones, could have instant access to more information via QR codes, barcodes or web links. Given they are available, and if the consumer is willing to investigate the product further (United Nations Environment Programme, 2017).

If consumers have too much disposable income, or the garments are comparably too low-priced, unconscious overconsumption can happen. Consumer behavior change toward buying less and purchasing sustainable clothing (instead of short-lived fast fashion) would probably be easier if underlying positive effects could be found. An example of a company encouraging such behavior is the Patagonia ad “Don’t buy this jacket” that asked consumers to think twice about environmental impacts before buying, and decide if it is really needed (Patagonia, 2011). Aside from the positive social impact on worker lives when buying Fairtrade clothing or environmentally conscious products like GOTS certified ones, less clothing can lead to fewer space issues in the wardrobe and less time spent on de-cluttering. Furthermore, as mentioned, the consumer can have an additional significant impact by increasing the lifetime of apparel products by not disposing of them as frequently and saving water by decreasing washing times. Line drying helps to keep energy use down. Consumers should also prefer clothing that is recyclable by current technology and recycle at end-of-life. The following brands are, according to their websites, examples that sell GOTS and/or Fairtrade certified apparel:

Threads 4 Thought, PACT, People Tree, ARMEDANGELS, Greenality, Bleed, Switcher, Synergy, Kuyichi, and Noctu, among many more.

Research Limitations

This research is a snapshot of current labels and requirements. Although several databases were used to collect the applicable labels, it still might be possible that some relevant labels were missed. This research does not look at the overall effectiveness of social and sustainable labels.

Sometimes the social label requirement evaluation was dependent on my own judgment; hence it could be that another researcher would decide differently. Research and recommendations exist that suggest labeling should move to indexing. The EU is already working on this. In the unlikely case that currently used labels would be replaced this might lower the significance of this paper. Furthermore, the indexing is currently focused on ecological criteria; hence, the social and socio-economic evaluation of the labels is still relevant.

As mentioned before, the textile supply chain is generally very complex and production processes can vary greatly depending on the product and manufacturing facility. On these grounds, this study should be used with caution and not be generalized. The baseline E-LCA is based on average data with simple processes. There are many factors that can affect the LCA outcome; the differences found between the base case blouses and sustainably labeled ones might vary significantly in other studies with thicker cotton threads, prints, different dyeing and/or manufacturing processes etcetera. A similar statement is true for the S-LCA. The assessment was done for textile

and apparel production in India based on general country and sector specific data. The S-LCA conducted with the adjusted risk of potential social issues based on a Fairtrade label guided these findings on main impacts of label criteria. The SHDB contains general data and were not granular enough to generate results on all existing label requirements; on the other hand, not all label requirements impacted social risks in the SHDB.

Conclusions

For this thesis I evaluated criteria of social and sustainable labels. These criteria were applied in a cotton blouses E-LCA and S-LCA to assess the differences compared to conventional cotton blouses produced in India and used in the USA.

Amongst the labels evaluated the Fairtrade Textile Standard was found to be the most comprehensive. It has a strong focus on workers and supplier relationships (small-scale producers). My research shows that there is room for improvement in regards to label requirements. First of all, the Fairtrade Textile Standard and other labels could expand the coverage of social issues to include topics such as avoidance of corruption and conflict, to also include the stakeholder “society”. Second, social risk for already covered subcategories such as injuries & fatalities, migrant and forced labor could be further reduced through additional requirements. The S-LCA was India-specific and the label evaluation was general, therefore no fixed ranking for the social labels was proposed due to potentially different outcomes depending on the country of appliance.

Eco and social labels are one movement that can drive a necessary shift in the textile and apparel industry towards sustainable practices. Many initiatives exist to work towards a sustainable textile and apparel industry. New innovations and technologies are

needed to efficiently recycle mixed garments.

Consumers play an important role and can reduce environmental impact considerably by washing less and line drying. Additionally, if consumers increase their demand for socially-responsible-produced-garments, it will help workers to increase their livelihood. Promoting the purchase of garments made from textiles, which can be recycled by current technologies, will help to reduce impact at end-of-life.

The cotton blouses E-LCA and S-LCA have shown that socially- and environmentally-labeled clothes have a positive impact compared to conventional blouses. The E-LCA results have shown that organic fertilizer usage can have a high environmental impact. Impact from energy usage plays also an important role in textile production; hence renewable energy usage should be encouraged. The S-LCA has shown reduced social risk, especially in subcategories with high social risk such as injuries & fatalities, gender equity, forced, and migrant labor. Not all label criteria could be matched with SHDB entries, hence not all criteria led to reduced social risk in the S-LCA.

This research shows specific areas where labels help to enhance livelihoods and reduce environmental impacts. Hopefully, this encourages end consumers to demand sustainable clothing. It should not be the case that another tragic incident such as the Rana Plaza collapse has to happen to keep consumers' attention on requesting further strengthening of social responsibility in product supply chains. We all can contribute to enhance work conditions and reduce social and environmental impacts along the textile supply chain with our daily purchasing choices.

Future research could assess the impacts of other social and sustainable labels through S-LCAs. Furthermore, social hotspots in countries with significant textile and

apparel production could be identified and paired with social labels that cover the hotspots. If future long-term trials on organic cotton could confirm higher yield than conventional cotton this would present another advantage for organic cotton.

Appendix 1

Input and Output Sets of E-LCA Life Cycle Inventory

Table 17. Outputs for Indian cotton fibers, ginned at farm (baseline).

▼ Outputs			
Flow	Category	Amount	Unit
F cotton fibres, ginned, at farm - IN		1.00000	kg
F Fluometuron	Emission to soil/agricultural	0.00023	kg
F Prometryn	Emission to soil/agricultural	0.00023	kg
F Nitrogen oxides	Emission to air/low population...	0.00108	kg
F Monocrotophos	Emission to soil/agricultural	8.29400E-5	kg
F Dinitrogen monoxide	Emission to air/low population...	0.00513	kg
F Imidacloprid	Emission to soil/agricultural	8.29400E-5	kg
F Cadmium	Emission to soil/agricultural	1.35300E-6	kg
F Heat, waste	Emission to air/low population...	1.95500	MJ
F Glyphosate	Emission to soil/agricultural	0.00023	kg
F Zinc	Emission to soil/agricultural	2.88480E-6	kg
F Lead	Emission to soil/agricultural	2.99590E-6	kg
F Ammonia	Emission to air/low population...	0.02074	kg
F Nickel	Emission to soil/agricultural	3.07330E-6	kg
F Copper	Emission to soil/agricultural	-4.46080E-8	kg
F Cyfluthrin	Emission to soil/agricultural	8.29400E-5	kg
F Trichlorfon	Emission to soil/agricultural	8.29400E-5	kg
F Chromium	Emission to soil/agricultural	9.26410E-5	kg
F Phosphorus	Emission to water/river	0.00039	kg
F Mercury	Emission to soil/agricultural	-6.23330E-8	kg
F Piperonyl butoxide	Emission to soil/agricultural	8.29400E-5	kg
F MSMA	Emission to soil/agricultural	0.00014	kg
F Phosphate	Emission to water/ground water	0.00012	kg
F Dicofol	Emission to soil/agricultural	8.29400E-5	kg
F Alachlor	Emission to soil/agricultural	0.00023	kg
F Phosphate	Emission to water/river	0.00039	kg
F Nitrate	Emission to water/ground water	0.08840	kg

Outputs stem from ecoinvent database in OpenLCA.

