mistra future fashion

REPORT

Environmental assessment of Swedish fashion consumption

Five garments – sustainable futures

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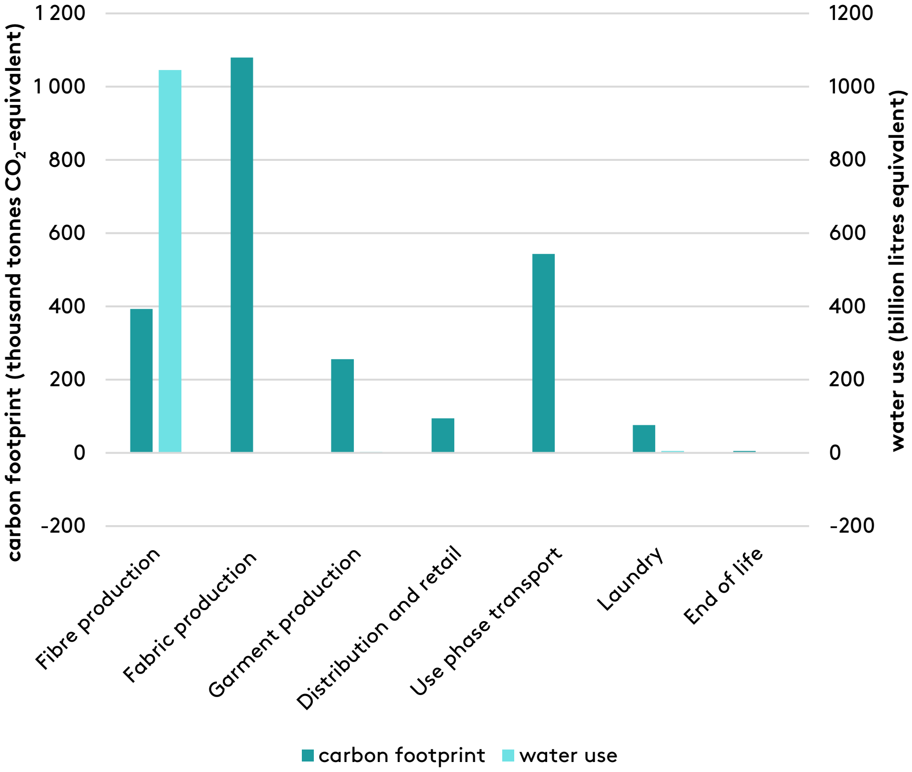
Executive summary

The Mistra Future Fashion research program was created to deliver knowledge and solutions that the Swedish fashion industry and its stakeholders can use to improve the fashion sector's environmental performance and strengthen its global competitiveness. Within the program, Project 2, called "Clarifying sustainable fashion", aimed to clarify what sustainable fashion means for the Swedish fashion industry. To achieve this, five key garments were examined using Life Cycle Assessment (LCA), to give a representative picture of Swedish fashion consumption. LCA is a globally used and accepted method for assessing environmental impacts of a product's life cycle from cradle to grave, including raw material extraction, material processing, product manufacture, distribution, use, disposal and recycling.

The selected garments were: a T-shirt, a pair of jeans, a dress, a jacket and a hospital uniform. The environmental impact of "one average use" of each of these garments was assessed to permit the detailed study, such as the examination of the environmental significance of different life cycle phases. The environmental impact of the five garments was then scaled up to represent Swedish national clothing consumption for one year. This permitted the study of broader aspects, such as the relative importance of different garments and the potential of a range of interventions for impact reduction.

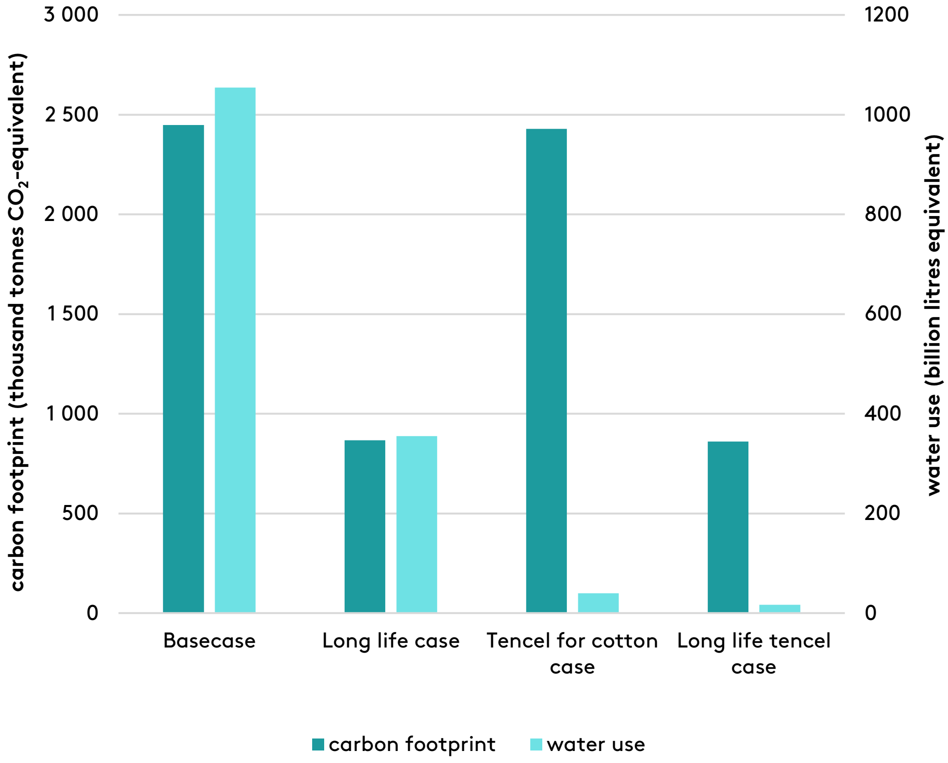
The environmental impact of the garments was expressed using indicators for water use, non-renewable energy use, agricultural land occupation, contributions to climate change (also called "carbon footprint"), freshwater ecotoxicity, freshwater eutrophication, human toxicity (carcinogenic and non-carcinogenic), photochemical oxidant formation, and acidification.

The carbon footprint from the Swedish fashion consumption is approximately 0.25 tonnes CO_2-equivalents per capita and year. This figure can be compared with the average carbon footprint for a Swedish person, which is around 10 tonnes of CO_2-equivalents per year. Although the share from fashion to the total carbon footprint is only 2.5% today, the climate impact from textile consumption needs to be reduced considerably in a sustainable future.



This figure summarises the results of the LCA for two of these indicators (carbon footprint and water use) for all five garments, scaled up to represent total clothing purchases in Sweden over one year. The water use figures were weighted according to the scarcity of the water in the country it is used. This explains why the fibre production stage dominates the whole life cycle so completely: the use of water for washing clothes in Sweden is less significant since there is an abundance of rain in this country, whereas cotton production frequently challenges the environmental values of the aquatic ecosystems where it occurs. The carbon footprint is more evenly spread among the life cycle phases, but there were two aspects of the result profile that may come as a surprise. One is the significance of the transport of the garment from the retail outlet back to the user's home, which has generally been ignored in previous studies. We found this to be a surprisingly significant component of the overall life cycle, and tested its significance in sensitivity analyses. The other surprise was the relatively large contribution of the fabric production stage to the carbon footprint.

These results suggested that examination of scenarios which reduced the pre-user environmental burden of clothing would be most worthwhile. We have examined several. In the graph below, the results of two interventions are shown: increasing the life span of garments, and replacing thirsty cotton fibre with forest-based Tencel.



Increasing the practical lifespan of garments is an interesting scenario considering that so much clothing is discarded before the end of its technical lifespan, and so much of the fashion industry's current output is directed towards "fast fashion" – rapidly produced garments with shorter technical and practical lifespans. The graph shows what happens if the practical lifespan of the average garment is increased by a factor of three, with the simple and unsurprising result (given the previous graph) that the carbon footprint and water use are reduced by 65 and 66 percent respectively. The practical lifespan of some garments might not ever be this much longer, while others may exceed this factor. National statistics on T-shirt consumption, for example, suggest the practical lifespan of these garments can be extended far beyond this. This illustrative scenario is a challenge both to manufacturers, to make and market more durable garments, and consumers, to buy fewer of them.

Replacing cotton with Tencel affects only the T-shirt, jeans and hospital uniform in the other example scenario illustrated in the graph. The key outcome there is the reduction in water use impacts on account of using a biomass resource from regions that do not suffer water stress, so this result supports increased investment in forest cellulosic fibres by the textile industry. The combination of longer lifespan and the use of such forest cellulosic fibre produces the optimum result among the four illustrated here.

Achieving such changes in the clothing industry will be a major challenge to existing business models, technical systems and consumer attitudes. This report examines a number of collaborative consumption models that allow the consumers to experience variation in their wardrobes, extending the practical lifespan of garments towards their technical lifespan by shifts in ownership. It also evaluates alternative dyeing techniques and alternative fibres against a wide range of life cycle impact indicators.

The potential to do this kind of environmental evaluation is continuously improving, with the publication of new data on fibre production and the improvement in life cycle impact assessment methods. Further work remains to be done for the fashion industry to reap the full potential of LCA. For example, the growth of product category rules offers the promise of greater consistency between life cycle assessments, but such rules must properly encompass the garment lifespan if the assessments are to provide useful guidance.

Content

Glossary

BAT	Best available technology
BREF	BAT reference document from the European IPPC Bureau
CN (1)	Combined nomenclature.
CN (2)	CN is found in the names of data from the Ecoinvent database in the report where CN denotes a *process relevant at the Chinese level*. Nomenclature from Eurostat.
dtex	Decitex = the mass in grams per 10,000 meters. This is a common parameter for textile yarns.
GLO	GLO is found in the names of data from the Ecoinvent database in the report where GLO denotes a *globally relevant process*.
ILCD	International reference life cycle data system
IPCC	Intergovernmental panel for climate change
IPPC	Integrated pollution prevention and control
ISO	International organization for standardization
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
NOEC	No-observed effect concentration
PA	polyamide
PAF	Potentially affected fraction of species
PES	polyester
PET	polyethylene terephthalate, one of the possible polymer bases for polyester materials
RER	RER is found in the names of data from the Ecoinvent database in the report where RER denotes a *process relevant at the European level*. Nomenclature from Eurostat.
SE	SE is found in the names of data from the Ecoinvent database in the report where SE denotes a *process relevant at the Swedish level*.[1] Nomenclature from Eurostat.

[1] Also other country/regional level abbreviations occur from Eurostat.

1 Introduction

1.1 Mistra Future Fashion research program

The purpose of the Mistra Future Fashion research program is to deliver knowledge and solutions that the Swedish fashion industry and its stakeholders can use to significantly improve the fashion sector's environmental performance and strengthen its global competitiveness. The program was originally (in 2011) developed around eight different major projects, representing core disciplines of relevance to the industry, with interdisciplinary activities between them. This report is written by participants in Project 2 (P2), entitled "Clarifying sustainable fashion", in the Mistra Future Fashion research program. For more information on the program, visit www.mistrafuturefashion.com.

1.2 Purpose of P2 "Clarifying sustainable fashion"

The overall purpose of P2 is to clarify what sustainable fashion means for the Swedish fashion industry. To achieve this, the aims include improving the information available for environmental assessments of apparel, map the environmental impact of Swedish fashion consumption and evaluate the potential of interventions for impact reduction suggested in the Mistra Future Fashion program and elsewhere. Main activities in P2 are a Life Cycle Assessment (LCA) of five garments selected to give a representative picture of Swedish fashion consumption, and, with the LCAs as a basis, an evaluation of the environmental potential of different interventions for improvement. These activities are reported in this report. To provide context for interpreting the LCA results in this study, we have also mapped the environmental impact reduction that is necessary according to thresholds in natural systems and targets in the fashion industry. This is reported separately (Roos et al. n.d.; Sandin et al. n.d.).

1.3 What is LCA?

LCA is a globally used and accepted method for assessing environmental impacts of a product's life cycle from cradle to grave, including life cycle phases such as raw material extraction, material processing, product manufacture, distribution, use, disposal and recycling. An LCA according to the ISO standard 14040 consists of four phases: goal and scope definition, life cycle inventory (LCI) analysis, life cycle impact assessment (LCIA), and interpretation (ISO 2006). In this report, the goal definition is found in section 1.4, the scope definition in section 2, and the LCI results in Chapter 2 and in Appendix 2, and the LCIA results and the interpretation in Chapters 3, 4 and 3.

1.4 Goal of this LCA study

The goal of the LCA was to provide the Swedish fashion industry with an up-to-date and reliable mapping of the environmental impact of Swedish fashion consumption and the potential consequences of proposed interventions for impact reduction. This was done by studying a "baseline scenario" for five garments selected to represent Swedish fashion consumption: a T-shirt, a pair of jeans, a dress, a jacket and a hospital uniform.

The environmental impact of "one average use" of each of these garments was assessed – this allows us to study micro-level aspects, such as the environmental significance of different life cycle phases of a garment. It also allows us to study the potential environmental benefits of garment-level interventions for impact reduction, such as a change of textile fibers, changed laundry behaviour among consumers and more uses per garment (through changed user behaviour and collaborative consumption business models). Also, the garment-level impact was scaled to the national Swedish level to assess the environmental impact of Swedish fashion consumption in one year – this allows the study of macro-level aspects, such as the relative importance of different garments and the potential of national-level interventions for impact reduction.

2 Baseline method

This chapter describes the methodology applied to create the baseline scenario. It contains detailed information about the choices made for the modelling of the environmental impact of the five garments.

2.1 Methodology

The LCA was conducted according to the ISO 14044 standard (ISO 2006) and the ILCD guidelines (European Commission 2010). Five different garments were analysed using attributional LCA. The environmental impacts for each garment were then scaled up according to the Swedish consumption statistics for garments, in order to give an estimate of the order of magnitude of the environmental impact of the total Swedish fashion consumption.

The environmental potential of different interventions for impact reduction was evaluated by building scenarios of how the baseline scenarios are influenced by the interventions. The studied interventions include a change to business models for collaborative consumption (which extends the service life of each garment), increased material recycling, changed consumer behaviour (influencing transportation and laundry), a change to dope dyed synthetic fibres and a change to new types of fibres.

2.1.1 Software and databases

Two different LCA software packages have been used for practical reasons: GaBi v 6.0 (PE International 2014) for modelling the T-shirt, jeans and dress scenarios, and SimaPro v 8.0 (PRé Consultants 2014) for modelling the jacket and hospital uniform scenarios. This enabled cross-checks of inventory data and characterisation methods, which reduced risks of software-related errors. The implications of the choice of software are analysed in the discussion section. Background processes have been modelled with data from databases, mainly the Ecoinvent database (Hischier 2003).

2.2 System description

2.2.1 Selected garments

A selection of garments for the study was made with the primary aim that they would be representative for Swedish fashion consumption and public sector procurement. Additionally, the intent was to choose garments with sufficiently different life cycles so that they would be able to show the significance of interventions in different life cycle phases for different types of garments. For example, T-shirts are washed more often than jackets, so jackets are expected to more clearly exemplify the value of changes to the garment life cycle outside the use phase.

We selected four fashion garments: a T-shirt, a pair of jeans, a dress and a jacket, and one garment for the public sector: a hospital uniform. These are shown in Table 1. Each of these garments is a common high volume product that consists of materials that are used also for other types of garments, and can thus represent also other garments (as is further discussed in sections 2.8 and 3.6). To be able to answer the question about the potential consequences of proposed interventions for impact reduction, the process technology is chosen to be quite modern. This means that Best Available Technology (BAT) or close BAT is modelled for textile processes. The alternative, if we would have chosen to model technology that is known to be outdated and will be replaced within the next few years, the answer to what interventions that are needed would be to change to BAT, and that would have reduced the value of the study. The choice means that the environmental impact of the Swedsih fashion consumption will be slightly underestimated.

Table 1 summarizes for each garment how the material content of the five garments was modelled. The specific modelling of the production process for each material can be found in Appendix 0. Table 1 also provides some key assumptions for the baseline scenario about the assumptions for the life cycle phases, and the percentage of Swedish fashion consumption they represent.

Table 1 The garments selected for the study

Garment	**T-shirt**	**Jeans**	**Dress**	**Jacket**	**Hospital uniform**
					
Mass	110 g	477 g	478 g	444 g	340 g
Textile material	100% cotton	98% cotton 2% elastane	100% polyester	44% polyamide 48% polyester 18% cotton/ elastane mix	50% cotton 50% polyester

Garment	T-shirt	Jeans	Dress	Jacket	Hospital uniform
Other material	-	3% other material: Zipper Buttons Leather label	-	13% other material: Zippers Buttons	1% other material: Buttons
Packaging	7 g	16 g	13 g	12 g	0.4 g
Details on fabrics	110 g white cotton tricot, single jersey, 167 dtex	Weave consisting of: 299 g blue cotton warp, 578 dtex 144 g white cotton/ elastane mix weft, 470 dtex	241 g printed polyester weave, 119/114 dtex (warp/weft) 231 g black polyester tricot, 114 dtex	57 g black and 110 g olive green polyamide weave, 200/90 dtex (warp/weft) 59 g orange polyester lining, 70 dtex 85 g polyester padding (dtex not measured) 72 g cotton/ black and olive green elastane gussets, (dtex not measured)	340 g 50/50 blue cotton polyester weave (dtex not measured)
Interconti nental transport	Ship 100%	Ship 100%	Ship 100%	Ship 100%	Ship 100%
Retail	Includes stores, staff transport and business travel	Includes stores, staff transport and business travel	Includes stores, staff transport and business travel	Includes stores, staff transport and business travel	No retail
Consumer transport	50% car 50% bus 17 km distance back and forth	50% car 50% bus 17 km distance back and forth	50% car 50% bus 17 km distance back and forth	50% car 50% bus 17 km distance back and forth	Distribution between laundry and hospital included
Number of uses	22	200	10	100	75
Use phase	Washed after 2 uses % dryed with heat[2]: 34 % ironed: 15	Washed after 10 uses % dryed with heat: 29 % ironed:	Washed after 3 uses % dryed with heat: 19	Washed once % dryed with heat: 21 % ironed: 5	Washed after 1 use % dryed with heat: 100 % ironed: 0

[2] Drying of laundry is performed with or without added heat, but for the purpose of this report we use the term "drying" for the case when heat is added.