Table 18. Nitrogen emissions calculation for organic cotton cultivation.

Calculation of nitrogen emissions. Adopted from (Brentrup, Kuesters, Lammel, & Kuhlmann, 2000)	Value	Unit
Chicken slurry contains	8.7	N (kg/t)
Chicken slurry contains	6	NH4-N (kg/t)
Yield of IN organic fiber (82%) allocation of 87.2 included	1065	kg
Field needed for 1 kg cotton fiber	0.000938967	ha
Total organic fertilizer/manure applied (0,87% Nitrogen content)	6,896.55	kg
Total N applied (6,896.55 kg/100*0.87)	60.00	N kg / ha
Total NH4-N (6,896.55 kg/100*0.6)	41.38	NH4 -N kg / ha
Manure per kg cotton (0.000938967 ha*6,896.55 kg)	6.475633803	kg
N applied for 1 kg cotton fiber (60 * 0.000938967)	0.06	kg
Ammonia (NH3) application from compost/poultry manure for 1 kg cotton (41.38 * 0.000938967)	0.04	kg
Ammonia (NH3) emission to air (75% * 0.45 (4 h later irrigated) = 33.75% are released to air when temperature 15-20C, medium infiltration, irrigation and dry manure)	0.013113158	kg
N2O (Nitrous Oxide, Dinitrogen monoxide) emission to air for 1kg cotton. N2O emission factor = 0.0125. (0.06-0.0135*0.0125)	0.000540311	kg
N2-N emission to air ((Total N - Ammonia emission)*0.09)	0.003890237	
NO3 (Nitrate) emission to soil for 1kg cotton	0.038794308	kg
NO (Nitrogen Oxides) = 43% of fertilizer input	0.024225349	kg
CH4 for (1kg N) = 0.45 gram CH4	2.53521E-05	kg

Used for outputs in OpenLCA.

Table 19. Outputs for Indian cotton fibers, ginned, at farm - GOTS.

Outputs			
Flow	Category	Amount	Unit
F cotton fibres, ginned, at farm - GOTS IN		1.00000	kg
F Dinitrogen monoxide	Emission to air/low population density	0.00054	kg
F Heat, waste	Emission to air/low population density	2.86903	MJ
F Cadmium	Emission to water/fresh water	9.00000E-8	kg
F Methane	Emission to air/low population density	2.53521E-5	kg
F Chromium	Emission to water/fresh water	6.00000E-7	kg
F Arsenic	Emission to air/low population density	1.30000E-7	kg
F Ammonia	Emission to air/low population density	0.01311	kg
F Copper	Emission to water/fresh water	5.00000E-7	kg
F Nickel	Emission to water/fresh water	2.60000E-6	kg
F Nitrate	Emission to soil/agricultural	0.03879	kg
F Zinc	Emission to air/unspecified	5.00000E-7	kg
F Zinc	Emission to water/fresh water	1.30000E-6	kg
F Carbon dioxide	Emission to air/low population density	0.43500	kg
F Sulfur dioxide	Emission to air/low population density	0.00382	kg
F Nitrogen oxides	Emission to air/low population density	0.02423	kg

Ajusted dataset from ecoinvent database/OpenLCA.

Table 20. Inputs and outputs for cotton yarn production in India.

Inputs			
Flow	Category	Amount	Unit
electricity, low voltage, at grid - IN		8.50000	kWh
transport, lorry 16-32t, EURO3 - RER	transport systems/road	0.45000	t*km
packaging box production unit - RER	paper & cardboard/cardboard...	1.00000E-9	Item(s)
Outputs			
Flow	Category	Amount	Unit
yarn production, cotton fibers - IN		1.00000	kg
Heat, waste	Emission to air/unspecified	30.60000	MJ

Data applicable for both E-LCAs. Adapted from ecoinvent database in OpenLCA.

Table 21. Cotton weaving inputs and outputs.

Inputs			
Flow	Category	Amount	Unit
packaging box production unit - RER	paper & cardboard/cardboard...	1.00000E-9	Item(s)
electricity, low voltage, at grid - IN		7.07780	kWh
transport, lorry 16-32t, EURO3 - RER	transport systems/road	0.35000	t*km
transport, transoceanic freight ship - OCE	transport systems/ship	4.80000	t*km
electricity, low voltage, production RER, at grid - RER	electricity/production mix	3.03330	kWh
Outputs			
Flow	Category	Amount	Unit
weaving, cotton - IN		1.00000	kg
Heat, waste	Emission to air/unspecified	36.40000	MJ

Data applicable for both E-LCAs. Adapted from ecoinvent database in OpenLCA.

Table 22. Cotton textile refinement inputs and outputs (baseline).

Inputs				
Flow	Category	Amount	Unit	
F ₂ heat, light fuel oil, at industrial furnace 1MW - RER	oil/heating systems	30.54600	MJ	
F ₂ tap water, at user - RER	water supply/production	138.00000	kg	
F ₂ electricity, low voltage, at grid - IN		1.10917	kWh	
F ₂ treatment, sewage, to wastewater treatment, class 5 - CH	waste management/wastewate...	0.13800	m3	
F ₂ carboxymethyl cellulose, powder, at plant - RER	washing agents/auxiliary agents	0.01000	kg	
F ₂ chemical plant, organics - RER	chemicals/organics	1.00000E-10	Item(s)	
F ₂ alkylbenzene sulfonate, linear, petrochemical, at plant - RER	washing agents/tensides	0.01000	kg	
F ₂ sodium perborate, tetrahydrate, powder, at plant - RER	washing agents/bleaches	0.01000	kg	
F ₂ transport, lorry >16t, fleet average - RER	transport systems/road	0.25000	t*km	
F ₂ fatty alcohol sulfate, mix, at plant - RER	washing agents/tensides	0.01000	kg	
F ₂ sodium chloride, powder, at plant - RER	chemicals/inorganics	0.54700	kg	
F ₂ chemicals organic, at plant - GLO	chemicals/organics	0.13000	kg	
F ₂ heat, natural gas, at industrial furnace >100kW - RER	natural gas/heating systems	5.39050	MJ	

Outputs				
Flow	Category	Amount	Unit	Costs/Re
F ₂ textile refinement, cotton - IN		1.00000	kg	
F ₂ Heat, waste	Emission to air/unspecified	3.99300	MJ	

Adapted from ecoinvent database in OpenLCA (Ecoinvent, 2010).

Appendix 2

Label Evaluation by Subcategories

Table 23. Remaining risk per label standard and subcategory.

		Fairtrade Textile Standard		Global Organic Textile Standard (GOTS)		Fair Wear Foundation (FWF)		STeP part of Made in Green by OEKO-TEX		Fair for Life	
Stakeholder Group	Subcategories	low	medium	low	medium	low	medium	low	medium	low	medium
Stakeholder “worker”	Freedom of association and collective bargaining	6	4	2	2	3	0	3	4	3	3
	Child labor	3	3	5	1	3	0	7	0	2	2
	Fair salary	6	3	2	1	2	1	4	2	3	4
	Working hours	3	4	2	0	3	0	2	3	2	2
	Forced labor	4	0	4	0	2	0	5	1	5	0
	Equal opportunities/discrimination	5	2	5	0	2	0	7	1	4	3
	Health and safety worker	14	3	9	0	2	1	9	4	11	4
	Social benefits/social security	4	5	1	1	1	0	2	2	3	3
	Commitment to Voluntary	3	1	1	0	0	0	1	0	3	0

	Sustainability Standards (VSS) / Labels											
	Capacity building	4	2	0	0	0	0	3	0	0	0	0
	Worker rights	1	0	0	1	0	0	1	0	1	0	0
Stakeholder “consumer”	Health and safety consumer	0	0	0	0	0	0	0	0	0	0	0
	Feedback mechanism	0	0	0	0	0	0	1	0	0	0	0
	Consumer privacy	0	0	1	0	0	0	0	0	0	0	0
	Transparency	2	0	2	0	1	0	2	0	3	0	0
	Governance	0	0	0	0	0	0	0	0	0	0	0
	End of life responsibility	0	0	0	0	0	0	0	0	0	0	0
Stakeholder “local community”	Access to material resources	1	0	2	0	0	0	1	0	0	0	0
	Access to immaterial resources	0	0	0	0	0	0	0	0	0	0	1
	Delocalization and migration	0	0	0	0	0	0	0	0	1	0	0
	Cultural heritage	0	0	0	0	0	0	0	0	0	0	1
	Safe and healthy living conditions	1	0	1	0	0	0	0	0	0	0	1
	Respect of indigenous rights	0	0	0	0	0	0	0	0	0	0	0
	Community engagement	0	1	0	0	0	0	0	1	0	0	0
	Local employment	0	0	0	0	0	0	0	0	1	1	1
	Secure living conditions	0	0	0	0	0	0	0	0	0	0	0
Stakeholder “society”	Public commitments to sustainability issues	0	0	0	0	0	0	1	1	1	0	0

	Contribution to economic development	0	0	0	0	0	0	0	0	0	0
	Prevention and mitigation of armed conflicts	0	0	0	0	0	0	0	0	0	0
	Technology development	0	0	0	0	0	0	0	0	0	0
	Corruption	0	0	1	0	0	0	1	0	0	0
Value chain actors* (not including consumers)	Fair competition	0	0	0	0	0	0	1	0	0	0
	Promoting social responsibility	1	1	0	0	0	0	1	0	0	0
	Supplier relationships	10	4	3	0	0	0	2	0	10	2
	Buyer relationships	1	0	0	0	0	0	0	0	1	0
	Supplier relationships/Transparency	1	0	0	0	0	0	0	0	1	0
	Respect of intellectual property rights	0	0	0	0	0	0	0	0	0	0
	Management	3	3	2	0	0	0	4	1	2	3
	Management / labor rights	0	0	0	0	0	0	1	0	0	0
	HR Management / labor rights	0	0	0	0	0	0	1	0	1	0
	Management / Legal	0	0	0	0	0	0	1	0	0	1
	Collaboration	2	1	0	0	0	0	0	1	1	2
	Hazardous substances	1	1	0	0	0	0	0	0	0	0
	Wastewater	0	1	1	0	0	0	1	0	1	0
	(Waste) water	0	0	0	1	0	0	0	1	0	1
Emissions to Air	1	1	0	0	0	0	1	0	0	1	
Energy consumption	0	1	0	0	0	0	1	0	0	1	

Waste	2	1	0	0	0	0	2	0	2	0
Packaging, Storage Transport	0	0	1	0	0	0	1	0	0	1
Product Design	0	0	0	0	0	0	0	0	0	0
Legal System	0	0	0	0	0	0	0	1	0	0

Table shows how many label criteria reduced the remaining risk to low and medium per evaluated subcategory.

Appendix 3

Original SHDB Social Risks entries for the Indian Textile Sector

Table 24. Original SHDB social theme risk entry and changed entry.

Social Theme	Original SHDB entry	Comment	Changed Yes/No	New SHDB entry	Reason for change; Fairtrade / Flocert criteria
Wage Assessment	Wage below Minimum Wage:HR		Yes	Wage below Minimum Wage:MR	3.5.0.01 3.5.0.03
Poverty	Poverty: Wages being under \$2 per day:VH		Yes	Poverty: Wages being under \$2 per day:MR	3.5.0.05
Forced Labor	ILO's FL Regional estimates:VH		Yes	ILO's FL Regional estimates:LR	3.2.0.01
Forced Labor	FL in Country (qualitative): VH		Yes	FL in Country (qualitative): LR	3.2.0.01
Forced Labor	FL by Sector:VH		Yes	ILO's FL Regional estimates:LR	3.2.0.01
Child Labor	Child labor (qualitative):VH		Yes	Child labor (qualitative):LR	3.3.0.01
Child Labor	Child labor (quantitative):VH	% in cty total	Yes	Child labor (quantitative):LR	3.3.0.01
Working Time	Excessive working time by sector:VH		Yes	Excessive working time by sector:LR	3.5.0.18 3.5.0.19
Freedom of Association	No freedom of Association rights:MR		Yes	No freedom of Association rights:LR	3.4.0.09 3.4.0.10
Migrant Labor	Women immigrants not		Yes	Women immigrants not	3.5.0.07

Social Theme	Original SHDB entry	Comment	Changed Yes/No	New SHDB entry	Reason for change; Fairtrade / FloCERT criteria
	accepted:MR			accepted:LR	
Migrant Labor	Migrant Workers treated unfair(qualitative):VH		Yes	Migrant Workers treated unfair(qualitative):MR	2.1.0.07
Occupational Health&Safety	fatal injuries by country:VH		Yes	fatal injuries by country:LR	3.6.0.01
Occupational Health&Safety	non-fatal injuries by sector:VH		Yes	non-fatal injuries by sector:LR	3.6.0.12, 3.6.0.13
Occupational Health&Safety	fatal injury by sector:VH		Yes	fatal injury by sector:LR	3.6.0.01
OHS occupational toxics&Hazards	Noise exp to males-indicator1:MR	85-90 dBA	Yes	Noise exp to males-indicator1:LR	3.6.0.32, 3.6.0.33, 3.6.0.34, 3.6.0.35, 3.6.0.36
OHS occupational toxics&Hazards	Noise exp to females-indicator1:MR	85-90 dBA	Yes	Noise exp to females-indicator1:LR	3.6.0.32, 3.6.0.33, 3.6.0.34, 3.6.0.35, 3.6.0.36
OHS occupational toxics&Hazards	Overall noise exp. Both genders:MR		Yes	Overall noise exp. Both genders:LR	3.6.0.32, 3.6.0.33, 3.6.0.34, 3.6.0.35, 3.6.0.36