Garment	T-shirt	Jeans	Dress	Jacket	Hospital uniform
		41	% ironed: 18		
End of life	Municipal incineration with cogeneration of heat and electricity				
Percentage of the modelled Swedish consumption	24	19	25	26	7

In mapping the life cycles of the garments, the aim was not to map life cycles of particular examples of the garments, but life cycles that are statistically representative for Swedish fashion consumption. Thus it is assumed that each garment is manufactured in several countries, i.e. the most common countries of origin according to the statistics on Swedish imports of clothes. In 2012 Sweden imported clothes from 133 different countries according to Statistics Sweden, whereof three countries stood for 49%: China 32%, Bangladesh 11% and Turkey 6% (Statistics Sweden 2014). Therefore, for example, the electricity use in production is modelled based on the electricity mix of these three countries, in proportion to their share of Swedish clothing imports.

Due to the poor traceability of fibre raw materials and other materials used in garment manufacturing, and due to the global trade in raw materials for the fashion industry, LCI data representative for global average is assumed for all material inputs to garment manufacturing.

2.2.2 Functional unit

The functional unit is the basis for the calculation of the environmental impact, which means that all environmental impacts are expressed per functional unit.

In the present study, the functional unit is "one use" for each of the five garments. "One use" refers to the use occurring within a 24 hour time period, which can be the use of a pair of jeans during a full day, the use of a dress for a few hours in the evening, or the use of a jacket on several occasions during one day. It should be noted that one use of a T-shirt is not comparable with one use of a dress or a jacket since they provide different functions. The choice of one use as the functional unit means that the influence on the service life is considered when comparisons are made between the baseline scenarios and scenarios evaluating different interventions for impact reduction.

2.2.3 Process flowchart and system boundaries

Cradle to grave modelling is applied for the garments. The process steps included for each of the garments are showed in Figures 1-5 below. "Trp" refers to transport. The life cycle has been divided into production, distribution and retail, use and end of life.

Generally, manufacturing of machinery and equipment are not included in the models unless there has been a specific reason for doing so. For example, in processes modelled with Ecoinvent datasets, manufacturing of machinery and equipment is often included but has shown to be so insignificant, that the effort of removing it is not warranted, nor is the effort of including it in the foreground processes developed for this work.

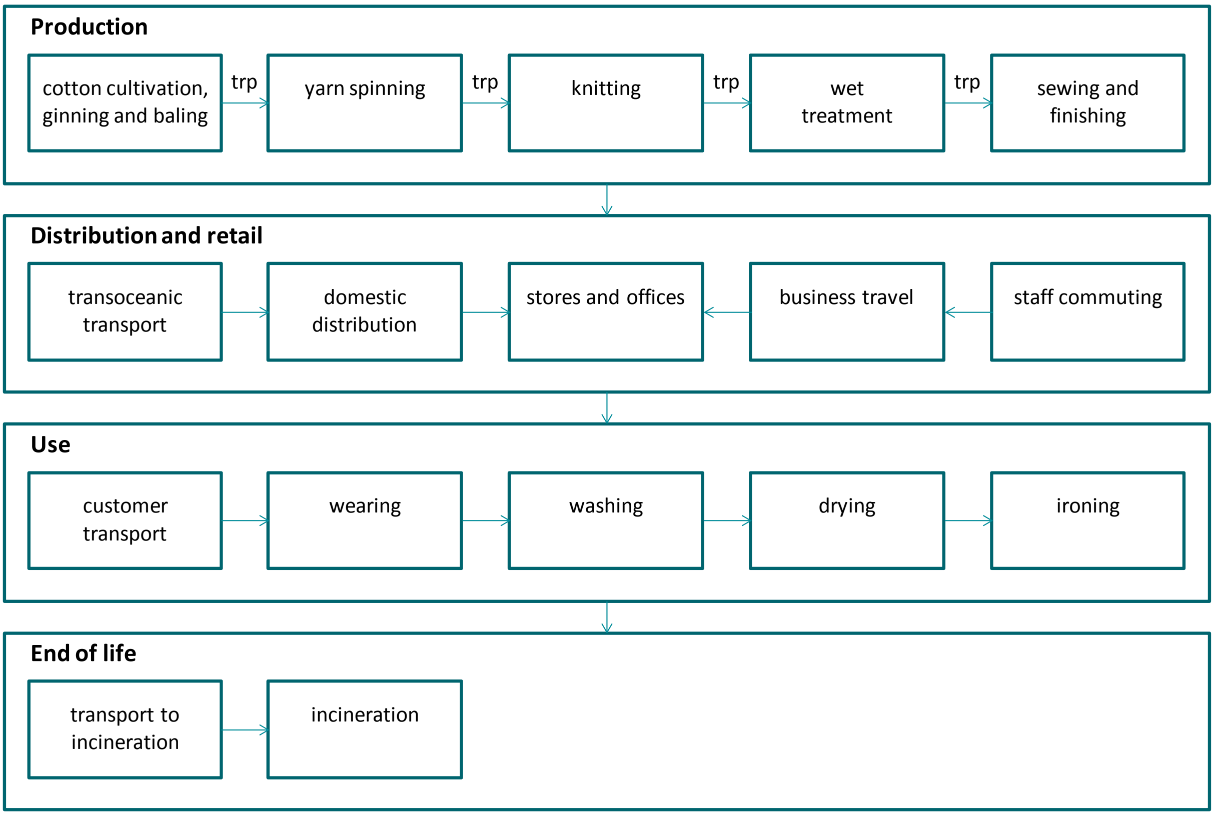


Figure 1 T-shirt process flowchart

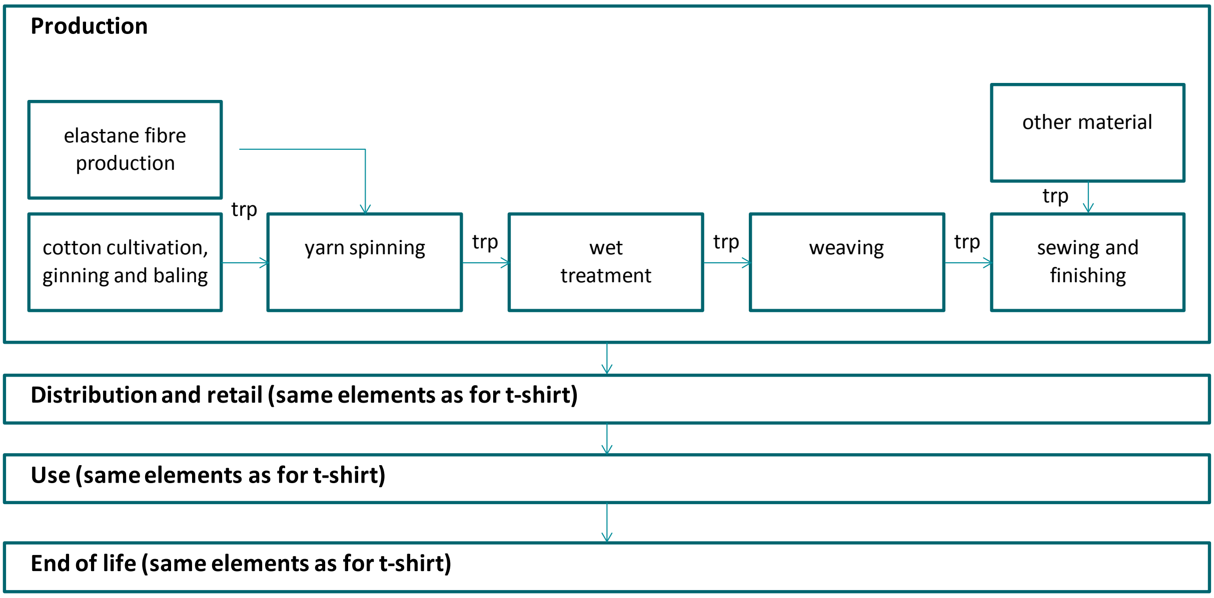


Figure 2 Jeans process flowchart[3]

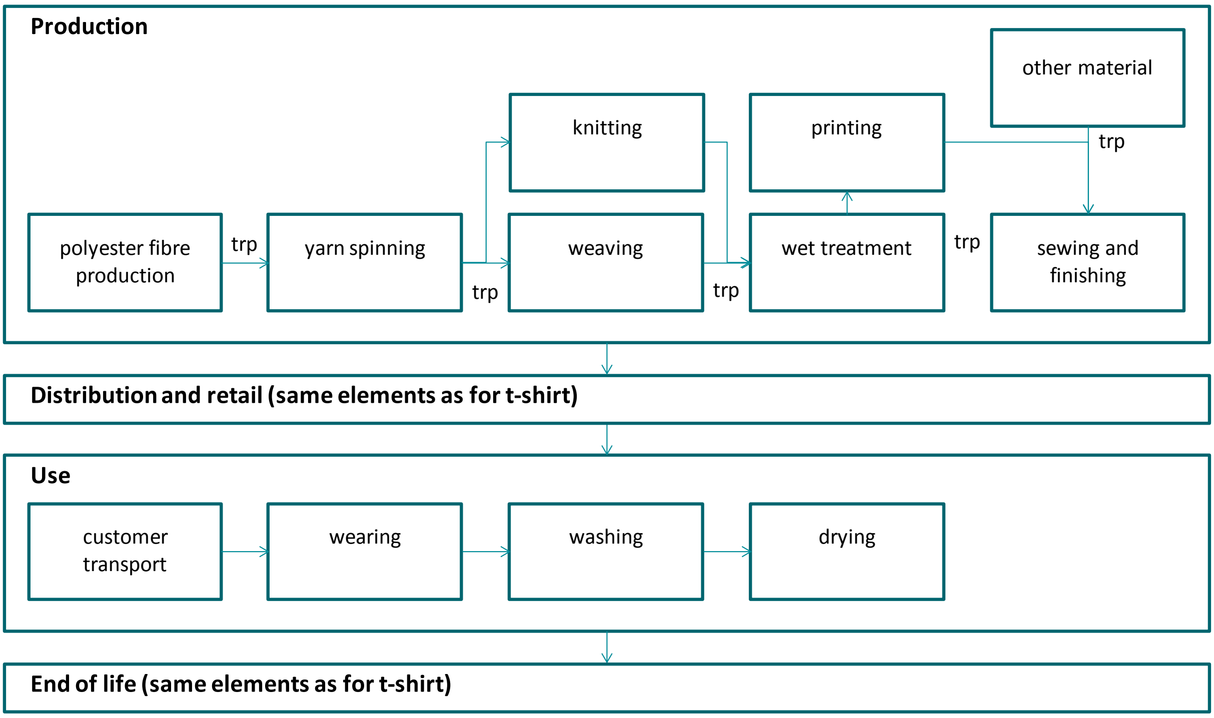


Figure 3 Dress process flowchart

[3] Note that where the elements within a life cycle phase are the same as for other garments, the actual parameter values applied in the modelling were varied where appropriate, as described later in this chapter.

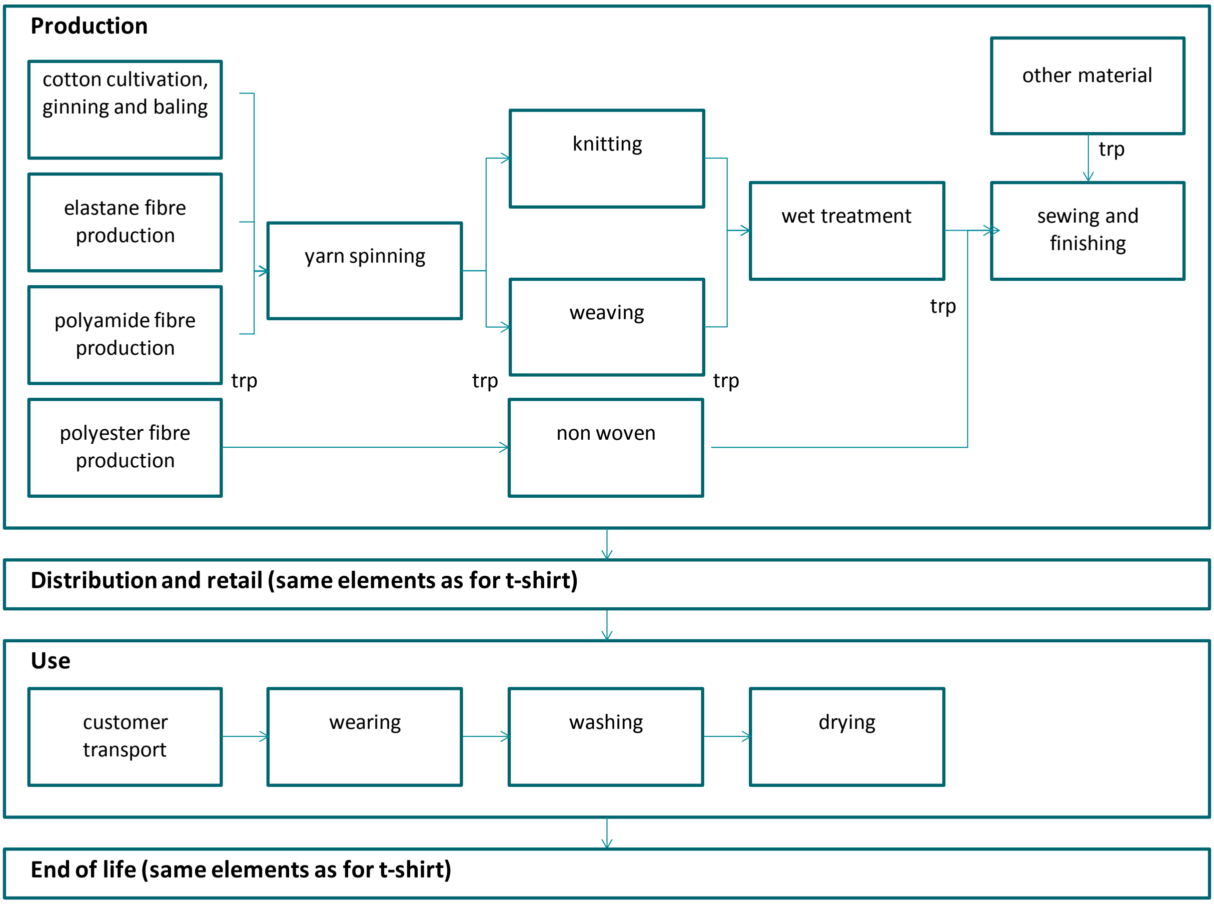


Figure 4 Jacket process flowchart.

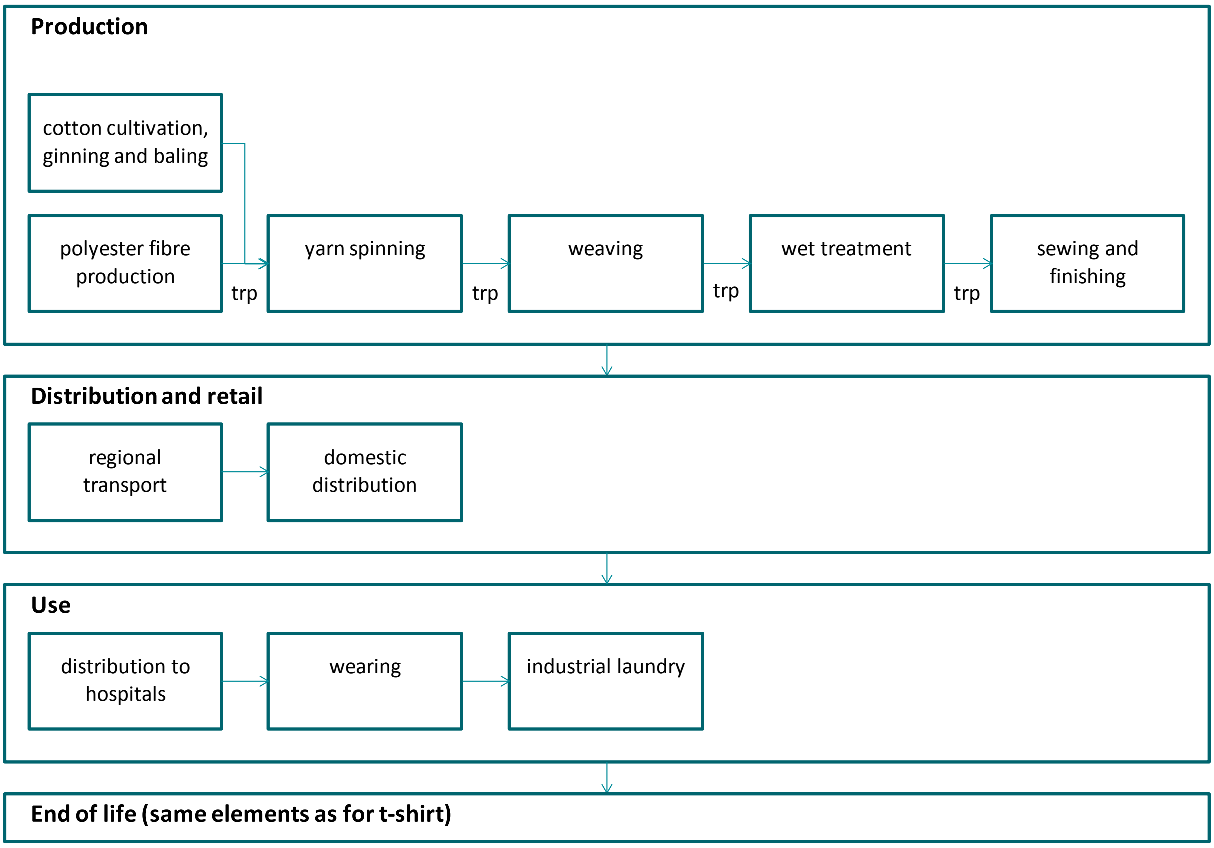


Figure 5 Hospital uniform process flowchart.

2.3 Life cycle inventory of textile processes

The textile processes cover the production, distribution and retail, use and end-of-life phases of the garments. Sections 3.4–3.7 describe the modelling of the processes in each phase in terms of data sources used for the process model and assumptions made. *Appendix 2. Modelling of processes* contains the detailed inventory of inputs and outputs for each process model. Below are described the common data selection for the models.

2.3.1 Common data selection – production phase

In the modelling of the production phase, the same data sets were used in all the textile processes for electricity, heat, waste management and transport.

The processes outside the textile and fashion industries are taken primarily from the Ecoinvent database, and these processes remain unchanged. For more information about such processes, see Appendix 2.

2.3.1.1 Electricity production

Electricity production was modelled based on the electricity mixes of the three countries that contributed most to Swedish clothing imports in 2012 (Statistics Sweden 2014), in proportion to their share of imports. Thus, the mix consisted of electricity from China (65%), Bangladesh (23%) and Turkey (12%).

For China, the Ecoinvent dataset on Chinese medium voltage (220–1000 V) electricity at grid has been used. The difference in environmental impact between high voltage, medium voltage and low voltage electricity is due to the different grid losses for the voltages, and is estimated to be a maximum of 5%.

As Ecoinvent does not include electricity mixes of Bangladesh and Turkey, these were modelled based on data on electricity mixes and grid losses for these countries (IEA 2011) combined with Ecoinvent datasets on different means of electricity production. Se Appendix 02 for further information on the modelling of the electricity production.

2.3.1.2 Heat production

The default processes that were used are the Ecoinvent processes ”Heat, light fuel oil, at boiler 10kW, non-modulating/CH” (Jungbluth 2007) and “Heat, natural gas, at boiler condensing modulating <100kW/RER” (Faist Emmenegger et al. 2007).

2.3.1.3 Transport in the production phase

The transport between the production steps were estimated to 750 km in total, based on the study of Althaus et al. (2007a). The ecoinvent dataset “Transport, lorry 16-32t, EURO3/RER S” has been used.

The garments are transported from Asia to Europe by boat. Some rough assumptions were made about ports, vehicles and distances. As the results show that production phase transportation is not an important environmental aspect, these assumptions were not refined. No drying agents or biocides to protect against e.g. mould were assumed to be used.

2.3.1.4 Waste management of textile industrial waste

The industrial waste from textile processes is generally a valuable by-product and reused for manufacturing of scarves, money bills or for energy production within the factories. It was assumed that the textile is then incinerated after different additional uses. The emissions of pollutants from combustion are therefore included, but no credit for substitution of heat or electricity was granted. The latter is because this heat is already included in the figures on energy use in the factories.

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2.3.2 Common data selection – use and end-of-life phases

For the use phase, Swedish conditions were assumed, and the Ecoinvent data set "Electricity, low voltage, at grid/SE S" (Frischknecht & Faist Emmenegger 2007) was used for electricity. For heat, the average Swedish district heating production was modelled (Swedish Energy Agency 2012). These datasets were also used for the credits in the end-of-life phase. For water use, the Ecoinvent process "Tap water, at user/RER" was used (Althaus et al. 2007b).

2.4 Production phase

The production phase included fibre production, yarn spinning, fabric production, wet treatment, sewing and finishing.

The fibres are synthetic fibres such as polyester, polyamide and elastane, or natural fibres such as cotton. Synthetic fibres are used as filament yarns or cut to staple fibres (cotton fibres are staple fibres by nature) that are used for yarn spinning. Filament fibres need to be twisted into yarn to be used for textile products. All yarn manufacturing processes are called yarn spinning below.

In order to create the fabric the yarn is either weaved, knitted or produced by nonwoven technique, depending on the product.

The choice of wet treatment method depends on the material, the type of fabric and the intended design. For white and light coloured natural materials, bleaching is needed. Bleaching also improves the dyeing result and can be used as a pre-treatment also before dyeing to darker colours. The type of dyestuff and auxiliary chemicals applied depends on the fibre. For cellulose materials such as cotton, reactive dyes, vat dyes or direct dyes are used. For synthetic materials such as polyester and polyamide, disperse dyes and sometimes vat dyes are used. Synthetic fibres can also be coloured by adding pigment already in the fibre production process, which is a dry process instead of the wet treatment. Further, colour and design can be added via printing on the textiles.

Normally, a textile wet-treatment process for knitted fabric includes the following steps: bleaching/dyeing process (in jet/airjet or jigger), opening and drying in stenter frames. Opening refers to the mechanical opening of the wrinkled "tube" of fabric that has been pressed through the jet-machine. The electricity consumption of this process is assessed to be insignificant in comparison to the energy needed for drying. For woven fabrics, continuous processes (pad batch, foullard) are common in the wet treatment although batch (exhaust) dyeing is also used. Also the woven fabrics are dried and fixed in stenter frames. For yarn dyeing, the machinery is either bobbin dyeing machines or hank dyeing machines for very delicate materials.

Whether the material is dyed as yarn or as fabric depends on design and production volume. Yarn dyeing can only be applied for large production volumes. To be able to create patterns like chequering or stripes, yarn dyeing must be applied. The wet treatment does however almost always begin with a wash and end with a finishing process. All the wet treatment processes include treatment of waste water and air emissions. For more information on dyeing, printing and wet treatment, the reader is referred to the BAT (Best Available Techniques) Reference Document (BREF) for the Textiles Industry (European Commission 2003).

The confectioning part of the life cycle includes several different processes such as cutting, sewing, printing, finishing, ironing and packaging. An important environmental aspect is the waste material from the cutting, which normally is around 15–20% of the original fabric.

All process steps also involve supplementary processes such as personnel premises, lighting, air conditioning, ventilation, etc. Data for raw material extraction and production processes for the accessories to the garments, such as zippers, buttons, paper labels and packaging have been taken from the Ecoinvent database.

2.4.1 Cotton cultivation, ginning and baling

Data from the LCA study on cotton textiles from the National Cotton Council, Cotton Council International and Cotton Inc., as implemented in SimaPro and GaBi, were used for the cotton cultivation process. For information on how carbon dioxide uptake and water use were accounted for, see Appendix 1. The dataset for cultivation and ginning of cotton fibres is found in Appendix 2 (A2.1.2 Cotton cultivation, ginning and baling, per kg cotton fibre).

2.4.2 Polyester fibre production

Textile polyesters are commonly produced from DMT (dimethyl terephthalate) and EG (ethylene glycol). The dominating raw material for DMT is fossil petroleum while EG is sometimes made from biobased material, e.g. in the Sorona fibres (DuPont 2014). In the baseline scenario, it is assumed that the polyester is of 100% fossil and virgin origin.

The polyester is synthezised in a batch polycondensation unit process is a two-step reaction: 1) the ester interchange process and 2) the polycondensation process. To start the ester interchange process, DMT and an excess of EG from the storage tanks are fed together into the ester interchange vessel with an EI (ester interchange) catalyst. Methanol is condensed in the process and is assumed to be recycled. The polycondensation process is started by adding this catalyst and is finished when the desired intrinsic viscosity is reached, which depends on the type of product. The polyethylene terephthalate (PET) is pressed out by nitrogen, cooled with water (normal/deionised), cut, dried and sieved. The cut PET chips are then stored in storage silos for further processing (European Commission 2007).

The dried polyester polymer is transported to extruders where it is melted, and pumped to spinning packs held in a spin manifold. The spin packs contain spinnerets with a large number of fine holes through which the melted polymer flows to form filaments. Any contaminants in the polymer are removed by filtration prior to the spinneret. Spin draw finish is applied as an aid to subsequent processing, which consists of mineral oil, esterified oil, anti-static agents, etc. The spun tows are combined at the creel and drawn to optimise the tensile properties of the fibres. The tow is then crimped to give it the necessary bulk characteristics for different end uses. The crimped tow is dried and a final finish is applied to suit customer requirements. Common finishes include the addition of spinning oil and optical brighteners. The tow is cut to the required fibre length, which e.g. enables mixing with natural fibres, before being baled ready for dispatch (European Commission 2007).

The dataset "Polyethylene terephthalate, granulate, amorphous, at plant/RER" from the Ecoinvent database were used for polyester polymer production (Sutter 2007), with the modification that Chinese electricity (medium voltage) has been used since China is the main polyester producer (Oerlikon 2010). Data from Fimreite and Blomstrand (2009), EDIPTEX (Laursen et al. 2007), IDEMAT (2012) and the BAT (Best Available Techniques) Reference Document (BREF) for Polymers (European Commission 2007) were used to create a data set for melt spinning into fibres. The dataset for production of PES fibres is found in Appendix A2.1.3 Polyester fibre production, per kg.

2.4.3 Polyamide fibre production

Polyamide is a synthetic material also known as nylon. There are two types of polyamide: PA 6 and PA 66. For the jacket, PA 6 was used, modelled using data from the European plastic industry (Plastics Europe) via the data set "Nylon 6, at plant/RER S" from the Ecoinvent database (Hischier 2003).

PA 6 is produced by polyaddition of caprolactam rings producing a macromolecular chain, whose length is determined by the presence of a chain terminator (e.g. acetic acid). Due to the equilibrium situation of the polyaddition reaction, the conversion of the caprolactam to PA 6 is 89–90%, the rest being monomer and cyclic oligomers. These oligomers must be removed by hot water extraction, in other words 'washing' the polymer chips in a countercurrent demineralised water flow (European Commission 2007). After drying, the fibres are melt spun and cut to staple fibres before spinning to yarn takes place. During the melting process for the production of the fibre (melt spinning), the caprolactame content rises again and is partially emitted during the following thermal treatments (European

Commission 2003). The thread lines are entangled with compressed air and then lubricated with special chemicals (spin finish) that give the yarn the required physical properties. Some effluents and fumes are produced in this section and sent to a treatment facility. Data from the textile BREF document (European Commission 2003) was used in the study for staple fibre production together with complementary data (Allwood et al. 2006; Laursen et al. 2007; Fimreite & Blomstrand 2009). The dataset for production of PA fibres is found in Appendix A2.1.4 Polyamide fibre production, per kg.

2.4.4 Elastane fibre production

Elastane is a synthetic material also known as spandex or lycra. Elastane is a polyurethane blend, spun to fibres through dry spinning (solvent based spinning).

As regards synthetic fibres (staple fibres), the amount of preparation agents applied at the yarn manufacturing stage is especially relevant in the case of elastomeric fibres where the final content of preparation agents (mainly silicone oils) can be in the order of 6-7% of the weight of the fibre. In the study it was assumed that elastane is 94% polyurethane, spun with dimethyl acetamide. The polyurethane was modelled using the data set "Polyurethane, flexible foam, at plant/RER S" from the Ecoinvent database. The dimethyl acetamide was modelled using the data set "Dimethylacetamide, at plant/GLO S" from the Ecoinvent database (Sutter 2007). Data from the textile BREF document (European Commission 2003) was used for the dry spinning in the study together with complementary data (Fimreite & Blomstrand 2009). The dataset for production of elastane fibres is found in Appendix A2.1.5 Elastane fibre production, per kg.

2.4.5 Yarn spinning from staple fibres

The processes included in the yarn production from staple fibres of the different materials are, in sequence: opening, carding, combing, drawing, roving, spinning, twisting and winding (European Commission 2003).

The yarn production begins with opening of the bales containing staple fibres. The fibres are sent into the carding machine where impurities and short fibres are sorted out. The waste was assumed to be recycled for use as insulation or similar. Combing is only required for cotton fibres to sort out the fibres that are too short for spinning but were not removed in the carding, this fraction is suitable to use for production of currency notes. Around 0.5% of synthetic fibres (viscose, elastane, polyamide) and around 8% of natural fibres (cotton) becomes waste from the yarn spinning.

All staple yarns were assumed to be spun with a technique called "ring spinning" which gives a smooth yarn with good pilling resistance and high strength. No spinning oils are assumed to be used. After the spinning, the yarn must be twisted to hold for knitting or weaving. Winding includes relaxing the yarn and rolling the yarn up on rolls for the customers.

The energy use of the spinning depends strongly on the yarn size. In the Idemat database there is data for electricity consumption available for yarn spinning with different dtex[4], however, the documentation does not show what type of equipment is used and whether also supplementary processes have been included. The report by Wendin et al. (Wendin 2007) provides data for ring spinning of a 250 dtex yarn, including supplementary processes, and was used as reference for cotton spinning. For polyamide and elastane yarn, ring spinning was also assumed, using data from the EDIPTEX report (Laursen et al. 2007). The datasets for yarn spinning is found in Appendix A2.1.6 Yarn spinning, per kg.

For the hospital uniform, yarn spinning and weaving is reported together under weaving, since the uniform is manufactured at a vertical mill, see section 2.4.11.5 below.

2.4.5.1 Measured fibre thickness for the garments

Measurements of the fibre dtex were made at Swerea IVF.

Table 2 Results for measurements of the fibre dtex.

Garment	Colour	Direction	dtex (g/10000 m)
Jacket	Black	Warp	200
Jacket	Black	Weft	90
Jacket	Orange	Warp	70
Jacket	Orange	Weft	70
Jacket	Green	Warp	200
Jacket	Green	Weft	90
Dress (under part)	Black	Tricot	114
Dress (cover part)	Black & white	Warp	119
Dress (cover part)	Black & white	Weft	114
Jeans	White	Weft	470
Jeans	Blue	Warp	578
T-shirt	White	Tricot	169

[4] dtex = the mass in grams per 10,000 meters

2.4.6 Yarn spinning from filament fibres

Synthetic fibres are produced as filaments (continuous fibres) and can either be converted to filament yarns or cut to staple fibres, in order to be able to blend them with natural fibres or to achieve a more "natural fibre" hand feel.

For the jacket fabrics, filament fibres were used and the conversion from melt spun filament fibres into filament yarns included only texturizing, drawing, twisting and winding. The datasets for yarn spinning from filament fibres are found in Appendix A2.1.6 Yarn spinning, per kg.

2.4.7 Knitting to tricot

Knitting of fine tricot is performed in a circular knitting machine. Knitting is generally an energy intensive process with an energy use of in average 1-2 kWh/kg tricot (Fimreite and Blomstrand 2009). The energy use of the knitting depends on the yarn size, and data from the Idemat database were used for validation (Idemat 2012). Data for consumption of knitting oil was modelled using data from the BREF Textiles document (European Commission 2003). The knitting oil was assumed to be a synthetic and water soluble product based on white oil (paraffin oil). The datasets for knitting to tricot are found in Appendix A2.1.7 Knitting to fabric, per kg0.

2.4.8 Weaving to fabric

Weaving is the process by which yarns are assembled together on a loom and a woven fabric is obtained. The process requires electricity and also, in case of air jet weaving, compressed air. Lubricants and oils are used to lubricate the loom, but in particular cases they may contaminate the fabric (European Commission 2003). The energy used for knitting depends on the yarn size, and data from the Idemat database was used to model weaving (300 dtex) for the other garments (Idemat 2012).

For the denim, the two yarns are produced separately, the white cotton/elastane yarn via spinning, bleaching and drying; and the blue cotton yarn via spinning, dyeing and drying. Then the two yarns are woven together to form a fabric.

For the hospital uniform, the weaving was inventoried at Lauffenmühle, a textile mill in Germany. The monthly average electricity use was 2.636 MWh (German electricity mix assumed), the natural gas use was 450 kWh and the production was 2 213 271 sqm. Total energy use per sqm is 1.19 kWh/sqm electricity and 0.0002 kWh/sqm natural gas. Included operations are: ring spinning (20% of the yarn), air jet/open end spinning (80% of the yarn), weaving, warping, winding and storage. The weight of the fabric was 215 g/sqm.

The datasets for weaving are found in Appendix A2.1.8 Weaving to fabric, per kg.

2.4.9 Nonwoven fabric production

Nonwoven materials can be produced from both staple fibres and filament fibres. For the jacket lining polyester staple fibres have been used. The staple fibre non-woven line is an entirely dry process, with no air emissions or water use or emissions. Fibres that are cut-off from edges are recirculated. No scrap is thus produced. The process includes opening and blending, carding, needlepunching and padding. Data has been taken from a previous non public study from Swerea IVF where data was collected from a specific operator. The electricity has been exchanged to the Chinese electricity mix. The dataset for non-woven production is found in Appendix A2.1.9 Non-woven process, per kg.

2.4.10 Wet treatment, dyeing and printing

The combination of wet treatment processes, dyeing and printing for the five different garments is summarised in Table 3. The process descriptions for the T-shirt, jeans, dress and jacket were compiled by Kaj Otterqvist, Swerea IVF. The chemical composition were taken from TEGEWA's International Textile Auxiliaries Buyer's Guide 2008/09 (TEGEWA 2008). Electricity consumption and heat consumption for jet dyeing machines were provided by an equipment manufacturer. For the emissions and waste water treatment, assumptions have been made. Wastewater treatment systems are able to reduce all forms of pollution in wastewater by 90% or more according to LeBlanc et al., and for most substances 99% is assumed in the modelling (LeBlanc et al. 2008). For the hospital uniform, the wet treatment was inventoried at Lauffenmühle, a vertical textile mill in Germany. The datasets for each of the processes are found in Appendix A2.1.10 Wet treatment, dyeing and printing, per kg. An overview is found in the table below.

Table 3 Overview of wet treatment, dyeing and printing processes for the five garments.

Processes included in wet treatment	T-shirt	Jeans	Dress	Jacket	Hospital uniform
A2.1.10.1 Bleaching of fabric for T-shirt	X	-	-	-	-
A2.1.10.2 Drying of cotton fabric	X	X	-	-	-
A2.1.10.3 Dyeing denim blue yarn for jeans warp yarn	-	X	-	-	-
A2.1.10.4 Bleaching of white cotton/elastane yarn for jeans weft yarn	-	X	-	-	-
A2.1.10.5 Dyeing PES tricot black in jet dyeing machine	-	-	X	-	-
A2.1.10.6 Pretreatment in jet machine of PES weave before printing	-	-	X	-	-
A2.1.10.7 Dispersion print of PES weave on rotation printer	-	-	X	-	-
A2.1.10.8 Dyeing polyamide weave black and green in beam dyeing machine	X	-	-	X	-
A2.1.10.9 Dyeing PES weave orange in jet dyeing machine	-	-	-	X	-
A2.1.10.10 Dyeing CO/EL tricot green in jet dyeing machine	-	-	-	X	-
A2.1.10.11 Dyeing CO/PES weave blue in jet dyeing machine	-	-	-	-	X
A2.1.10.12 Drying and fixation of cellulosics in stenter frame	X	X	-	-	X
A2.1.10.13 Drying and fixation of synthetics in stenter frame	-	-	X	X	-

2.4.11 Confectioning

The confectioning part of the life cycle includes processes such as cutting, sewing, printing, finishing, ironing, packaging and supplementary processes such as lighting, air conditioning and ventilation for personnel premises. Waste material from the cutting is normally around 15-20% of the incoming material (Roos 2012). For the T-shirt (a relatively simple garment), 15% waste was assumed, and for the other garments 20% waste was assumed. The confectioning template was assumed to be 5% of the material's weight. For sewing time, data from Fimreite (2009) was used, except for the hospital uniform case when supplier data is used. It was assumed that the textile waste was incinerated after different additional uses, see section 3.3.1.4. Further general assumptions about the sewing and finishing are described below.

The material composition of the garments was acquired by weighting the components for all garments except the hospital uniform, where this data was given by the supplier. The individual packaging of the garments was weighed by hand, it was then assumed that the garments are packed in cardboard boxes, assumed to weigh 60 g/kg garment. No biocides for protection during the transport were assumed to be applied.

The modelling of product assembly for each garment and specific confectioning processes for each garment is found in Appendix A2.1.11 Product assembly, per kg.