OHS occupational toxics&Hazards	Risk of loss of life years by mesothelioma:HR		Yes	Risk of loss of life years by mesothelioma:MR	3.6.0.15, 3.6.0.16, 3.6.0.18, 3.6.0.20, 3.6.0.31
OHS occupational toxics&Hazards	Overall loss of life year exposure to carcinogens:VH		Yes	Overall loss of life year exposure to carcinogens:MR	3.6.0.15, 3.6.0.16, 3.6.0.18, 3.6.0.20, 3.6.0.31
OHS occupational toxics&Hazards	Overall risk of death due to exposure to carcinogens:HR		Yes	Overall risk of death due to exposure to carcinogens:MR	3.6.0.15, 3.6.0.16, 3.6.0.18, 3.6.0.20, 3.6.0.31
OHS occupational toxics&Hazards	Risk of loss of life years by asthma due to airborne particulates:VH		Yes	Risk of loss of life years by asthma due to airborne particulates:MR	3.6.0.15, 3.6.0.16, 3.6.0.18, 3.6.0.20, 3.6.0.31
OHS occupational toxics&Hazards	Risk of loss of life years by (heart disease) pulmonary disease due to airborne particulates:VH		Yes	Risk of loss of life years by (heart disease) pulmonary disease due to airborne particulates:MR	3.6.0.15, 3.6.0.16, 3.6.0.18, 3.6.0.20, 3.6.0.31
OHS occupational toxics&Hazards	Risk of loss of life years by asbestosis due to airborne particulates:HR		Yes	Risk of loss of life years by asbestosis due to airborne particulates:MR	3.6.0.15, 3.6.0.16, 3.6.0.18, 3.6.0.20, 3.6.0.31
OHS occupational toxics&Hazards	Risk of loss of life years by silicosis due to airborne particulates:HR		Yes	Risk of loss of life years by silicosis due to airborne particulates:MR	3.6.0.15, 3.6.0.16, 3.6.0.18,

					3.6.0.20, 3.6.0.31
OHS occupational toxics&Hazards	Risk of loss of life years by airborne particulates:VH		Yes	Risk of loss of life years by airborne particulates:MR	3.6.0.15, 3.6.0.16, 3.6.0.18, 3.6.0.20, 3.6.0.31
Gender Equity	World Economic Forum's Global Gender Gap:VH		Yes	World Economic Forum's Global Gender Gap:LR	3.5.0.07
Gender Equity	Cingranelli-Richards HR dataset indicator 1:HR	economic	Yes	Cingranelli-Richards HR dataset indicator 1:LR	3.5.0.07
Gender Equity	Overall risk of gender inequality in country:VH		Yes	Overall risk of gender inequality in country:LR	3.5.0.07
Human Health - Non Communicable Diseases	Respiratory diseases:VH		Yes	Respiratory diseases:LR	3.6.0.07, 3.6.0.37
Community Infrastructure	No access to improved drinking water total:MR		Yes	No access to improved drinking water total:LR	3.6.0.58, 3.6.0.59, 3.6.0.60, 3.6.0.61, 3.6.0.62, 3.6.0.63, 3.6.0.64
Community Infrastructure	No access to improved sanitation total:HR		Yes	No access to improved sanitation total:MR	3.6.0.58, 3.6.0.59, 3.6.0.60, 3.6.0.61, 3.6.0.62, 3.6.0.63, 3.6.0.64
Social Benefits	Risk of unpaid or inadeq. Paid sick leave:VH		Yes	Risk of unpaid or inadeq. Paid sick leave:MR	3.5.0.28, 3.5.0.30

Social Benefits	Risk of unpaid or inadeq. Paid maternity leave:VH		Yes	Risk of unpaid or inadeq. Paid maternity leave:LR	3.5.0.34, 3.5.0.38
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The table shows the original SHDB social issue entries for the Indian textile sector. The column ‘new SHDB entry’ illustrates the social risk after applying a social label. This entry was used for the 2nd S-LCA.

Appendix 4

Label Criteria and Evaluation of remaining Risks

Excerpt from the Fairtrade Textile Standard label evaluation for the ‘worker’ stakeholder group and the subcategory ‘freedom of association and collective bargaining’. The column ‘specific analysis’ shows criteria from the UNEP/SETAC methodology sheets. In case a criterion is a different color than black, it was added based on a label standard requirement. The column ‘original requirement text’ shows, in this case, requirements from the Fairtrade Textile Standard. This label requirement was then evaluated based on its potential social risk reduction. The table also gives information on due date of requirement and where it can be found in the standard. The Cradle to Cradle Standard was evaluated at the silver level. For the Fair for Life Standard a large company was assumed and level/score ‘2’ of compliance.

Table 25. Label criteria compared to UNEP/SETAC analysis.

Criteria from UNEP/SETAC methodology	Fairtrade Textile Standard / Control No 5.1 = Trader Standard				
Specific Analysis	Due in (years)	Criteria (C = Core, M = Major, D =Develop mt)	Original Requirement text (FLOCERT)	Remaining risk (high, moderate or low)	Control number in Std
Employment is not conditioned by any restrictions on the right to collective bargaining	0	M	1. You do not punish, threaten, intimidate, harass or bribe union members or representatives, nor discriminate against workers for their past or present union membership or activities. 2. You do not base your hiring on not joining or giving up union membership.	low	3.4.0.09 3.4.0.10
Presence of unions within the organization is adequately supported (availability of facilities to union, posting of union notices, time to exercise the representation functions on paid work hours)	0	M	1. There is a form of democratically elected and independent workers' organization established to represent workers in the company and negotiate with management. 2. You respect the right of workers to bargain collectively in practice.	moderate	3.4.0.01 3.4.0.04
Check the	0	C	1. You accept your duty to bargain in good faith	low	3.4.0.05

availability of collective bargaining agreement and meeting minutes (e.g. copies of collective bargaining negotiations and agreements are kept on file)			with unions 2. Workers are allowed to take the initiative themselves and are allowed to organize independently of management. 3. You have not opposed any of these rights in the last 2 years prior to application for certification, unless there is proof that the circumstances have changed.		3.4.0.06 3.4.0.08
Workers are free to join unions of their choosing. Workers are free to form and organize unions.	0	M	1. You respect the rights of workers to form or join unions. 2. You do not make any statements or offer or take any actions which interfere with (or seek to influence) worker's choice to form or join a trade union.	low	3.4.0.03 3.4.0.11
Employee/union representatives are invited to contribute to planning of larger changes in the company, which will affect the working conditions	0	C	1. You respect the self-organization of workers by engaging with representatives of these organizations through regular dialogue. 2. You do not interfere in any way with formation, elections, recognition or governance of the trade unions. 3. Only applicable in situations where workers are not represented by a trade union recognized for collective bargaining with your company). You allow representatives of trade union organizations that represent workers in the sector or region to meet with workers in order to communicate about unionisation and/or to carry out their representative functions at an agreed and reasonable time and place. Workers may choose the place to meet with these trade	moderate	3.4.0.02 3.4.0.07 3.4.0.16 3.4.0.17 3.4.0.18

		<p>union representatives, on company premises or at any other location.</p> <p>4. You allow access to trade union representatives representing workers in the workplace in order to communicate about unionisation and/or to carry out their representative functions at an agreed time and place.</p> <p>5. You do not interfere in any way with, nor conduct any surveillance of the meetings with the trade union representatives.</p>			
<p>Written commitment to Freedom of Association and communication to workforce including local trade union contacts.</p>	1	C	<p>1. You have signed the Freedom of Association protocol provided by Fairtrade International in Annex 3 to the Hired Labour Standard.</p> <p>2. (Only applicable if the ownership or senior management of a company changes) The FoA protocol is signed by the new owners / management within 3 months.</p> <p>3. The Workers' Right to Unionise Guarantee', which is included in the Freedom of Association protocol, has been communicated to workers by</p> <ul style="list-style-type: none"> • having it translated into the appropriate local languages • having it translated in to appropriate pictograms for the illiterate workers and by having it displayed publically in the workplace <p>4. (Only applicable if there is no union present in the workplace) You provide information and contact details of 'local point of contact' of trade unions. It is displayed publicly in the workplace in local languages and pictograms easily understandable by the workers.</p>	<p>low</p>	<p>3.4.0.12</p> <p>3.4.0.13</p> <p>3.4.0.14</p> <p>3.4.0.15</p>