2.4.11.1 T-shirt

The weight of the T-shirt was 110 g and consists of 100% white cotton tricot measured to 167 dtex. 10 minutes of sewing was assumed per T-shirt. After sewing it was assumed that ironing, packaging and distribution was performed, but no print or finishing. For ironing the same energy use per kg garment was assumed as in the use phase (see section 2.6.1).

2.4.11.2 Jeans

The weight of the jeans was 477 g. The fabric for the jeans consisted of denim blue cotton yarn, measured as 578 dtex, in the warp (70%) and white elastane cotton mixed yarn, measured as 470 dtex, in the weft (30%; 7% elastane content). Remaining materials were zippers, buttons and threads. The ready-made garment was assumed to be washed once before packaging and distribution (assuming the same energy, water and detergent use per kg garment as in the use phase (see section 2.6.1)).

2.4.11.3 Dress

The weight of the dress was 478 g. It consisted of a woven and printed exterior of 241 g PES, measured as 119 dtex (warp) and 114 dtex (weft) and a knitted black PES lining of 231 g, measured as 114 dtex. There was also a small amount of back elastic. The sewing of the dress was assumed to take 20 minutes.

2.4.11.4 Jacket

The weight of the jacket was 444 g. It consisted of 167 g PA weave (57 g black PA and 110 g olive green PA), 59 g PES lining, 85 g PES padding, 72 g cotton/elastane gussets, zippers and buttons. The sewing of the jacket was assumed to take 44 minutes per jacket.

2.4.11.5 Hospital uniform

The weight of the uniform was 340 g. It consisted of a 50/50 mixed cotton and polyester weave (215 g/m^2). The cutting waste was assumed to be 15%. The sewing time for the hospital uniform was calculated to around 20 minutes by the producer.

The material composition was given by the producer for the hospital uniform. Weight of plastic buttons and thread was based on assumptions.

No washing label was applied; instead this information was printed in the back of the garment. The dresses were packed in cardboard boxes with a rubber band around every five uniforms. The box was assumed to contain 50 uniforms, weigh 200 g, and be recirculated 20 times. The rubber bands were assumed to weigh 2 g, and be recirculated 10 times.

2.5 Distribution & Retail phase

The distribution and retail phase was modelled by data from the H&M Conscious Actions Sustainability Report 2012[5] which includes data on energy use at stores and offices and data on distribution of goods. Assumptions were made for staff commuting to work and business trips. The consumer's transportation to and from the store was included in the use phase.

In the retail phase, 1% of textile waste was assumed, as the consumers largely take care of the surplus material via sales, outlet stores and "bargain corners" (Carlsson et al. 2011). The packaging waste was assumed to be the sum of the packaging materials described in section 2.4.11.

For the hospital uniform, there was no retail phase, as hospital textiles are subject to public procurement. Therefore, only distribution to the customer was included, in this case transport by truck and by boat from Latvia to Norrköping. The transoceanic transport of cotton fibres from Asia was included in the production for the uniform.

The datasets for distribution and retailing is found in Appendix A2.2.

2.6 Use phase

The use phase includes the consumer's transport to and from the store, residential laundry for the fashion garments (T-shirt, jeans, dress and jacket), and industrial laundry and transport from the laundry to the hospital and back for the hospital uniform. For each fashion garment, we assumed a consumer transport of 17 person-km/kg of purchased garment based on Granello et al. (2015). Out of this, 50% was assumed to be by car and 50% by public transport (bus). The influence of alternative assumptions for modes and distances for the consumer transportation were tested in the collaborative consumption scenarios (see section 2.10.1).

Table 4 summarises assumptions about the number of uses and washes per lifespan for the five garments. The average number of uses per garment is based on the number of garments an average Swede buys per year (excluding second hand) according to Swedish statistics on net annual

[5] http://sustainability.hm.com/en/sustainability/downloads-resources/reports/sustainability-reports.html

imports of garments in 2008 (Statistics Sweden 2014) and the SMED study of the textiles flow in Sweden (Carlsson et al. 2011). The number of days per year each garment is used was based on a study of consumer behaviour carried out in project 7 in Mistra Future Fashion (Gwozdz et al. 2013) and on a survey among 225 Swedish fashion consumers carried out in project 4 in Mistra Future Fashion (Granello et al. 2015); also, some complementary assumptions were necessary. Furthermore, it was assumed the amount of garments in Swedish wardrobes is constant over time. The number of washes per lifespan was based on assumptions informed by data from the aforementioned surveys (Granello et al. 2015; Gwozdz et al. 2013).

Table 4 The use phase assumptions for the five garments.

Garment	Number of uses	Number of washes	Reasoning behind estimation of lifespan and number of washes per lifespan
T-shirt	22	11	Swedes buy about 9 T-shirts per year per capita (Statistics Sweden 2014). Based on Granello et al. (2015), it is assumed Swedes wear T-shirts 200 times per year. For calculating the number of washes per life span, it is assumed a T-shirt is on average used 2 times before wash, based on Gwozdz et al. (2013), where two uses before wash was the most common alternative (38.6%) for "shirts/T-shirts/tops" and Granello et al. (2015), in which 2-3 uses before wash the most common alternative followed by 1 use before wash
Jeans	200	20	Swedes buy about 1 pair of jeans per year per capita (Statistics Sweden 2014). Based on Granello et al. (2015), it is assumed Swedes wear jeans 200 times per year. For calculating the number of washes per life span, it is assumed a pair of jeans is on average used 9 times before wash, based on Granello et al. (2015) for which the most common altenative was 6-14 uses before wash
Dress	10	3.33	Swedish women buy about 5 dresses per year per capita (Statistics Sweden 2014). For calculating the lifespan and number of washes, it is assumed women in Sweden wear a dress 50 times per year and wash it after every third use. This is based on Granello et al. (2015), in which 6-50 uses per year is the most common alternative among women (followed by 51-150 uses per year) and 2-3 uses before wash is the most common alternative, followed by 4-5 uses.
Jacket	100	1	Swedes buy about 3.25 jackets per year per capita (Statistics Sweden 2014). For calculating the lifespan and number of washes, it is assumed jackets are worn 325 days per year and are washed once during their service life.
Hospital uniform	75	75	The hospital uniform is washed after every use (Roos 2012).

The use phase includes user exposure to chemicals via direct skin contact and also via linting of fibres from the garments that can be inhaled. Allergic skin reactions from textiles are commonly documented (Malinauskiene 2012) while concerns are also raised for the content of carcinogenic, mutagenic and reproduction toxic substances (Poulsen et al. 2011). The exposure of the user to chemicals was, however, not included in our model.

2.6.1 Residential laundry

Residential laundry includes washing, drying and ironing. The preparatory studies for the ecodesign directive for washing machines (Faberi 2007) and tumble dryers (Lefèvre 2009) were used for data on detergent, electricity and water use, as further described below.

In the calculations, it was assumed, based on Granello et al. (2015), that the amount of detergent used corresponds to the recommended dosage of 50 ml for a normal wash, which corresponds to 13 g/kg wash. Inventory data of detergent production was from Saouter & van Hoof (2002). No softeners were assumed to be used.

A washing temperature of 40 degrees Celsius was assumed for all fashion garments (T-shirt, jeans, dress and jacket) as this is the most common washing temperature according to Gwozdz et al. (2013). The average washing load in Sweden is 59% of a full load (Faberi 2007). Assuming a 6 kg capacity washing machine (most common machine capacity according to Faberi (2007), the average load was thus assumed to be 3.6 kg. As the average washing machine in 2005 was 5.6 years old (Faberi 2007), it was deemed reasonable to assume that the electricity use of today's average machine corresponds to the most energy efficient 6 kg capacity washing machine in 2005. The electricity use of an average load was then assumed to be 27% lower than for a full load (25-29% according to Faberi (2007)), and standby and other low power modes were assumed to increase the energy use by 6% (4-8% according to Faberi (2007)).

To calculate the water used for washing, it was assumed that the amount of water is adjusted to the amount of load, which was standard for most machines already in 2005 (Faberi 2007). Just as for electricity use, it was assumed that the most efficient machines available in 2005 are used (Faberi, 2007). Furthermore, it was assumed that the same water use per kg of load is used as a fully loaded 6 kg capacity washing machine.

Drying of laundry is performed with or without added heat, but for the purpose of this report we use the term "drying" for the case when heat is added. For drying the laundry, the use of tumble dryer was assumed. In Sweden, drying cabinets ("torkskåp") or a drying room ("torkrum") is also a common means of drying washed garments, but as the energy use of such a cabinet or room could vary greatly, and data was unavailable for an average drying room, the electricity use of a tumble dryer was deemed to be a reasonable proxy also for this practice. The tumble dryer was assumed to be a condenser dryer adhering to the A classification of the European energy label, which corresponds to the most energy efficient tumble dryer in 2008 (Lefèvre 2009). Furthermore, the tumble dryer was assumed to be a 5 kg capacity dryer filled to 59% of full load with some extra electricity use due to standby modes – these assumptions are all consistent with Lefèvre (2009). Some types of tumble dryer (condensing) contribute to the heating of the premises in which they are placed, particularly in cold months, whereas other types of tumble dryers (air vented) increase the need for heating (Lefèvre 2009). In the present study, such effects on the heating systems were disregarded. Drying was not assumed after every wash, but after a certain percentage of washes depending on garment, based on Granello et al. (2015): 34% for the T-shirt, 29% for the jeans, 19% for the dress and 21% for the jacket.

The energy use per minute of ironing, and number of minutes each garment was ironed, is from Wolf et al. (2012). Furthermore, it was assumed that the T-shirt and jeans were ironed after 15% of the washes and the jacket after 5% of the washes (Granello et al. 2015), and the dress after 18% of the washes (Lefèvre 2009).

Datasets for detergent production, washing, drying and ironing are found in tables A2.3.1-A2.3.4 in Appendix 2. This includes details of assumed datasets for background processes.

2.6.2 Industrial laundry

Data inventoried at TvNo Textilservice AB was used (Roos 2012). Each uniform is in average used 75 times and washed after every use. The energy use for the washing and drying of 1 kg garment is 0.4 kWh electricity and 1.9 kWh heat from internal combustion of biopellets. The water consumption for 1 kg garment is 12 litres.

The distribution to the hospitals and back to the laundry is made with trucks driven on RME, with a fuel consumption of around 0.005 l of RME per kg of garment for the 75 washes.

2.7 End of life phase

2.7.1 Base case - incineration

All garments were modelled as incinerated at a municipal waste incineration plant at the end of their life (Palm et al., 2014).

The transportation from consumer to incineration plant was modelled as 30 km for all garments, using the Ecoinvent dataset "Transport, lorry 3.5-7.5t, EURO5/RER S" (Spielmann et al. 2007).

The process from the ELCD database "Waste incineration of textile fraction in municipal solid waste (MSW), EU-27" was used (European Commission 2014). In waste incineration, heat and electricity were produced as by-products. In this study, system expansion was applied, which means that the studied garments were given credits for the heat and electricity production that was avoided because of these by-products. For the avoided electricity production, the Ecoinvent process "Electricity, low voltage, production SE, at grid" was used (Frischknecht & Faist Emmenegger 2007). For the avoided heat production, the average Swedish district heating production was used, as modelled from Swedish Energy Agency (2012). Furthermore, the aforementioned ELCD dataset of textile waste incineration was adjusted according to the origin of the fibres used in the incinerated garment, i.e. for cotton and regenerated cellulose fibres all carbon dioxide emissions were assumed to be of biogenic origin and for polyester/polyamide/elastane all carbon dioxide emissions were assumed to be of fossil origin. Also, the energy content of the waste was adjusted according to the fibres of the garment, which influence the how much credits were obtained due to the by-products. The calorific value of cotton is 17.32 MJ/kg (Gemtos & Tsiricoglou 1999), and the calorific value of polyester is 24.13 MJ/kg (Gaur & Wunderlich 1981). It was further assumed about 70% efficiency in the generation of energy from the waste (Grosso et al. 2010)

For further details, see Appendix A2.4 End of life phase.

2.8 Scale-up to Swedish national fashion consumption

The study of the environmental impact of "one average use" of each of the five garments allows for studying micro-level aspects, such as the environmental significance of different life cycle phases. Next, this impact was scaled to assess the environmental impact of the total Swedish fashion consumption in one year. This allows a study of macro-level aspects, such as the relative importance of different garments and the potential of different measures for impact reduction.

The scaling was performed using the statistics on import, export and domestic production from the Swedish statistics for 2012 (Statistics Sweden 2014). These statistics are based on 34 groups of garments; for the total list, see Appendix 3. Statistics for import of garments to Sweden. As shown in the list, the models of the five garments were created to be representative for more than its own statistical group. The environmental impact of the total Swedish fashion consumption was then calculated based on the weight of each statistical group.

Table 5 The representation of Swedish fashion consumption based on 2012 statistics.

Garment	Volume (tonnes)	Percentage of the modelled Swedish fashion consumption
T-shirt	19 672	24%
Jeans	16 138	19%
Dress	21 518	26%
Jacket	20 500	25%
Hospital uniform	5 604	7%
Total	**83 432**	**100%**

The Swedish statistics were divided into tricot textile garments (Combined Nomenclature (CN) code 61) and non tricot textile garments (CN code 62) and the logic of the association of 34 different garments classifications with the representative garment was based on the following prioritisation of criteria:

1. Knitted or woven construction
2. Fibre type (cotton, synthetics, regenerated or denim)
3. Similarity, in terms of function of the garment, use pattern etc.

The hospital dress with its different use pattern and production energy system is only representative for a small part of the garments and was therefore only associated with 7% of the total garments.

A sensitivity analysis was made to investigate what happens when the weight given to each of our representative garments is changed (for example if the association between the representative garments and the statistical classes was changed), see results in section 3.6.1.

The laundry often gets considerable attention in discussions about the environmental impact of garments, and was therefore analysed using statistics about average household consumption of electricity from the Swedish Energy Agency (Swedish Energy Agency 2014a; Swedish Energy Agency 2014b), and the assumption that 20% of the household electricity is used for laundry (Vattenfall 2015). It was assumed that all household electricity for laundry, which is around 1 000 - 2 000 kWh per capita and year, was used for washing, drying and ironing of garments (2 000 kWh was assumed in the worst case scenario). Consumption of water and detergent was held unchanged for reasons of simplicity.

This scenario is a large overestimation, the consumer survey in project 4 in Mistra Future Fashion (Granello et al. 2015) showed that 34% of the mass of laundered material was home textiles (bed linen, towels etc.). Further home textiles are more frequently dried with added heat (tumble dryers, heating cabinets etc.) which is four times as energy intensive compared to washing (Lefèvre 2009; Faberi 2007). In the consumer survey, home textiles were dried with added heat in 51% of the cases and garments were dried with added heat in 24% of the cases.

2.9 Wet treatment toxicity

The use and emissions of textile wet treatment chemicals is an important topic in the textile industry. The challenges with including toxicity impacts from textile wet treatment chemicals in LCA are described in (Roos & Peters 2015). The textile production chain is long and complex, with large variance in both materials and processes. The number of textile wet treatment chemicals in use is also immense. In the Textile Auxiliaries Buyers' Guide more than 5 500 commercial products are reported, based on 400 to 600 active components (TEGEWA, 2008). Adding the pigments and dyestuffs used in textiles to this, the waste water treatment chemicals and the chemicals used in the raw material production and use phases, the list of relevant chemicals becomes long. The total number of chemicals that are applied in products have been estimated to well above 10 000 (Hauschild et al. 2011). At the same time as the compilation of the LCI of input chemicals and emissions is difficult, many substances are also currently lacking a published characterisation factors for the LCIA (Roos 2015). USEtox (Rosenbaum et al. 2008) is currently the method that covers most chemicals, although also this model is lacking characterisation factor for many textile chemicals.

2.9.1 Scenarios for wet treatment processes

In this study, LCIs including chemicals for the wet treatment processes have been performed, and a lot of effort has also been put in to match the emitted substances with USEtox characterisation factors (Rosenbaum et al. 2008). In the cases where a substance has not been covered in the current version of USEtox (1.01), characterisation factors and background data from the USEtox COSMEDE database (ADEME 2015) has primarily been used, and secondarily own new characterisation factors have been calculated.

For the wet treatment, five scenarios are reported in Chapter 3.7:

1) The default scenario with no detailed modelling of textile wet treatment chemicals
2) A BAT scenario where textile wet treatment chemicals are included and the waste water treatment plant (WWTP) has a 99% efficiency

3) A average scenario where textile wet treatment chemicals are included and the WWTP has a 90% efficiency

4) A worst case scenario where textile wet treatment chemicals are included and the WWTP is not in place.

5) A scenario where only direct toxic emissions are included from the cotton cultivation process and the wet treatment process (for the cotton garments
T-shirt and jeans).

2.9.2 Toxicity of electricity production

The difficulties of a relevant result for toxicity in LCA are partly caused by the fact that toxic emissions are seldom inventoried in the database data used, which has a main focus on energy use. An exception is the energy production systems and transports, where toxic emissions are inventoried to be of such amounts that these processes tend to dominate all toxicity calculations. The toxicity for one of the most important background processes in this study, the "MiFuFa electricity mix" (see section 2.3.1) was therefore traced back to its origin. Briefly, in order to compare the direct environmental impact of chemicals from different processes, it is only possible if energy sources, transport etc. are excluded.

2.10 Scenario method – Evaluating interventions for impact reduction

Apart from providing a baseline assessment of the environmental impact of Swedish fashion consumption as of today, this report also evaluates a range of different interventions that could potentially reduce the environmental impact of Swedish fashion consumption. The evaluated interventions were proposed within the Mistra Future Fashion research program or elsewhere. This section provides a detailed presentation of the evaluated interventions, grouped into four categories: business models for collaborative consumption, alternative fibres, changed dyeing technology and changed consumer behaviour. In the discussion section, we also discuss the potential environmental benefits of material recycling, for which LCA results have been reported elsewhere (Östlund et al. n.d.).

2.10.1 Business models for collaborative consumption

The general idea behind collaborative consumption (e.g. second hand stores, rental services or clothing libraries) is that each garment can be used more times before disposal compared to the conventional, non-collaborative consumption. It was hypothesised that this reduces environmental impacts, a hypothesis that was tested in this report by setting up 15 scenarios, including 3 baseline scenarios (variations of the baseline of this report) and 12 scenarios representing different types of business models for collaborative consumption. The intent was to make the scenarios representative for the business models of rental services or clothing libraries. All scenarios were evaluated for three of the domestic garments: T-shirt, jeans and dress.

As a basis for formulating the scenarios, questionnaires were distributed to five existing clothing libraries, whereof two replied (Klädoteket in Gothenburg and Lånegarderoben in Stockholm). The questionnaire and the replies can be found in Appendix 4.

The scenarios can be described as *cornerstone scenarios* (Pesonen et al. 2000), which means that a number of key assumptions were varied in order to generate a wide span of possible setups for collaborative consumption business models. This makes it possible to provide increased understanding regarding to what extent collaborative consumption in general can reduce environmental impacts and which parameters that influence the environmental feasibility of collaborative consumption. Although the scenarios should be representative for a wide range of possible business models, it should be noted that a specific setup could be better or worse (in environmental terms) than the results shown in this report.

The scenarios are presented in Table 6. The varied parameters were (i) the extension of garment service life due to the collaborative consumption business model (twice or four times the service life assumed in the the baseline scenario), (ii) the consumer transportation (the same means of transportation as in the baseline scenarios, or low or high impact means of transportation, respectively), and (iii) whether the setyp is an offline (physical store) or online (internet) solution (this influences transportation modes and distances). Further details of the modelling of the scenarios can be found in Table A4.1 in Appendix 4.

Table 6 Scenarios in the evaluation of business models for collaborative consumption

Scenarios with baseline consumer transportation (50% car/50% bus to/from store or pickup-point)

Scenario 1: Baseline (no rental service)

Scenario 2: Service life x2, offline

Scenario 3: Service life x4, offline

Scenario 4: Service life x2, online

Scenario 5: Service life x4, online

Scenarios with low impact consumer transportation (online: 100% bus to/from store (e.g. city centre); offline: bike/walk to/from pickup-point)

Scenario 6: Baseline (no rental service, but changed consumer transport)

Scenario 7: Service life x2, offline

Scenario 8: Service life x4, offline

Scenario 9: Service life x2, online

Scenario 10: Service life x4, online

Scenarios with high impact consumer transportation (online: 100% car to/from store (e.g. shopping mall); offline: car to/from pickup-point)

Scenario 11: Baseline (no rental service, but changed consumer transport)

Scenario 12: Service life x2, offline

Scenario 13: Service life x4, offline

Scenario 14: Service life x2, online

Scenario 15: Service life x4, online

2.10.2 Alternative fibres

A scenario where cotton fibres were substituted with eucalyptus based Tencel fibres was developed for the T-shirt and the hospital dress. The modelling of the T-shirt with new fibres is found in Appendix A4.2 Details for the fibre replacement scenario. The case study for the hospital dress is published separately as Roos (2012).

The fibre production and yarn spinning were the only parameters influenced by the fibre change, all other processes remained identical to the cotton baseline scenario.

2.10.3 From wet to dry

Here the influence of a transition to "spin dye" technology instead of conventional water based wet treatment was examined. In the spin dye scenario, only the dyeing of the fibres was altered. The data for the spun dyed fibres was taken from the recently published EPD study on WRSD Fabrics (spun dyed and piece dyed versions) (IES 2015).

2.10.4 Changed consumer behaviour

Here the influence of consumer behaviour-related assumptions was tested for particular garments. In the "your favourite T-shirt" scenario, the service life of the T-shirt was assumed to be prolonged with a factor of five (i.e. 110 uses instead of 22). In the "conscious T-shirt consumer" scenario, the consumer was assumed to walk or bike to and from the store (thus no consumer transportation impact) and the impact from washing, drying and ironing was assumed to be reduced by 50% (e.g. because of reduced washing frequency, lower washing temperatures, or similar changes).

2.11 Impact categories and characterisation methods

Table 7 shows the studied impact categories and corresponding characterisation methods. The choices of impact categories and characterisation methods have been based on the recommendations in the ILCD handbook (European Commission 2010), as this represents the most current consensus in the European LCA community. Some impact categories recommended by ILCD were omitted as they were deemed to be of low relevance for the textile industry (e.g. ozone layer depletion and ionising radiation), and some missing in the ILCD recommendations were added as they were deemed relevant for the textile industry (e.g. agricultural land occupation). In Appendix 1, each impact category and corresponding characterisation method are explained in further detail. Appendix 1 also includes a discussion of an omitted impact category, biodiversity loss, and how it relates to the incuded impact categories.

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Table 7 Impact categories included in the study and corresponding characterisation methods.

Impact category	Characterisation method	Unit for characterisation factors	Reference for characterisation method
Climate change	Global warming potential with a 100 year perspective (GWP_{100}), excluding biogenic CO_2 emissions	kg CO_2 equivalent	IPCC (2013) as implemented in SimaPro and GaBi
Acidification	Accumulated exceedence	mole H+ equivalents	Seppälä et al. (2006) and Posch et al. (2008) as implemented in SimaPro and GaBi
Freshwater eutrophication	Freshwater eutrophication potential (EUTREND model)	kg P equivalents	Struijs et al. (2009) as implemented in SimaPro and GaBi
Freshwater ecotoxicity	Ecotoxicity potential (USEtox model)	Comparative toxic units for human (CTUe)	Rosenbaum et al. (2008) as implemented in SimaPro and GaBi
Human toxicity, carcinogenic	Human toxicity potential (USEtox model)	Comparative toxic units for human (CTUh)	Rosenbaum et al. (2008) as implemented in SimaPro and GaBi
Human toxicity, non-carcinogenic	Human toxicity potential (USEtox model)	Comparative toxic units for human (CTUh)	Rosenbaum et al. (2008) as implemented in SimaPro and GaBi
Photochemical ozone formation	Photochemical ozone formation potential (LOTOS-EUROS model)	kg NMVOC equivalent	Van Zelm et al (2008) as implemented in SimaPro and GaBi
Agricultural land occupation	Agricultural land occupation	m^2*yr (agricultural land)	Guinée et al. (2002) as implemented in ReCiPe in SimaPro and GaBi
Freshwater consumption	Consumptive freshwater use (Swiss Ecoscarcity model)	scarcity-weighted freshwater consumption in litres (litre equivalents)	Frischknecht and Knöpfel (2013) as implemented in SimaPro and GaBi (with adjustments according to Appendix 1)
Non-renewable energy resources	Use of primary energy from non-renewable resources	MJ	Primary energy from non-renewable resources as implemented in SimaPro and GaBi

3 Results and discussion – baseline scenario

This chapter presents the the environmental impact for the baseline scenarios for the five garments. The results are displayed either per functional unit, i.e. one (1) use of each garment, or per garment service life (where the number of uses differ between garments). First, some results for all scenarios are compared, then follows more detailed results for each garment (sections 3.1-3.5), results from scaling up the results to the national level (section 3.6), results from detailed modelling of wet treatment toxicity (section 3.7)) and a discussion on the implications of the choice of software (section 3.8).

Figure 6 and Figure 7 show results for one of the studied impact categories, climate change, per garment service life and per garment use, respectively. From these results it is clear that the number of uses per garment service life strongly influences the relative importance of different garments. Noteworthy is that per service life, the T-shirt appears to have low impact relative all garments, but the impact per use are similar as for the jeans, the jacket and the hospital uniform. Moreover, in terms of impact per use, the dress appears to be particularly important, which emphasise the needs for using each purchased dress for a longer time than done in average. The importance of extending the number of uses per service life will be further showed and discussed later on in Chapters 3 and 0.4.

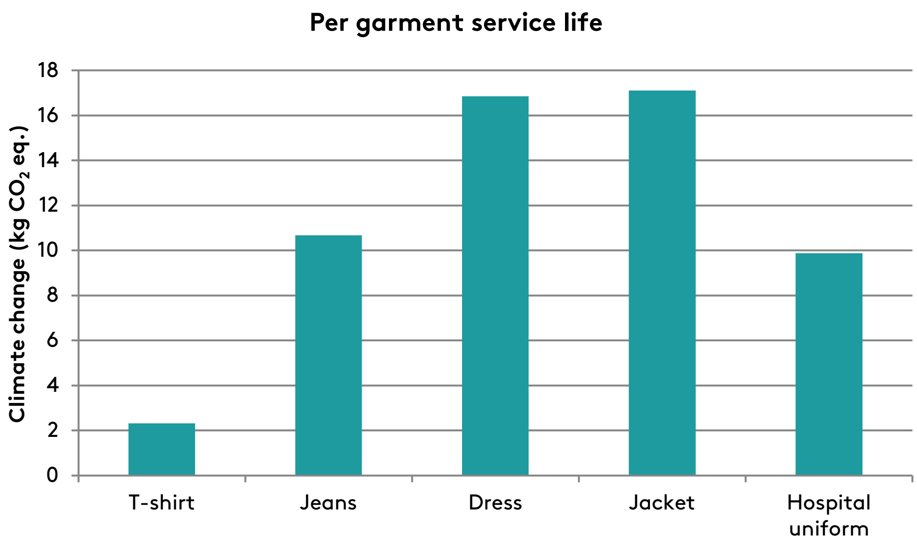

Figure 6 Climate impact for the five studied garments, per garment service life.

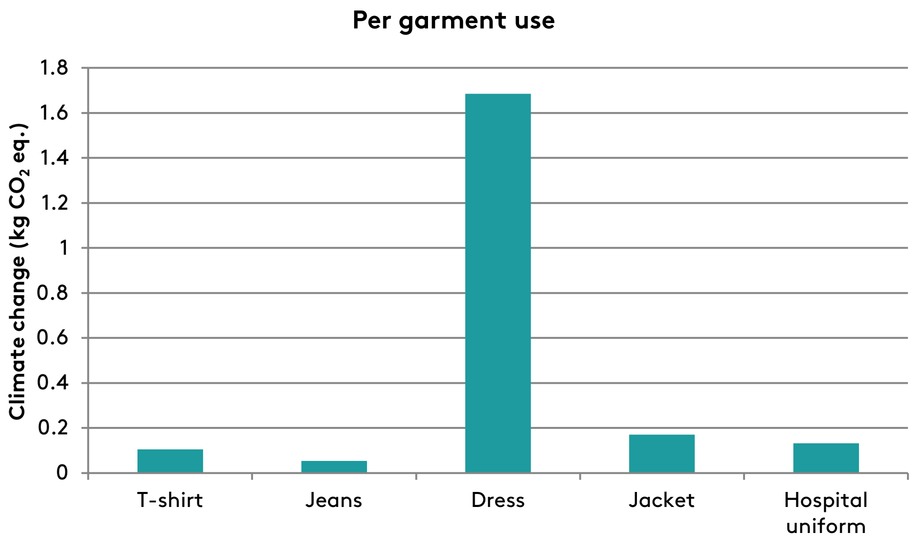

Figure 7 Climate impact for the five studied garments, per garment use.

Below follows results each garment. A common observation is that for the end of life phase, in terms of ecotoxicity, credits due to substituted production of the electricity and heat appear to be significant and are a result of the modelled toxicity for landfill of ash from the municipal solid waste incineration, see section 2.9 and 3.7.2 for further description of ecotoxicity modelling challenges.

3.1 T-shirt

Figure 8 shows normalised results for each impact category, and Figure 9 and Figure 10 show detailed results for climate change and freshwater consumption. In most impact categories, fabric and garment production give the main contribution to the total impact of the use of a T-shirt. Also the use phase is in important for most impact categories, particularly the consumer transportation to and from the store. For the influence of alternative consumer transportation assumptions, see the results of the collaborative consumption scenarios (Section 4.1.1). For freshwater consumption, agricultural land occupation and ecotoxicity, fibre production (cotton cultivation) is dominant.

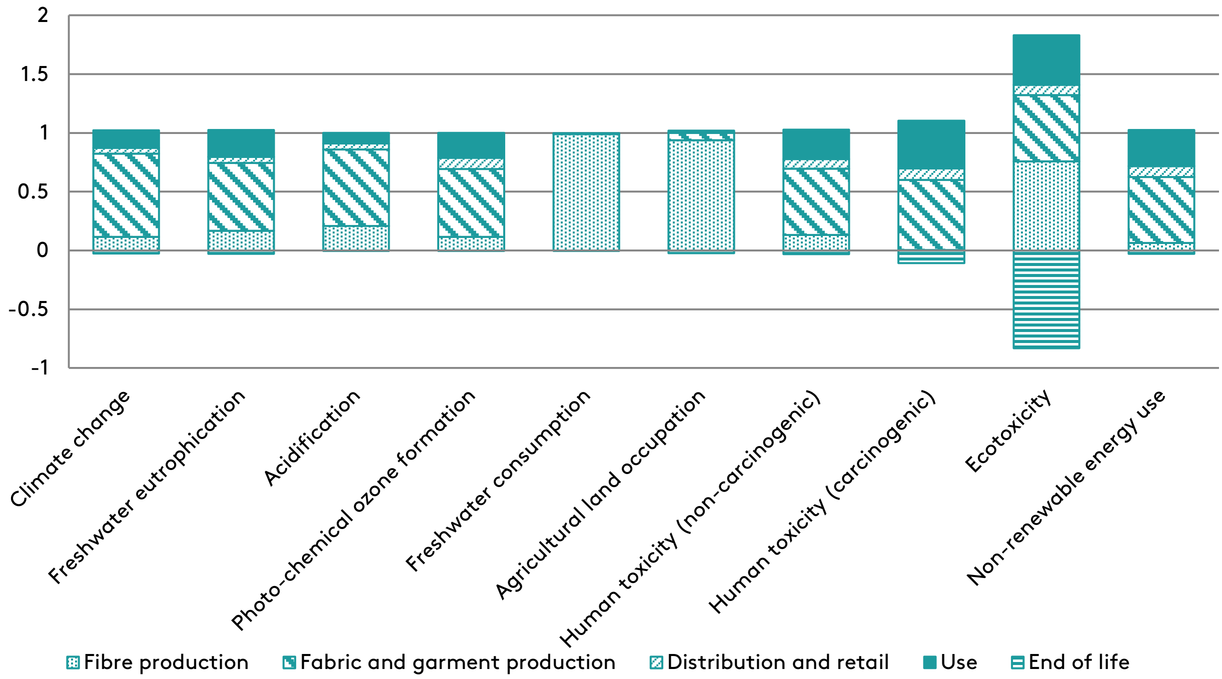

Figure 8 Normalised results of the environmental impact of one (1) use of the T-shirt.

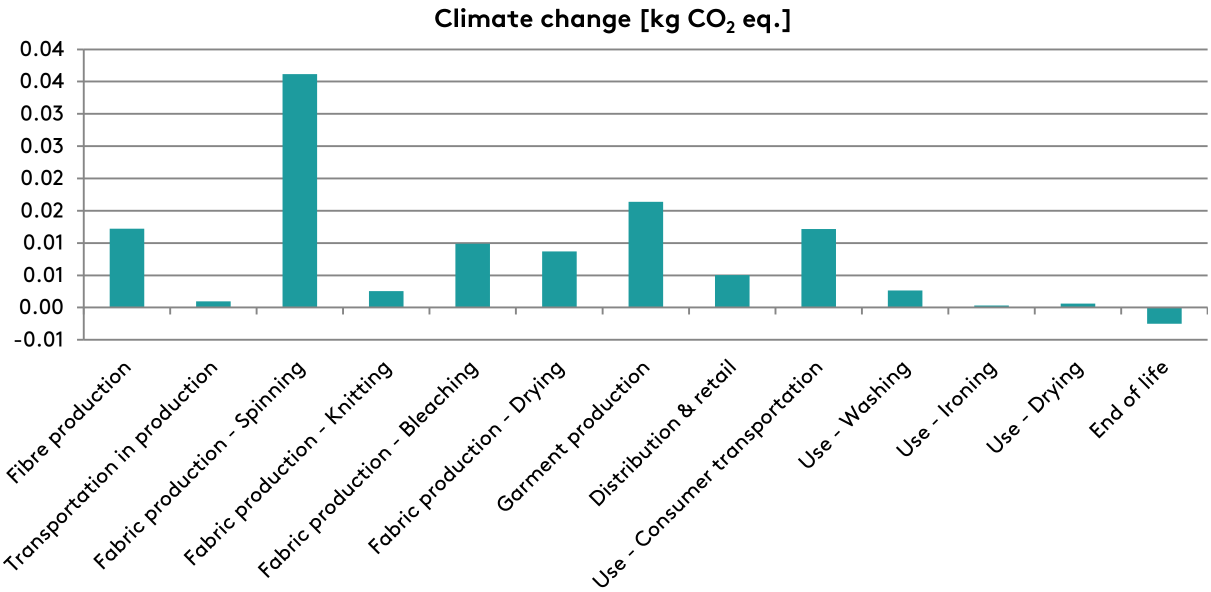

Figure 9 Global warming potential for one (1) use of the T-shirt.

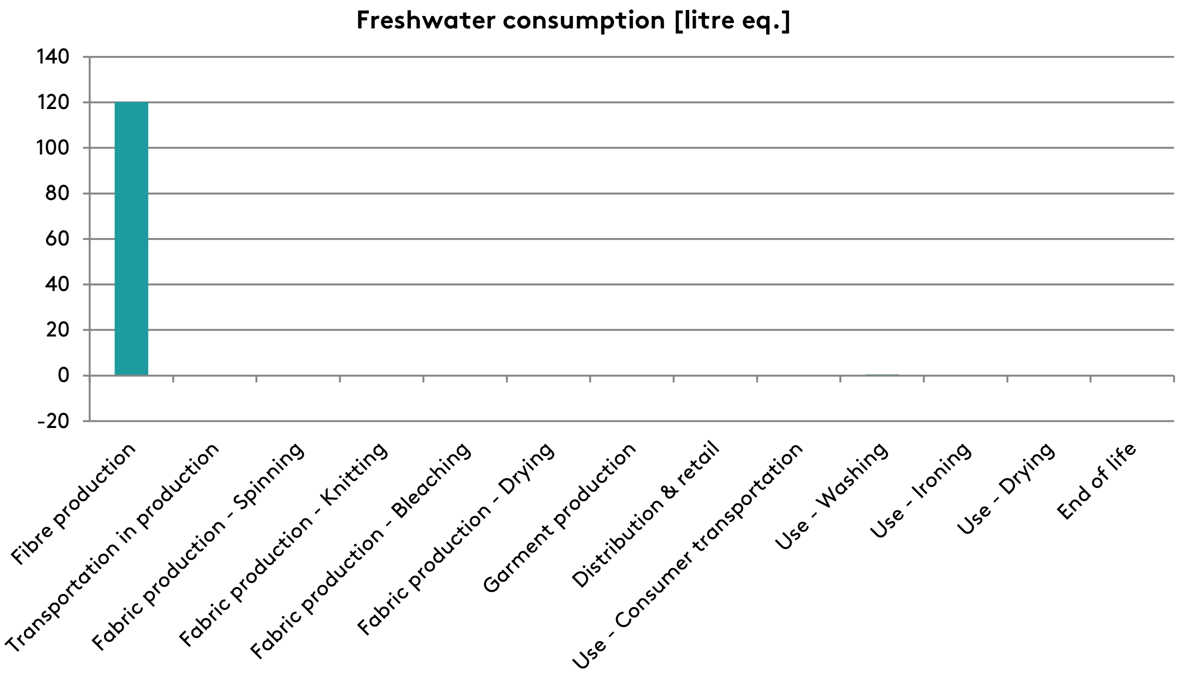

Figure 10 Scarcity-weighted freshwater consumption for one (1) use of the T-shirt.