Trade union/elected worker representatives have access to all workers and can meet frequently	0	C	<p>1. You ensure that trade union/elected worker representatives have access to all workers in the workplace during working time without interference or the presence of management representatives and at agreed times, on average one hour in every three months.</p> <p>2. You ensure that elected worker representatives can meet among themselves during regular working hours, at least once a month for one hour.</p> <p>3. You ensure that elected worker representatives meet with representatives of senior management during working hours at least once every 3 months.</p> <p>4. Meetings between elected worker representatives and representatives of senior management are scheduled on a regular basis and are documented.</p>	low	<p>3.4.0.19</p> <p>3.4.0.20</p> <p>3.4.0.21</p> <p>3.4.0.22</p>
Collective Bargaining Agreement (CBA) has been agreed to where applicable and terms include at least sector-wide CBA terms	1	C	<p>1. (Only applicable in countries where a Collective Bargaining Agreement (CBA) is agreed for the textile sector) You have signed and adhere to this agreement.</p> <p>2. (Only applicable in countries where a CBA is agreed for the textile sector and your company has a separate CBA at company level) The company level CBA agreements do not provide lesser terms and conditions than the sector-wide CBA agreement.</p>	moderate	<p>3.4.0.23</p> <p>3.4.0.24</p>

Number/percentage of pro-active engagements in negotiations of a collective agreement and numbers/percentage of refused collective bargain opportunities	0	C	<p>1. (Only applicable if there is no sectoral or company level CBA in place) You proactively engage in a process of negotiations with a recognized trade union or with legally authorised worker representatives to enter into a collective agreement.</p> <p>2.(Only applicable if there is no sectoral/company level CBA in place) You have not refused any genuine opportunity to bargain collectively with workers.</p>	moderate	3.4.0.25 3.4.0.26
Absence of collective bargaining is due to free will of workers	0	C	<p>(Only applicable in cases where workers have freely and specifically decided to not form or join a trade union and are not otherwise legally authorized to collectively bargain, then the collective bargaining requirement is waived) (Not applicable if there are no unions active in the sector/region or the workers have joined unions that can take part in CBA) You have not used any intimidation or coercion to make workers take this decision. The decision is not the result of any vote in which management was in any way involved.</p>	low	3.4.0.27

References

- Aden, N., Marty, A., & Muller, M. (2010). Comparative Life-cycle Assessment of Non-fossil Electricity Generation Technologies: China 2030 Scenario Analysis.
- Adidas AG. (n.d.). Innovation. Retrieved November 2, 2017, from <https://www.adidas-group.com/en/sustainability/products/sustainability-innovation/>
- Areppim AG. (2017). Converter of current to real US dollars. Retrieved December 31, 2017, from http://stats.areppim.com/calc/calc_usdlrxdeflator.php
- Austgulen, M. H., Stø, E., & Jatkar, A. (2013). *The dualism of eco-labels in the global textile market. An integrated Indian and European perspective I*. Oslo, Jaipur. Retrieved from http://www.global-standard.org/media/com_acymailing/upload/ecolabels__2013_paper__es__194.pdf
- Avery Dennison. (2016). Avery Dennison and EVERYTHING Switch on the Apparel Industry with 10 Billion Products in World's Largest IoT Deployment. Retrieved January 1, 2017, from <http://news.averydennison.com/press-release/corporate/avery-dennison-and-evrythng-switch-apparel-industry-10-billion-products-worl>
- Baumann, H., & Tillman, A.-M. (2004). *The Hitch Hiker's Guide to LCA. An orientation in life cycle assessment methodology and application*. Lund, Sweden: Studentlitteratur AB.
- Benoît Norris, C. (2014). Data for social LCA. *International Journal of Life Cycle Assessment*, 19(2), 261–265. <https://doi.org/10.1007/s11367-013-0644-7>
- Benoît Norris, C., Norris, G. A., & Aulision-Cavan, D. (2015). Social hotspots database - Supporting documentation. *New Earth*. <https://doi.org/10.1093/carcin/bgs054>
- Berger, D. (2001). II. Thermodynamic systems. Retrieved February 17, 2018, from http://www.bluffton.edu/homepages/facstaff/bergerd/nsc_111/thermo2.html
- Beton, A., Dias, D., Farrant, L., Gibon, T., Desaxce, M., Perwuelz, A., ... Dodd, N. (2014). *Environmental Improvement Potential of textiles (IMPRO Textiles)*. Luxembourg: Publications Office of the European Union. <https://doi.org/10.2791/52624>
- Big Room Inc. (2016). Ecolabel Index. Retrieved November 6, 2016, from http://www.ecolabelindex.com/ecolabels/?search=textile&as_values_091=
- BIO Intelligence Service. (2012). *Study on different options for communicating environmental information for products*. Paris, France.

- Bremen Cotton Exchange. (2017). Indian Cotton Sales. Retrieved December 31, 2017, from <https://baumwollboerse.de/en/2015/01/30/indian-cotton-sales/>
- Brentrup, F., Kuesters, J., Lammel, J., & Kuhlmann, H. (2000). Methods to Estimate On-Field Nitrogen Emissions from Crop Production as an Input to LCA Studies in the Agricultural Sector. *International Journal of Life Cycle Assessment*, 5(6), 349–357. <https://doi.org/10.1007/BF02978670>
- Center for Global Trade Analysis. (2013). GTAP Data Bases: Detailed Sectoral List. Retrieved January 1, 2018, from <https://www.gtap.agecon.purdue.edu/databases/contribute/detailedsector.asp>
- Clean Clothes Campaign. (n.d.). A Living Wage = A Human Right. Retrieved January 15, 2018, from <https://cleanclothes.org/livingwage>
- Coal Controller's Organisation. (2017). *Coal Directory of India 2015-16 - Coal Statistics*. Kolkata, India. Retrieved from [http://www.coalcontroller.gov.in/writereaddata/files/Coal Directory of India 2015-16.pdf](http://www.coalcontroller.gov.in/writereaddata/files/Coal%20Directory%20of%20India%202015-16.pdf)
- Cotton Incorporated. (2012). *The Life Cycle Inventory & Life Cycle Assessment of Cotton Fiber & Fabric Executive Summary*. Retrieved from <http://www.cottonleads.org/wp-content/uploads/Cotton-LCI-LCA-Executive-Summary.pdf>
- Cotton Incorporated. (2017). *LCA Update of Cotton Fiber and Fabric Life Cycle Inventory*. Cary, NC. Retrieved from <http://resource.cottoninc.com/LCA/2016-LCA-Full-Report-Update.pdf>
- D'Ambrogio, E. (2014). Workers' conditions in the textile and clothing sector : just an Asian affair? Issues at stake after the Rana Plaza tragedy. *European Parliament Research Service*. European Parliament. Retrieved from <http://www.europarl.europa.eu/EPRS/140841REV1-Workers-conditions-in-the-textile-and-clothing-sector-just-an-Asian-affair-FINAL.pdf>
- Ecoinvent. (n.d.). FAQs - What does an ordinary dataset look like? Retrieved November 14, 2017, from <http://www.ecoinvent.org/support/faqs/first-time-users/what-does-an-ordinary-dataset-look-like.html>
- Ecoinvent. (2010). ecoinvent 2.2 and onwards. Retrieved August 11, 2017, from <https://www.ecoinvent.org/database/older-versions/ecoinvent-version-2/ecoinvent-version-2.html>
- EcoTopTen. (2013). Siegel, die faire und / oder soziale Aspekte entlang der textilen Kette berücksichtigen. Retrieved October 2, 2017, from https://www.ecotopten.de/sites/default/files/ecotopten_textilien_labeluebersicht_0.pdf