3.2 Jeans

Figure 11 shows normalised results for each impact category, and Figure 12 and Figure 13 show detailed results for climate change and freshwater consumption. The pattern of results for the jeans is similar to the T-shirt. Other assumptions regarding user behaviour would change the relative importance of the production and user phases: longer service lives means the production phase is of less relative importance (while total impact per use decreases).

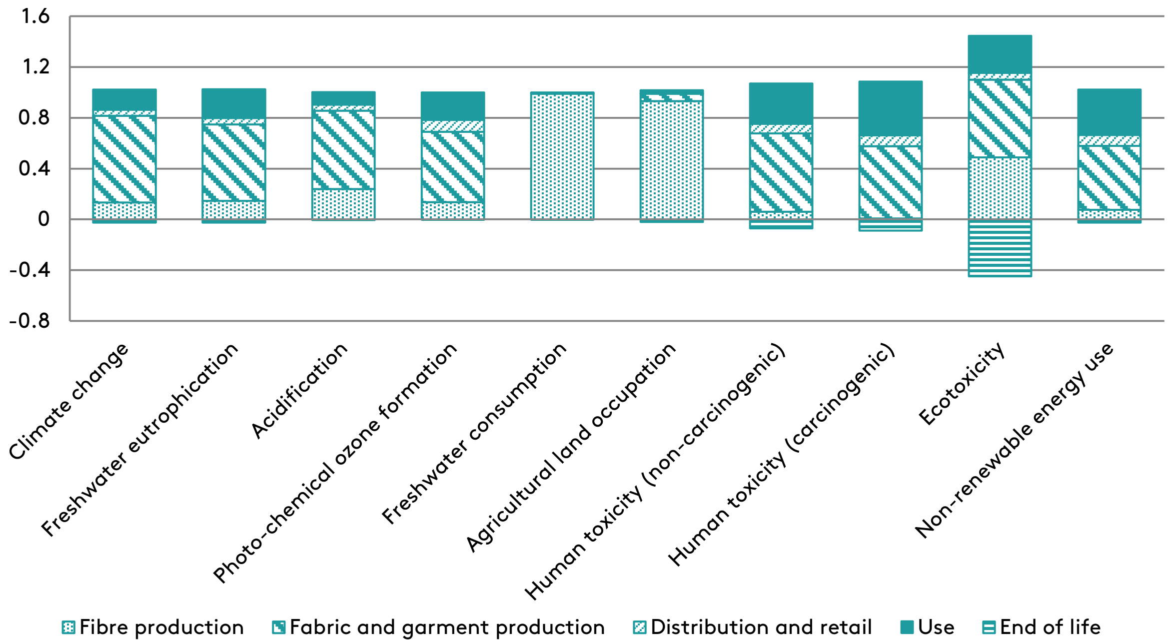

Figure 11 Normalised results of the environmental impact of one (1) use of the pair of jeans in the selected impact categories.

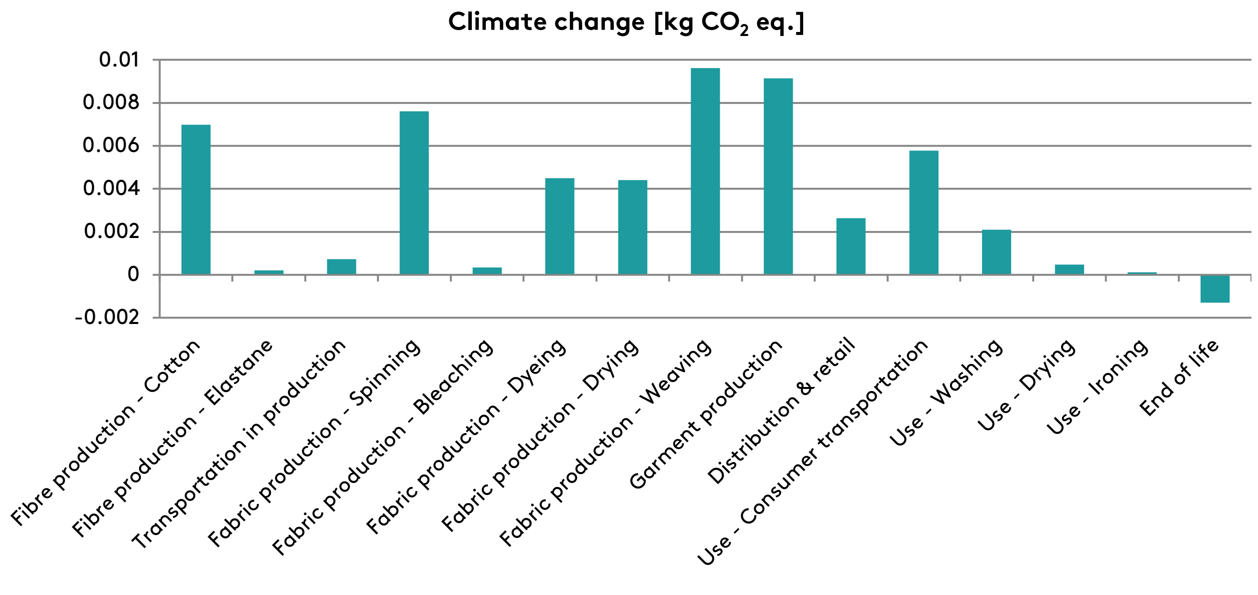

Figure 12 Climate impact for one (1) use of the jeans.

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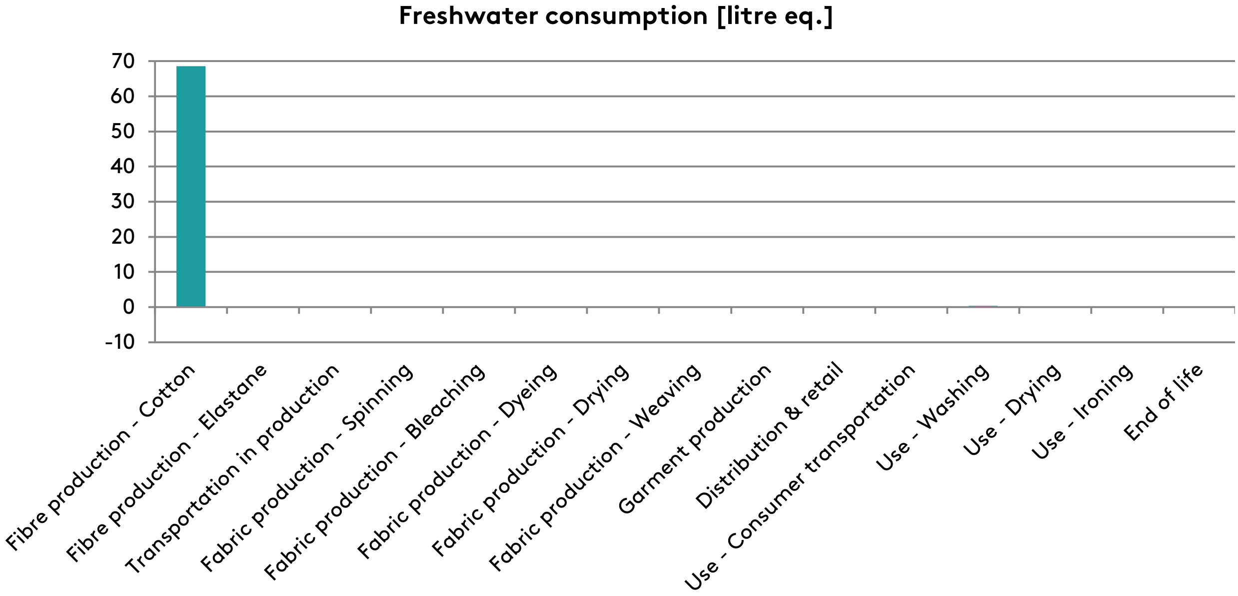


Figure 13 Scarcity-weighted freshwater consumption for one (1) use of the jeans.

3.3 Dress

Figure 14 shows normalised results for each impact category, and Figure Figure 15 and Figure 16 show detailed results for climate change and primary energy use.

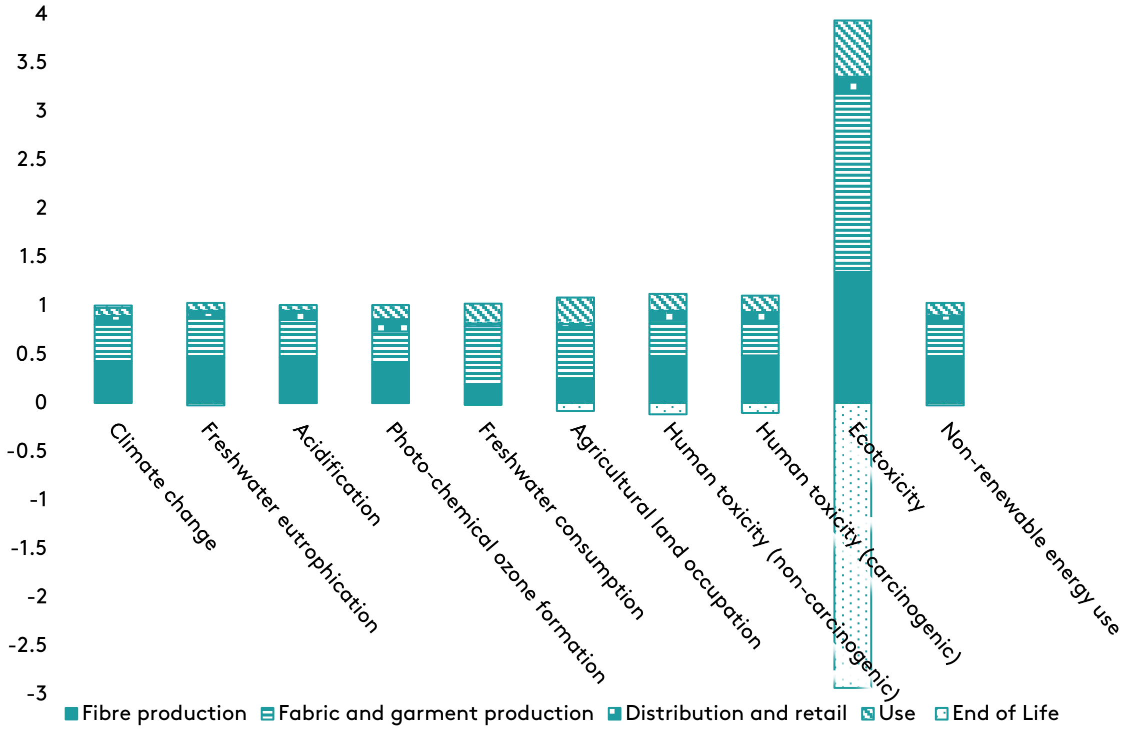


Figure 14 Normalised results of the environmental impact of one (1) use of a dress in the selected impact categories.

Impacts of the dress show a different profile to those of the T-shirt and jeans. This garment is made from polyester, so the production and washing processes are different. One consequence is that for most of the impact categories, the production phase dominates even more than for the cotton garments.

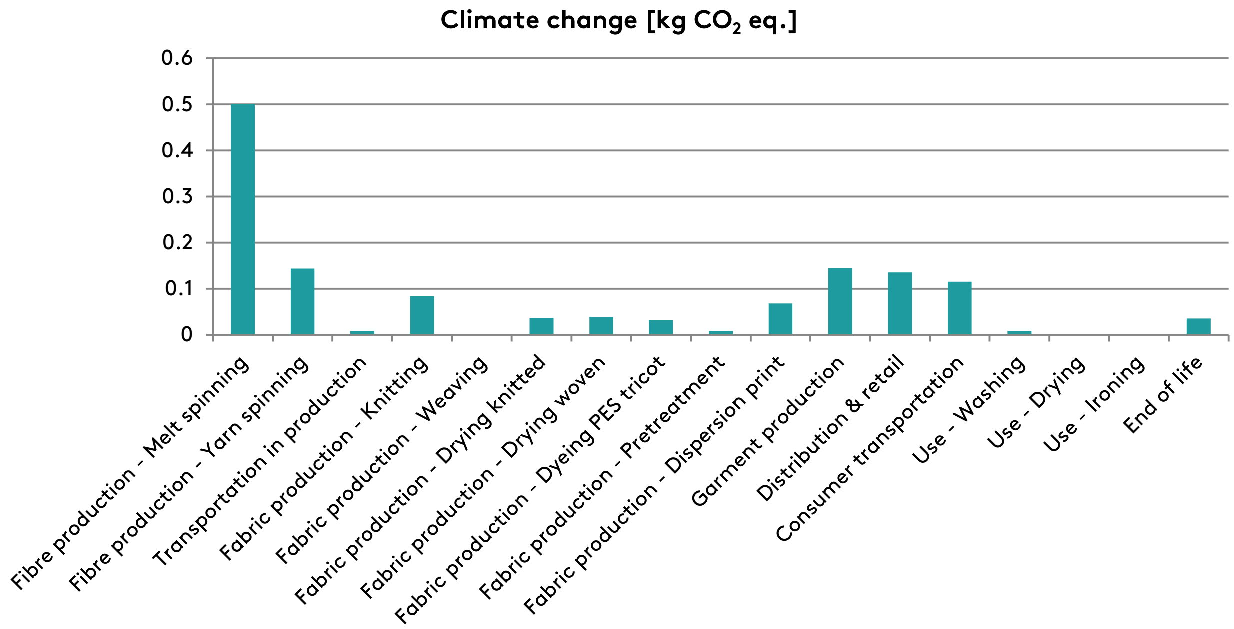


Figure 15 Climate impact for one (1) use of the dress.

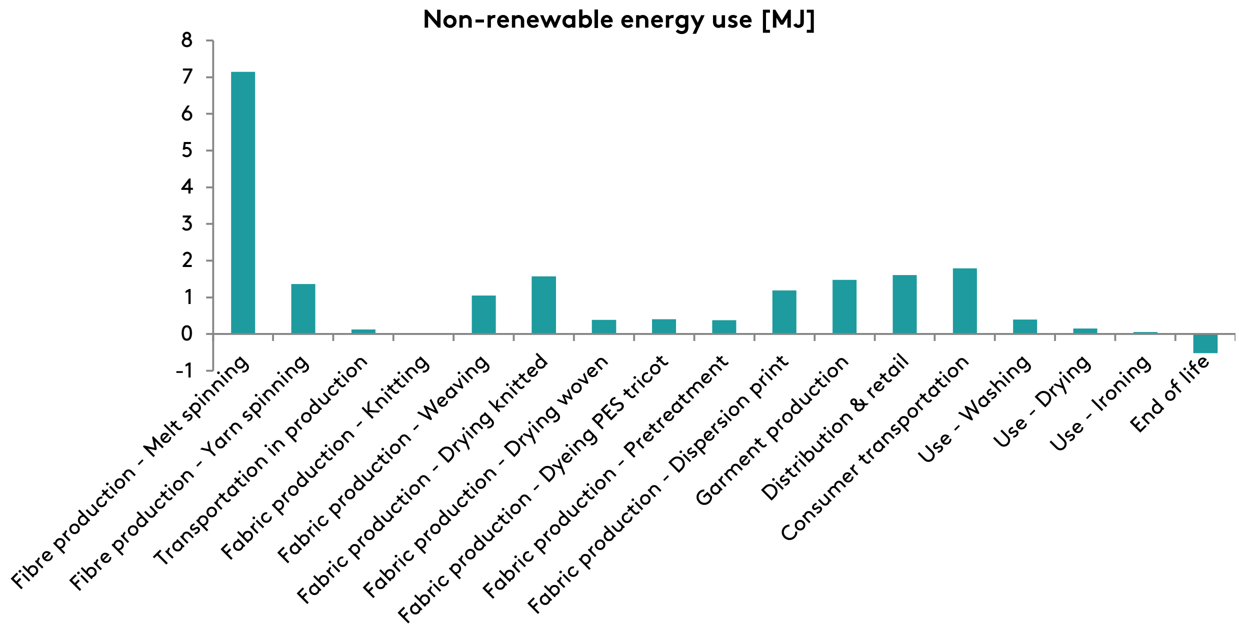


Figure 16 Non-renewable energy use for one (1) use of the dress.

3.4 Jacket

First normalised results for each impact category are presented (Figure 17), and then detailed results for climate change and freshwater eutrophication potential from the jacket life cycle are shown (Figure 18 and Figure 19). The total potential contribution to global warming for the life cycle of the jacket is 17.1 kg CO_2 equivalents, which corresponds to driving 143 km in a "green car"[6].

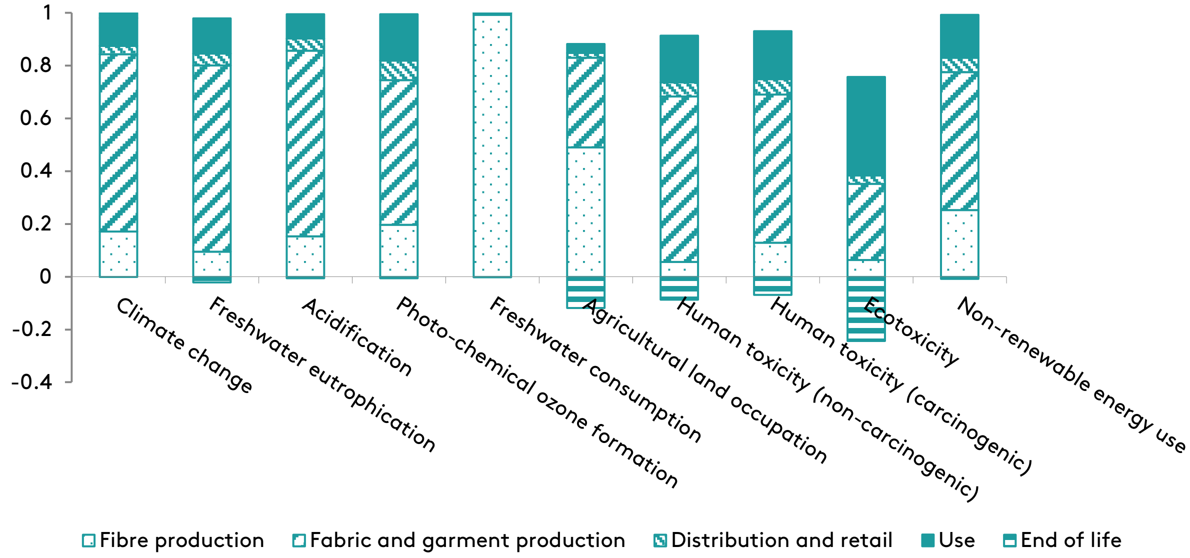


Figure 17 Normalised results on the environmental impact of use of the jacket in the selected impact categories.