- Energy Star. (2016). Energy Star Certified. Residential Clothes Washers. Samsung - WF45M55**A*. Retrieved November 11, 2017, from <https://www.energystar.gov/productfinder/product/certified-clothes-washers/details/2284808>
- European Commission. (2013). Commission Recommendation 2013/179/EU on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations. *Official Journal of European Union*, (L 124), 210. https://doi.org/doi:10.3000/19770677.L_2013.124.eng
- European Commission. (2016). *Product Environmental Footprint Pilot Guidance. Guidance for the implementation of the EU Product Environmental Footprint (PEF) during the Environmental Footprint (EF) pilot phase. Version 5.2*. Retrieved from http://ec.europa.eu/environment/eussd/smgp/pdf/Guidance_products.pdf
- Eyhorn, F., Ratter, S., & Ramakrishnan, M. (2005). Organic Cotton Crop Guide - A manual for practitioners in the tropics, pp.20. Retrieved from http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=pubmed&cmd=Retrieve&dopt=AbstractPlus&list_uids=3340393187889757828related:hL5N_ud1Wy4J%5Cnhttp://www.fibl.net/english/cooperation/projects/documents/cotton-guide-small.pdf
- Fair Wear Foundation. (2016). India Country Study 2016, p.5,p.27,p.36. Retrieved from <https://www.fairwear.org/wp-content/uploads/2016/09/CS-India-2016.pdf>
- Fairtrade International. (2011). Fairtrade Standard for Small Producer Organizations, 1–48. Retrieved from http://www.fairtrade.net/fileadmin/user_upload/content/2009/standards/documents/2011-08-12_SPO_Honey_EB.pdf
- Fairtrade International. (2016a). Fairtrade Textile Standard. *Fairtrade Standards Library*, p.5, 52. Retrieved from www.fairtrade.net/standards.html
- Fairtrade International. (2016b). Introducing the Fairtrade Textile Standard. Part of a comprehensive approach together with the Fairtrade Textile Programme to empower workers and improve wages and working conditions in the textile industry, (March), 1–3.
- Fairtrade International. (2017). Living Wage. Explanatory document for Fairtrade Textile Standard, p.4. Retrieved from https://www.fairtrade.net/fileadmin/user_upload/content/2009/standards/documents/2017-02-24_Living_wage_explanatory_document_Textile_EN.pdf
- Flocert. (n.d.). Fairtrade Certification. Retrieved February 25, 2018, from <https://www.flocert.net/solutions/standard-assurance/fairtrade-certification/>

- Forster, D., Andres, C., Verma, R., Zundel, C., Messmer, M. M., & Mäder, P. (2013). Yield and Economic Performance of Organic and Conventional Cotton-Based Farming Systems - Results from a Field Trial in India. *PLOS ONE*, 8(12), 4. <https://doi.org/10.1371/journal.pone.0081039>
- Global Standard gGmbH. (2017). Global Organic Textile Standard. Version 5.0. Retrieved from <http://www.global-standard.org/the-standard/latest-version.html>
- Golden, J. S., Dooley, K. J., Anderies, J. M., Thompson, B. H., Gereffi, G., & Pratson, L. (2010). Sustainable Product Indexing: Navigating the Challenge of Ecolabeling. *Ecology and Society*, 15(3). <https://doi.org/8>
- Golden, J. S., Vermeer, D., Clemen, B., Noyes, C., & Akella, A. (2010). An Overview of Ecolabels and Sustainability Certifications in the Global Marketplace An Overview of Ecolabels and Sustainability Certifications in the Global Marketplace. *Corporate Sustainability Initiative - Nicholas Institute for Environmental Policy Solutions at Duke University*, 1(10), 1–99. <https://doi.org/10.1002/uog.10110>
- Gould, H. (2015). Waste is so last season: recycling clothes in the fashion industry. Retrieved November 3, 2017, from <https://www.theguardian.com/sustainable-business/sustainable-fashion-blog/2015/feb/26/waste-recycling-textiles-fashion-industry>
- Greenpeace. (2016a). *Textil-Label unter der Detox-Lupe. Einkaufsratgeber fuer giftfreie Kleidung*. Hamburg, Germany. Retrieved from https://www.greenpeace.de/sites/www.greenpeace.de/files/greenpeace_textil-label-juni_2016.pdf
- Greenpeace. (2016b). *Timeout for fast fashion*. Hamburg, Germany. Retrieved from <http://www.greenpeace.org/international/Global/international/briefings/toxics/2016/Fact-Sheet-Timeout-for-fast-fashion.pdf>
- Grolleau, G., Ibanez, L., Mzoughi, N., & Teisl, M. (2016). Helping eco-labels to fulfil their promises. *Climate Policy*, 16(June), 792–802. <https://doi.org/10.1080/14693062.2015.1033675>
- Grubert, E. (2016). Rigor in social life cycle assessment: improving the scientific grounding of SLCA. *International Journal of Life Cycle Assessment*, 1–11. <https://doi.org/10.1007/s11367-016-1117-6>
- Gunther, M. (2016). Despite the Sustainable Apparel Coalition, there's a lot you don't know about that T-shirt. Retrieved January 7, 2017, from <https://www.theguardian.com/sustainable-business/2016/jun/14/sustainable-apparel-coalition-factory-environment-water-textiles>
- Henninger, C. E. (2015). Traceability the new eco-label in the slow-fashion industry?-

- Consumer perceptions and micro-organisations responses. *Sustainability (Switzerland)*, 7(5), 6011–6032. <https://doi.org/10.3390/su7056011>
- Inditex. (n.d.). Collect, Reuse, Recycle. Retrieved January 14, 2018, from <https://www.inditex.com/en/our-commitment-to-the-environment/closing-the-loop/collect-reuse-recycle>
- International Energy Agency. (2015). *India Energy Outlook. World Energy Outlook Special Report*. Paris Cedex, 15, France. Retrieved from http://www.worldenergyoutlook.org/media/weowebiste/2015/IndiaEnergyOutlook_WEO2015.pdf
- International Federation of Organic Agriculture Movements. (2014). *The IFOAM Norms for Organic Production and Processing*. Retrieved from https://www.ifoam.bio/sites/default/files/ifoam_norms_july_2014_t.pdf
- International Labour Organization. (2015). Labour standards in global supply chains. A programme of action for Asia and the garment sector. Strong export and job growth in Asia's garment and footwear sector, (October), 1–8. Retrieved from http://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/documents/publication/wcms_419798.pdf
- International Labour Organization. (2017). Up-to-date Conventions and Protocols not ratified by India. Retrieved January 18, 2018, from http://www.ilo.org/dyn/normlex/en/f?p=1000:11210:0::NO:11210:P11210_COUNT_RY_ID:102691
- International Organization for Standardization. (2006). International Standard ISO 14040. Environmental management — Life cycle assessment — Principles and framework. *Bmj*. Geneva, Switzerland: The International Standards Organisation. <https://doi.org/10.1136/bmj.332.7550.1107>
- International Organization for Standardization. (2010). ISO 26000, pp.6. Retrieved from https://www.iso.org/files/live/sites/isoorg/files/archive/pdf/en/iso_26000_project_overview-es.pdf
- International Organization for Standardization. (2012). Environmental labels and declarations. How ISO standards help. Retrieved January 2, 2017, from <http://www.iso.org/iso/environmental-labelling.pdf>
- International Organization for Standardization. (2016). ISO 14021:2016(en) Environmental labels and declarations – Self declared environmental claims (Type II Environmental labelling). Retrieved February 3, 2017, from <https://www.iso.org/standard/66652.html>
- International Trade Centre. (2015). Welcome to Standards Map. Retrieved November 19,

- 2016, from <http://standardsmap.org/identify>
- Kang, J., Liu, C., & Kim, S. H. (2013). Environmentally sustainable textile and apparel consumption: The role of consumer knowledge, perceived consumer effectiveness and perceived personal relevance. *International Journal of Consumer Studies*, 37(4), 442–452. <https://doi.org/10.1111/ijcs.12013>
- King, B. (2012). Consumers Want More Eco-Friendly Apparel. Retrieved January 15, 2017, from http://www.sustainablebrands.com/news_and_views/articles/consumers-want-more-eco-friendly-apparel
- Körber, A. (1998). Why everybody loves Flipper: the political-economy of the U.S. dolphin-safe laws. *European Journal of Political Economy*, 14(3), 475–509. [https://doi.org/10.1016/S0176-2680\(98\)00018-4](https://doi.org/10.1016/S0176-2680(98)00018-4)
- Koszewska, M. (2015). Life Cycle Assessment and the Environmental and Social Labels in the Textile and Clothing industry. In S. S. Muthu (Ed.), *Handbook of Life Cycle Assessment (LCA) of Textiles and Clothing* (pp. 325–342). Cambridge, UK: Woodhead Publishing.
- Kujanpää, M., & Nors, M. (2014). *Environmental performance of future digital textile printing*. Espoo, Finland. Retrieved from <http://www.vtt.fi/inf/julkaisut/muut/2014/VTT-CR-04462-14.pdf>
- Lenzo, P., Traverso, M., Salomone, R., & Ioppolo, G. (2017). Social Life Cycle Assessment in the Textile Sector: An Italian Case Study. *Sustainability*, 9(11), 2092. <https://doi.org/10.3390/su9112092>
- Levi Strauss & Co. (2015). The Life Cycle Of A Jean. Understanding the environmental impact of a pair of Levi's 501 jeans. Retrieved January 7, 2017, from <http://levistrauss.com/wp-content/uploads/2015/03/Full-LCA-Results-Deck-FINAL.pdf>
- Locke, R. M. (2013). The Promise and Perils of Private Compliance Programs. In *The Promise and Limits of Private Power - Promoting Labor Standards in a Global Economy* (pp. 24–45). New York: Cambridge University Press.
- Lopez-Acevedo, G., & Robertson, R. (2016). Apparel in South Asia. Based on the “Stitches to Riches” report. Retrieved December 12, 2017, from <http://documents.worldbank.org/curated/en/733041475749696084/text/108829-WP-P146865-Apparel-PUBLIC.txt>
- Ludvigsen, L., & Zeuthen, J. (2016). Strengthening the “Connecting Thread”: Engaging Consumers with Purposeful Brands in the Fashion and Apparel Value Chain. Retrieved January 13, 2017, from http://www.sustainablebrands.com/digital_learning/slideshow/products_design/stren

gthening_“connecting_thread”_engaging_consumers_purp

- McKinsey&Company. (2016). Style that’s sustainable: A new fast-fashion formula. Retrieved September 14, 2017, from <http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/style-thats-sustainable-a-new-fast-fashion-formula?cid=sustainability-eml-alt-mip-mck-oth-1610>
- Meyer, M. (2014). Chemical cotton. Retrieved November 2, 2017, from <https://rodaleinstitute.org/chemical-cotton/>
- Morales, B., & Vuerich, M. (2014). *Keep the EU Flower a label of environmental excellence. European Environmental Bureau* (Vol. 32). <https://doi.org/ANEC-SUST-2014-G-020> –
- Muthu, S. S. (2015). Environmental impacts of the use phase of the clothing life cycle. In S. S. Muthu (Ed.), *Handbook of Life Cycle Assessment (LCA) of Textiles and Clothing* (pp. 93–102). Cambridge, UK: Woodhead Publishing. <https://doi.org/10.1016/B978-0-08-100169-1.00005-8>
- Muthu, S. S., Li, Y., Hu, J. Y., & Ze, L. (2012). Carbon footprint reduction in the textile process chain: Recycling of textile materials. *Fibers and Polymers*, 13(8), 1065–1070. <https://doi.org/10.1007/s12221-012-1065-0>
- OECD Environment Directorate. (2016). Environmental Labelling and Information Schemes. Policy Perspectives, p.6, 8. Retrieved from <https://www.oecd.org/env/policy-perspectives-environmental-labelling-and-information-schemes.pdf>
- Patagonia. (2011). Don’t Buy This jacket. Retrieved February 11, 2018, from http://patagonia.typepad.com/files/nyt_11-25-11.pdf
- Pesonen, H. L., & Benoît Norris, C. (2014). Parallel Life Cycle Methods. In R. Schenck & P. White (Eds.), *Environmental Life Cycle Assessment: Measuring the Environmental Performance of Products*. Vashon Island, WA: American Center for Life Cycle Assessment.
- ReCiPe. (n.d.). Methodology. Quick introduction into ReCiPe LCIA Methodology. Retrieved January 5, 2018, from <https://sites.google.com/site/lciarecipe/project-definition>
- ReCiPe. (2010). Normalisation. Retrieved January 6, 2018, from <https://sites.google.com/site/lciarecipe/normalisation>
- ReCiPe. (2012). Characterisation. ReCiPe Mid/Endpoint method, version 1.08. Retrieved January 5, 2018, from <https://sites.google.com/site/lciarecipe/characterisation-and->