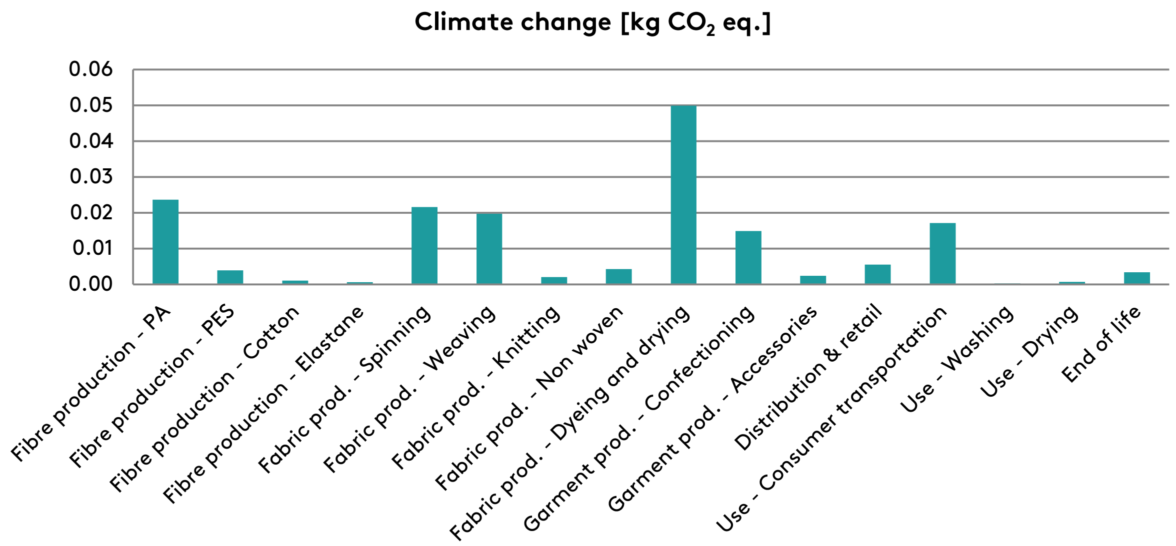


Figure 18 Global warming potential for one (1) use of the jacket.

In the life cycle of the jacket, it is the production phase that stands for the main climate impact. The second largest phase is the use phase which is totally dominated by the transport of customer to the store, as it has been

[6] 120 g CO_2 per km is assumed

modelled in this study. The distribution and retail phase is insignificant as the transport from the production countries has been assumed to be performed by boat. The end of life scenario is currently giving an environmental benefit as the heat from the combustion of the material is recovered to replace other electricity and heat production.

The total potential contribution to global warming for the production phase **per jacket** amounts to 14.4 kg CO_2 equivalents. In the life cycle of the jacket, it is the fibre production, spinning, weaving and dyeing processes that stand for the main climate impact. However, the quite long sewing time assumed (100 minutes per kg) makes the confectioning part also rather important.

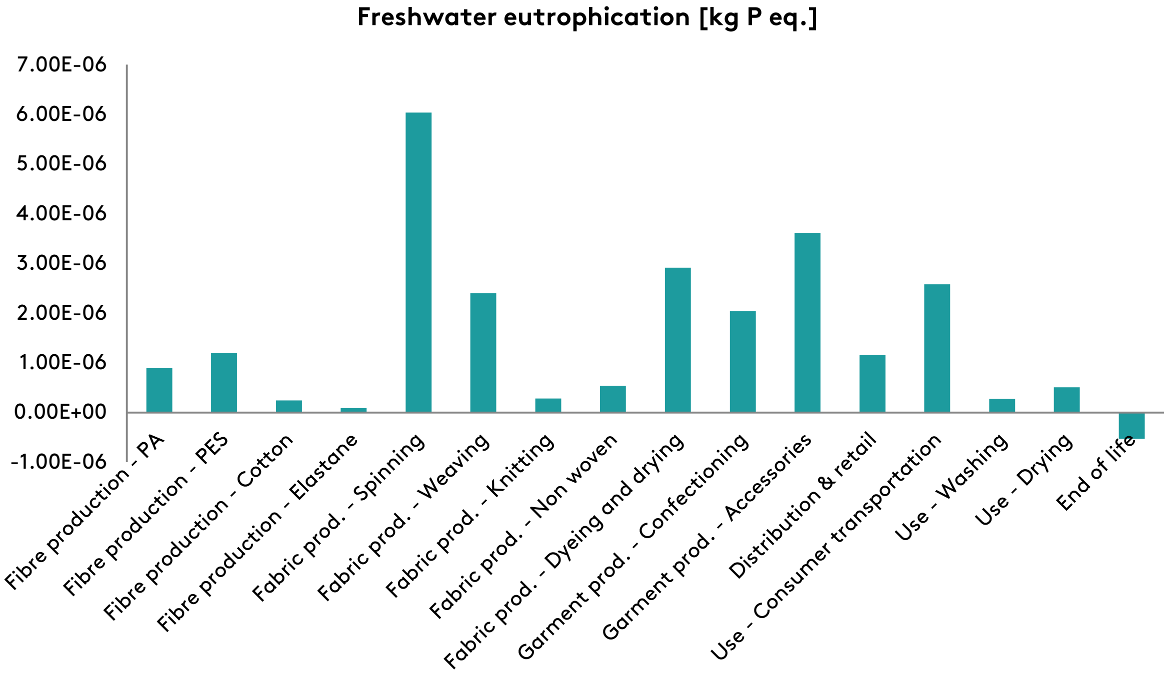


Figure 19 Freshwater eutrophication potential for one (1) use of the jacket.

The freshwater eutrophication is also dominated by the production phase, where yarn spinning, and production of accessories dominate. The total potential contribution to freshwater eutrophication for the life cycle of the jacket is 24 mg phosphorous equivalents.

3.5 Hospital uniform

First normalised results for each impact category are presented (Figure 20), and then detailed results for climate change and freshwater eutrophication potential from the hospital uniform life cycle are shown (Figure 21 and Figure 22). The total potential contribution to global warming for the life cycle of the uniform is 9.9 kg CO_2 equivalents, which corresponds to driving 82 km in a "green car"[7].

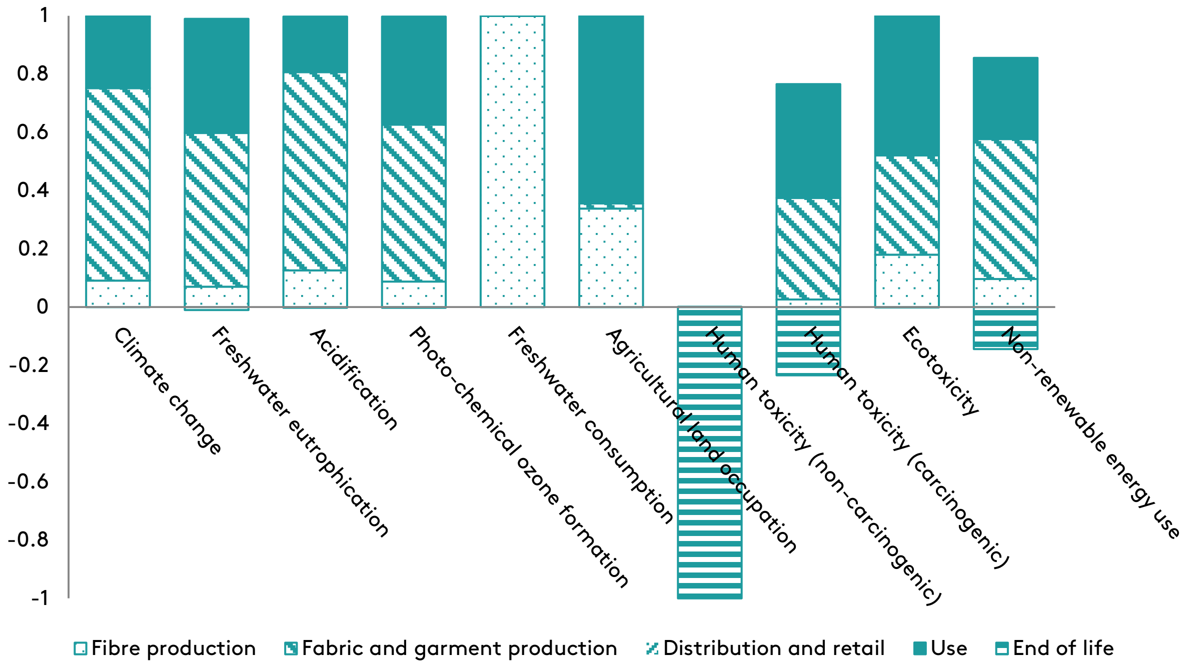
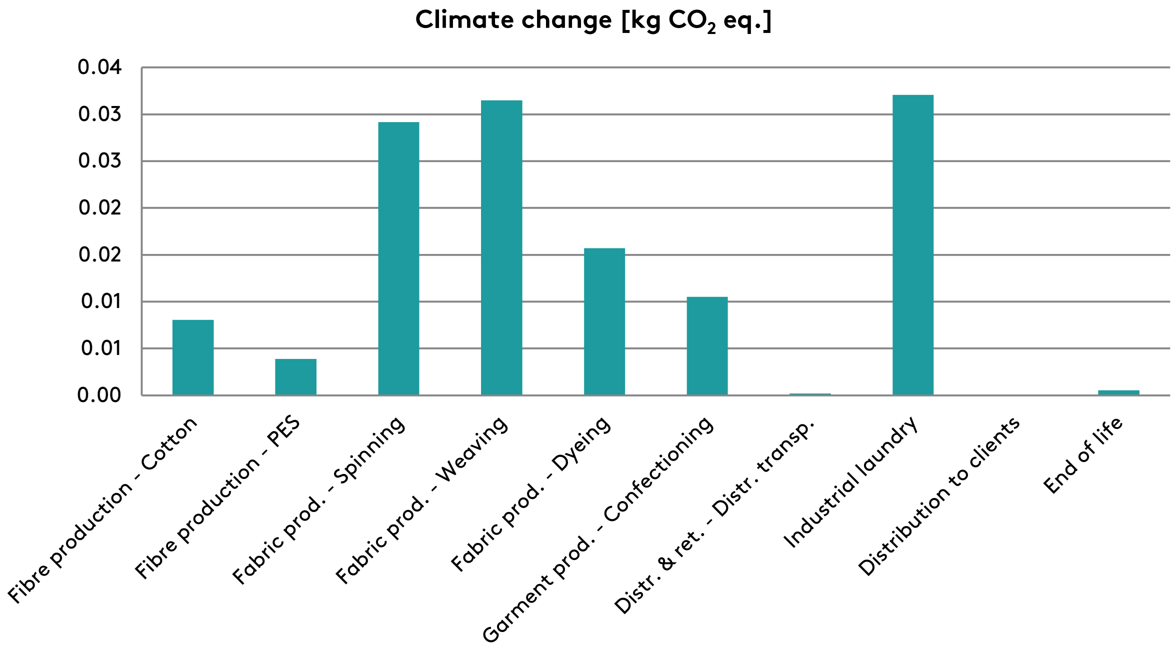


Figure 20 Normalised results on the environmental impact of one hospital uniform on the selected impact categories.



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[7] 120 g CO_2 per km is assumed

Figure 21 Global warming potential for one (1) use of the hospital uniform.

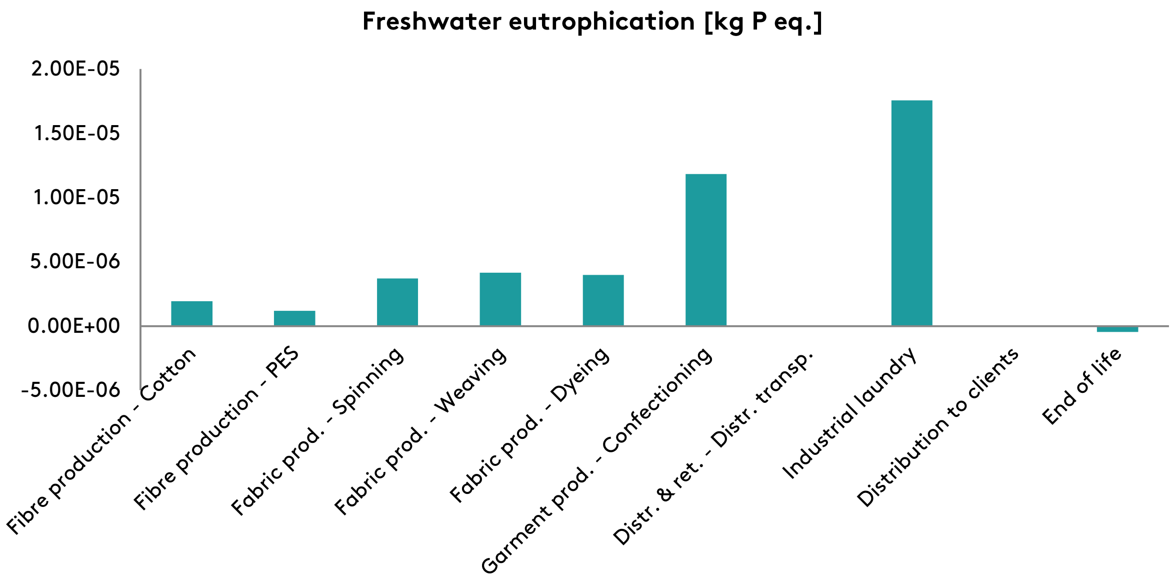

Figure 22 Freshwater eutrophication potential for one (1) use of the hospital uniform.

Washing of hospital uniforms is subject to high quality expectations, in terms of higher temperatures and need for a quick drying process, compared with consumer garments. This is reflected in the relatively large burden shown in the climate change and freshwater eutrophication indicators.

3.6 Result for scaling up to Swedish fashion consumption

The environmental impact of the different garments has been scaled up to the level of national yearly consumption, to assess the environmental impact of the total Swedish fashion consumption. The results are shown in the table below.

Table 8 Environmental impact potential for the yearly fashion consumption in Sweden, with the scale-up model.

Environmental impact category	Unit	Total
Climate change	tonnes CO_2 eq.	2.45E+06
Freshwater eutrophication	kg P eq.	3.98E+02
Acidification	mole of H+ eq.	1.87E+04
Photochemical ozone formation	kg NMVOC eq.	1.01E+04
Freshwater consumption	m^3 eq.	1.05E+09
Agricultural land occupation	m^2*yr	4.87E+07
Human toxicity, non-carcinogenic	CTUh	1.96E+05
Human toxicity, carcinogenic	CTUh	2.14E-01
Freshwater ecotoxicity	CTUe	1.03E+06
Non-renewable energy resources	MJ	2.17E+07

This calculation was made with the purpose of getting a rough estimation of the order of magnitude of the environmental impact of Swedish fashion consumption. It should be noted that these figures include only garments, which means that home textiles such as towels, sheets etc are not included. We have for many processes assumed quite modern equipment and the actual figures are most likely higher.

The Swedish population in 2012 was 9 555 893 people (SCB, 2013), which means that the carbon footprint from fashion consumption is around 0.25 tonnes CO_2-equivalents per capita and year. The average carbon footprint for a Swedish person is around 10 tonnes of CO_2-equivalents per year (Larsson 2015), which means that the carbon footprint share from fashion is only 2.5% today. However, for other environmental impacts, e.g. toxicity and water depletion, textiles bear a large burden of the global environmental impact, e.g. in the cotton cultivation and the textile wet treatment, see the discussion chapter for more details.

In a sustainable future where the 2 degree goal is reached, the Intergovernmental Panel on Climate Change (IPCC) anticipates that global annual greenhouse gas emissions will have to be reduced by 14–96% by 2050 compared to the emission levels of 1990, and that emissions must be close to zero by 2100 (scenario RCP2.6 in (IPCC 2013)) The authors behind the planetary boundary framework suggest that an atmospheric concentration of 350 ppm CO_2 (corresponds to about 400 ppm CO_2-eq.) corresponds to a safe level for humanity (using the precautionary principle; Steffen et al. 2015), which would probably require even lower per capita emissions by

2050 than indicated by the IPCC scenario corresponding to the lowest emissions. Regardless of approach this means that the climate impact from textile consumption needs to be reduced considerably in a sustainable future.

The figure below illustrates how the different life cycle phases contribute to the total climate impact of Swedish fashion consumption (Figure 23).

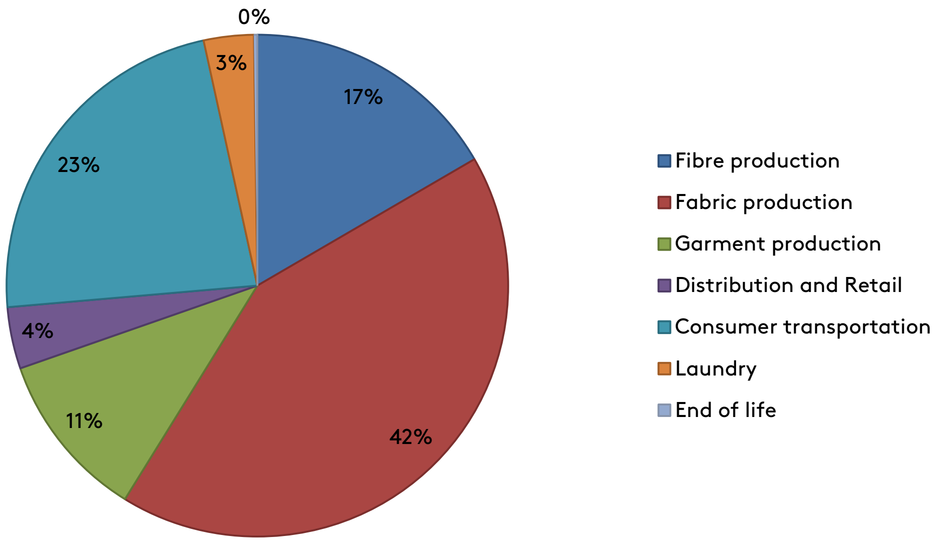

Figure 23 The climate impact from Swedish fashion consumption divided into the different life cycle phases.

3.6.1 Sensitivity analysis on representation of garments

A sensitivity analysis was made regarding the effect of changing the weight given to different representative garments. The figure below show that the base case (described in chapter 3.8) lies in the middle of the result span. The variation between the lowest result (lots of T-shirt) and the highest result (lots of jacket) is from 2.0 to 2.7 million tonnes carbon dioxide equivalents per year.