normalisation-factors

- Retail Forum for Sustainability. (2013). *Sustainability of textiles. Issue Paper* (Vol. 11). Retrieved from http://ec.europa.eu/environment/industry/retail/pdf/issue_paper_textiles.pdf
- Reuters. (2015). Fashion chain H&M offers \$1m recycling prize for reusable clothing. Retrieved January 12, 2017, from <https://www.theguardian.com/fashion/2015/aug/25/fashion-chain-hm-offers-1m-recycling-prize-for-reusable-clothing>
- Rodrigue, J.-P. (1998). *The Geography of Transport Systems. Freight Transport Costs per Ton-Mile* (in 1995 dollars). Retrieved from <https://people.hofstra.edu/geotrans/eng/ch3en/conc3en/modaltransportcosttonmile.html>
- Roos, S., Zamani, B., Sandin, G., Peters, G. M., & Svanström, M. (2016). A life cycle assessment (LCA)-based approach to guiding an industry sector towards sustainability: the case of the Swedish apparel sector. *Journal of Cleaner Production*, 133, 691–700. <https://doi.org/10.1016/j.jclepro.2016.05.146>
- RyanPartnershipChicago. (2012). Styling Sustainability - What's en vogue when it comes to eco-fashion? Retrieved from http://www.sustainablebrands.com/digital_learning/research/styling-sustainability
- Samsung. (2017). Washer - User manual WF45M5500A. Retrieved from http://downloadcenter.samsung.com/content/UM/201706/20170616171850756/WF5500M-03773A-03_EN_CFR_MES_170322.pdf
- Smith, L. (2016). Sustainable textiles from re:newcell. Retrieved November 2, 2017, from https://www.ispo.com/en/companies/id_79186754/sustainable-textiles-from-re-newcell.html
- Social & Labor Convergence. (2017). Built collaboratively. Owned collectively. Retrieved February 17, 2018, from <http://slconvergence.org>
- Society for Human Resource Management. (2012). Minimum Wage: What is the difference between minimum wage, prevailing wage and living wage, and to whom does each apply? Retrieved January 19, 2018, from <https://www.shrm.org/resourcesandtools/tools-and-samples/hr-qa/pages/minprevlivingwage.aspx>
- Steinberger, J. K., Friot, D., Jolliet, O., & Erkman, S. (2009). A spatially explicit life cycle inventory of the global textile chain. *International Journal of Life Cycle Assessment*, 14(5), 443–455. <https://doi.org/10.1007/s11367-009-0078-4>

- Sule, A. (2012). Life Cycle Assessment of Clothing Process. *Research Journal of Chemical Sciences Feb. Res.J.Chem.Sci*, 2(2), 87–89.
- Sustainable Apparel Coalition. (n.d.-a). Redefining Transparency: product environmental performance on display. Retrieved January 8, 2017, from <http://apparelcoalition.org/pef-project/>
- Sustainable Apparel Coalition. (n.d.-b). The Higg Index. Retrieved January 10, 2018, from <https://apparelcoalition.org/the-higg-index/>
- Sustainable Apparel Coalition. (2016). *Higg Materials Sustainability Index (MSI) Methodology*. Retrieved from http://msicontributor.higg.org/uploads/msicontributor.higg.org/sac_textpage_section_files/9/file/MSI_Methodology_9-12-2016.pdf
- Sweeny, G. (2015). It's the Second Dirtiest Thing in the World—And You're Wearing It. Retrieved January 12, 2017, from <http://www.alternet.org/environment/its-second-dirtiest-thing-world-and-youre-wearing-it>
- Textile Exchange. (2014). Life Cycle Assessment (LCA) of Organic Cotton - A Global Average, p.18, 27,p.39, pages76, 78. Retrieved from <http://gms-wga.org/wp-content/uploads/2014/08/LCA-of-Organic-Cotton.pdf>
- Textile Exchange. (2016). Organic Cotton Market Report 2016, p.32. Retrieved from <http://textileexchange.org/wp-content/uploads/2017/02/TE-Organic-Cotton-Market-Report-Oct2016.pdf>
- Textile Exchange. (2017). Quick Guide to Organic Cotton, p.6. Retrieved from http://textileexchange.org/wp-content/uploads/2017/06/Textile-Exchange_Quick-Guide-To-Organic-Cotton_2017.pdf
- The Good Trade. (2016). 35 Fair Trade & Ethical Clothing Brands Betting Against Fast Fashion. Retrieved January 14, 2017, from <http://www.thegoodtrade.com/features/fair-trade-clothing>
- U.S. Energy Information Administration. (2017). State Electricity Profiles - Massachusetts Electricity Profile 2015. Retrieved November 14, 2017, from <https://www.eia.gov/electricity/state/Massachusetts/>
- U.S. Environmental Protection Agency. (2016a). Advancing Sustainable Materials Management: 2014 Fact Sheet. Retrieved September 26, 2017, from https://www.epa.gov/sites/production/files/2016-11/documents/2014_smmfactsheet_508.pdf
- U.S. Environmental Protection Agency. (2016b). Volume-to-Weight Conversion Factors. Retrieved November 11, 2017, from

- https://www.epa.gov/sites/production/files/2016-04/documents/volume_to_weight_conversion_factors_memorandum_04192016_508fnl.pdf
- UNEP, & SETAC. (2009). Guidelines for Social Life Cycle Assessment of Products, pp.39, 49, 76. Retrieved from http://www.unep.fr/shared/publications/pdf/DTIx1164xPA-guidelines_sLCA.pdf
- UNEP, & SETAC. (2013). The Methodological Sheets for Subcategories in Social Life Cycle Assessment (S-LCA), pp.5. Retrieved from http://www.lifecycleinitiative.org/wp-content/uploads/2013/11/S-LCA_methodological_sheets_11.11.13.pdf
- United Nations Development Programme. (2015). Human Development Report 2015. Work for Human Development, p.108,p.125. Retrieved from http://hdr.undp.org/sites/default/files/2015_human_development_report.pdf
- United Nations Environment Programme. (2017). Guidelines for Providing Product Sustainability Information. Global guidance on making effective environmental, social and economic claims, to empower and enable consumer choice. UN Environment. Retrieved from http://www.spcclearinghouse.org/sites/default/files/guidelines_for_providing_product_sustainability_information_10yfp_ci-scp_2017.pdf
- Vadicherla, T., & Saravanan, D. (2015). Eco-Design/Sustainable Design of Textile Products. In S. S. Muthu (Ed.), *Handbook of Sustainable Apparel Production* (pp. 475–500). Boca Raton: CRC Press.
- Van Der Velden, N. M., Patel, M. K., & Vogtländer, J. G. (2014). LCA benchmarking study on textiles made of cotton, polyester, nylon, acryl, or elastane. *International Journal of Life Cycle Assessment*, 19(2), 331–356. <https://doi.org/10.1007/s11367-013-0626-9>
- Wenban-Smith, M., & UNFSS. (2013). Voluntary Sustainability Standards. Today's Landscape of Issues & Initiatives to Achieve Public Policy Objectives, (March), p.35. Retrieved from https://unfss.files.wordpress.com/2013/02/unfss_vss-flagshipreportpart1-issues-draft1.pdf
- WWF. (n.d.). Cotton Farming - Cotton: a water wasting crop. Retrieved November 2, 2017, from http://wwf.panda.org/about_our_earth/about_freshwater/freshwater_problems/thirsty_crops/cotton/
- WWF. (1999). The Impact of Cotton on Fresh Water Resources and Ecosystems. A Preliminary Synthesis. Retrieved February 17, 2018, from http://d2ouvy59p0dg6k.cloudfront.net/downloads/impact_long.pdf

Yardley, J. (2013). Report on Deadly Factory Collapse in Bangladesh Finds Widespread Blame. Retrieved January 30, 2018, from <http://www.nytimes.com/2013/05/23/world/asia/report-on-bangladesh-building-collapse-finds-widespread-blame.html>

Zamani, B. (2014). *Towards Understanding Sustainable Textile Waste Management: Environmental impacts and social indicators*. Chalmers Reportservice. Chalmers University of Technology, Gothenburg. Retrieved from <http://publications.lib.chalmers.se/records/fulltext/204502/204502.pdf>