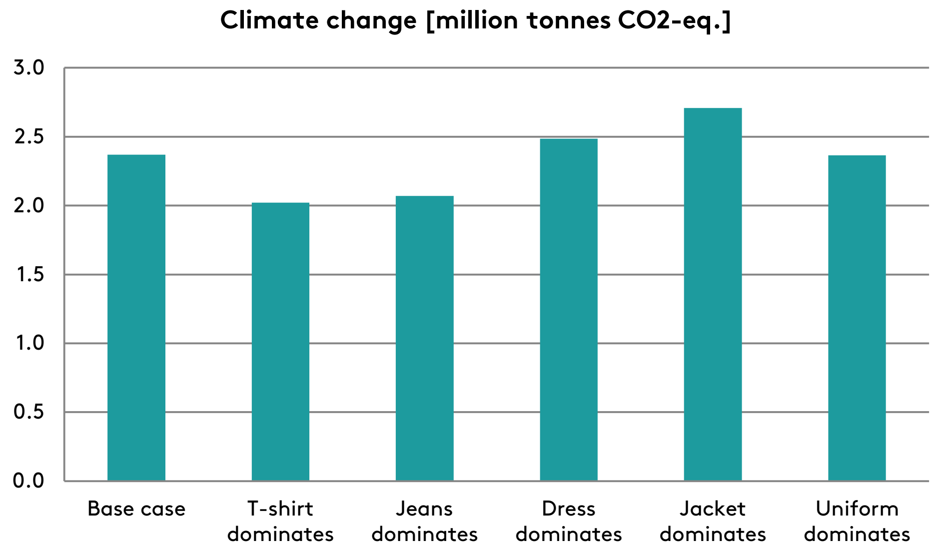

Figure 24 Variation in total climate change impact potential depending on which garments represent the imported textiles. The dominance scenario for each garment means that this garment stands for 50% of the Swedish national garment consumption and the other garments each stand for 12.5% in that scenario.

3.6.2 Sensitivity analysis on use phase

The laundry commonly gets a lot of attention in discussions about the environmental impact of garments. The actual knowledge about number of uses and consumer behaviour in terms of laundry and disposal is scarce, and often left open in guidance documents such as product category rules for environmental product declarations (Peters & Roos 2015). However, the results in Figure 23 above, based on the consumer survey in project 4 in Mistra Future Fashion (Granello et al. 2015), indicate that the use phase makes only a small (3%) contribution to the total climate impact of the Swedih fashion consumption. Below is shown an "overestimation scenario" where it is assumed that all household consumption of electricity for laundry is used for washing, drying and ironing of garments (Figure 25). This is a large overestimation, as home textiles (bed linen, towels etc.) are also laundried and this part of the laundry is more frequently dried in tumble dryers and heating cabinets which are four times as energy intensive compared to washing (Lefèvre 2009; Faberi 2007). The final contribution of laundry amounts in the overestimated scenario to 15% of the life cycle climate impact of garments. So, assuming that the baseline in our study represents an underestimation of the contribution of laundry, it most definitely does not contribute more than 15%.

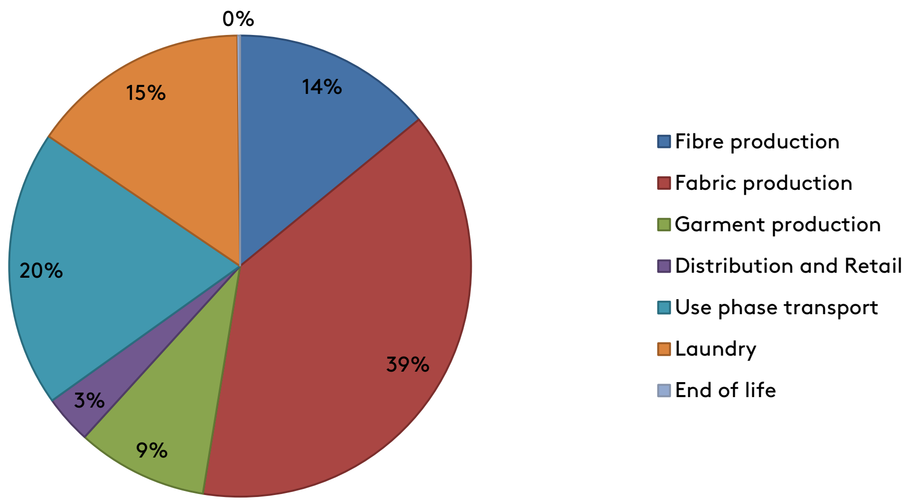

Figure 25 Climate change potential in the laundry overestimation scenario

Figure 26 shows the results for climate change and freshwater consumption scaled up to the Swedish national level, representing total clothing purchases and uses in Sweden over one year. The water use figures were weighted according to the scarcity of the water in the country it is used (as explained in Appendix 1). This explains why the fibre production stage dominates the whole life cycle so completely: the use of water for washing clothes in Sweden is less significant since there is an abundance of rain in this country, whereas cotton production frequently challenges the environmental values of the aquatic ecosystems where it occurs. The carbon footprint is more evenly spread among the life cycle phases, but there were two aspects of the result profile that may come as a surprise. One is the significance of the transport of the garment from the retail outlet back to the user's home, which has generally been ignored in previous studies. We found this to be a surprisingly significant component of the overall life cycle, and tested its significance in sensitivity analyses (see the collaborative consumption and consumer behaviour scenarios, sections 2.10.1 and 2.9.4). The other surprise was the relatively large contribution of the fabric production stage to the carbon footprint.

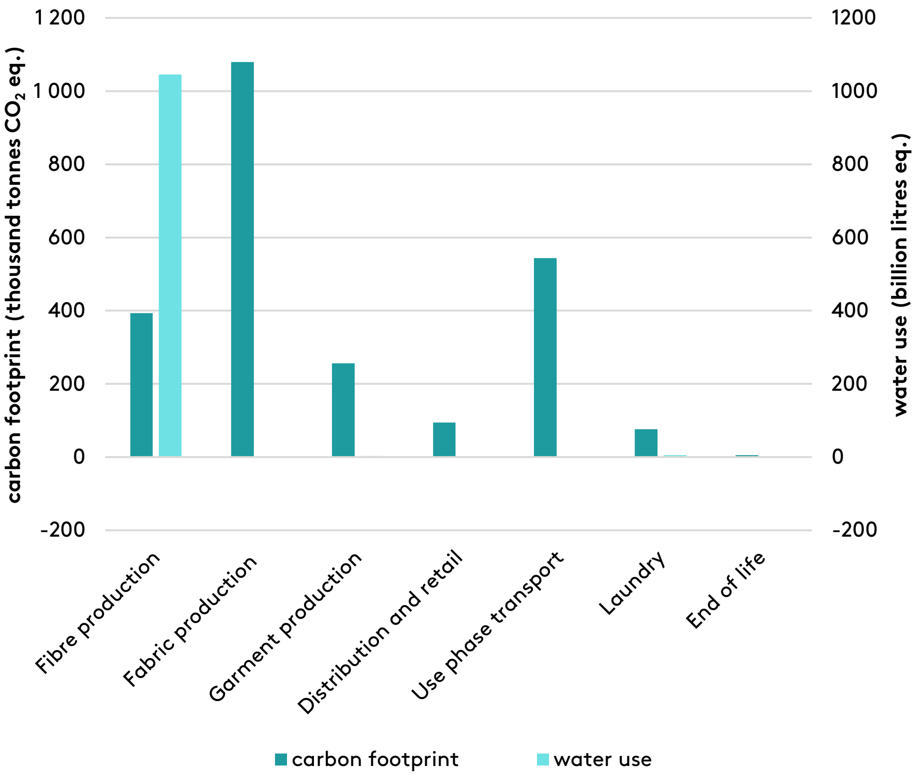

Figure 26 The results for climate change and freshwater consumption of Swedish fashion consumption, scaled up to the national level.

The results in Figure 26 suggested that examination of scenarios which reduced the pre-user environmental burden of clothing would be most worthwhile. We have examined several (the results of these are shown in Chapter 4). Figure 27 shows the results of two interventions: increasing the life span of garments, and replacing thirsty cotton fibre with forest-based Tencel. Increasing the practical lifespan of garments is an interesting scenario considering that so much clothing is discarded before the end of its technical lifespan, and so much of the fashion industry's current output is directed towards "fast fashion" – rapidly produced garments with shorter technical and practical lifespans. Figure 27 shows what happens if the practical lifespan of the average garment is increased by a factor of three, with the simple and unsurprising result (given the previous graph) that the carbon footprint and water use are reduced by 65 and 66 percent respectively. The practical lifespan of some garments might not ever be this much longer, while others may exceed this factor. National statistics on T-shirt consumption, for example, suggest the practical lifespan of these garments can be extended far beyond this. This illustrative scenario is a challenge both to manufacturers, to make and market more durable garments, and consumers, to buy fewer.

Replacing cotton with Tencel affects only the T-shirt, jeans and hospital uniform in the other example scenario illustrated in the graph. The key outcome there is the reduction in water use impacts on account of using a biomass resource from non-water stressed regions, so this result supports increased investment in forest cellulosic fibres by the textile industry. The combination of longer lifespan and the use of such forest cellulosic fibre produces the optimum result among the four illustrated here.

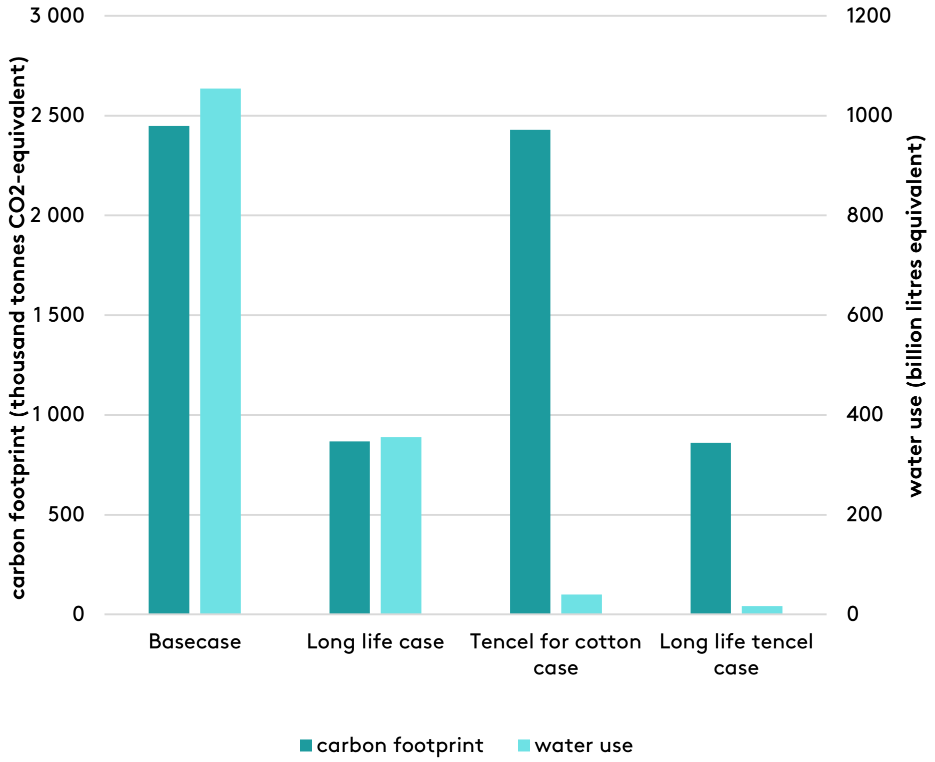

Figure 27 The results for two interventions for reducing the climate change and freshwater consumption of Swedish fashion consumption, namely extended service life (with a factor three) and a change of fibre, scaled up to the national level.

3.7 Results on wet treatment toxicity

This section presents the results from detailed modelling of LCIs including chemicals for the wet treatment processes, and matching the emitted substances with characterisation factors from USEtox (Rosenbaum et al. 2008). In the case of lacking characterisation factors, the USEtox COSMEDE database (ADEME 2015) has primarily been used, and secondarily own new characterisation factors have been calculated.

3.7.1 Scenarios for wet treatment processes

Below are shown the ecotoxicity impact results for the T-shirt. The default modelling of the wet treatment gives the result of 6.10 CTUe (Comparative Toxic Unit, ecotoxicity). When textile wet treatment chemicals are included, the result for the BAT scenario for the wet treatment is only insignificantly larger, while the average and the worst case scenarios score a total of 6.14 CTUe and 6.37 CTUe respectively.

The toxicity impact result for the direct emissions amounts to 3.67 CTUe, which equals 3.67 cubic meters of freshwater where the species in the ecosystem are exposed daily to a concentration above their no-observed effect concentration (NOEC). More information on the toxicity impact categories are found in Appendix 1.

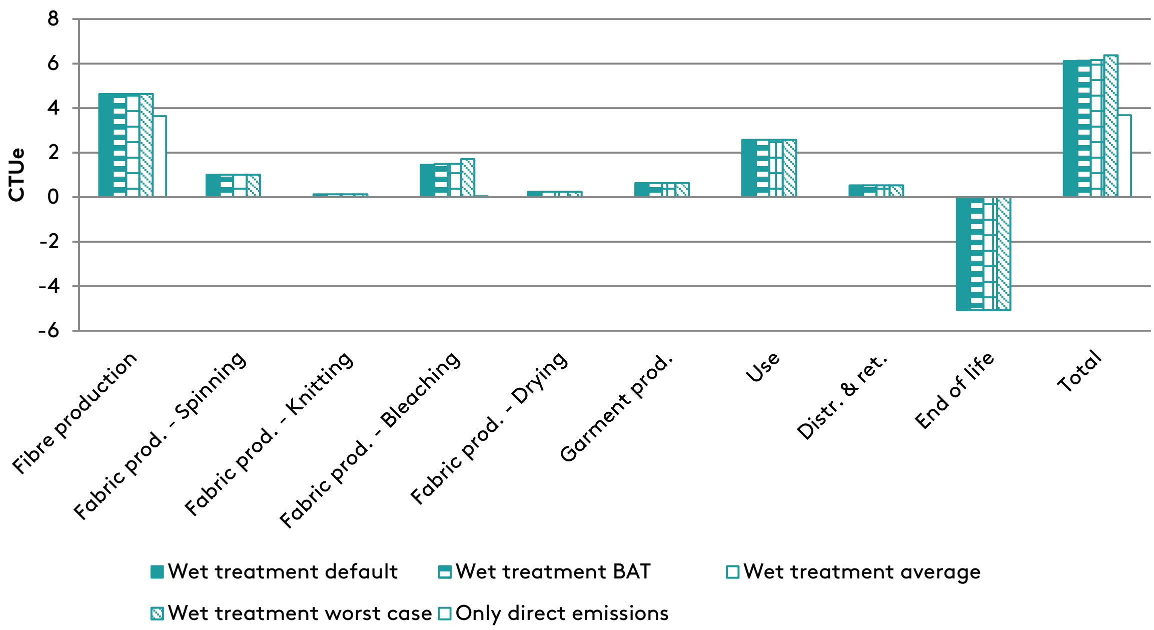

Figure 28 Results for inclusion of toxicity from textile wet treatment chemicals for the T-shirt, presented as CTUe per total life cycle of garment.

Below are shown the ecotoxicity impact results for the jeans. The default modelling of the wet treatment gives the result of 49.5 CTUe (Comparative Toxic Unit, ecotoxicity). When textile wet treatment chemicals are included, the result for the BAT scenario for the wet treatment is only insignificantly larger, while the average and the worst case scenarios score a total of 50 CTUe and 57 CTUe respectively. The toxicity impact result for the direct emissions amounts to 21 CTUe.

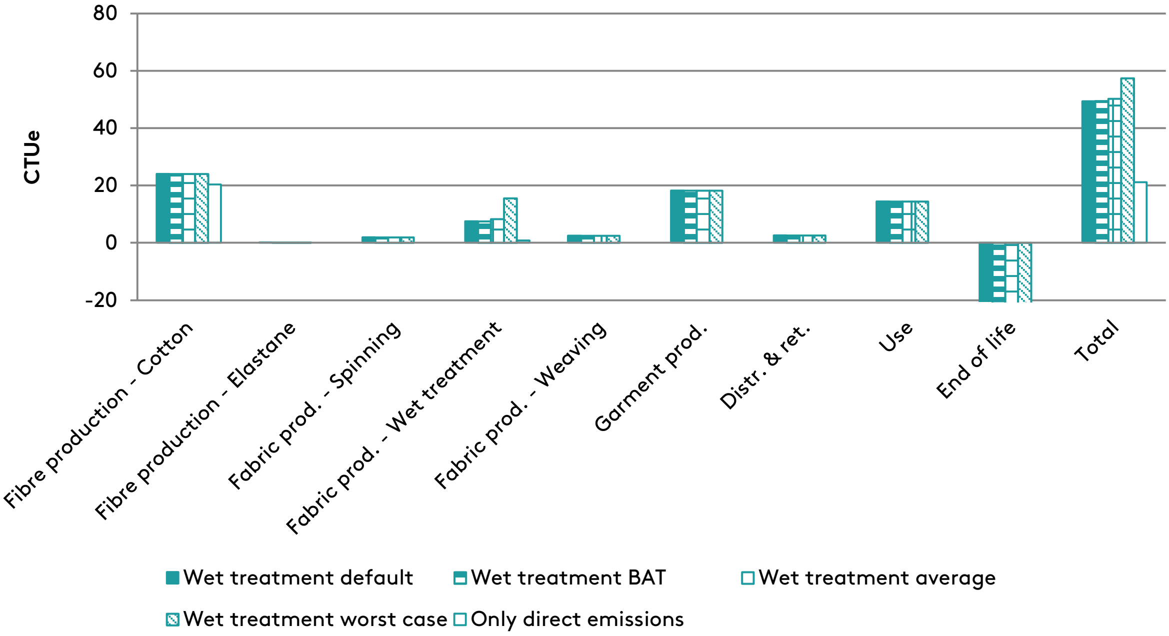

Figure 29 Results for inclusion of toxicity from textile wet treatment chemicals for the jeans, presented as CTUe per total life cycle of garment.

Below are shown the ecotoxicity impact results for the dress. The default modelling of the wet treatment gives the result of 10.2 CTUe (Comparative Toxic Unit, ecotoxicity). When textile wet treatment chemicals are included, the result for the BAT scenario for the wet treatment is only insignificantly larger, while the average and the worst case scenarios score a total of 10.7 CTUe and 14.4 CTUe respectively. The toxicity impact result for the direct emissions amounts to 0.42 CTUe.

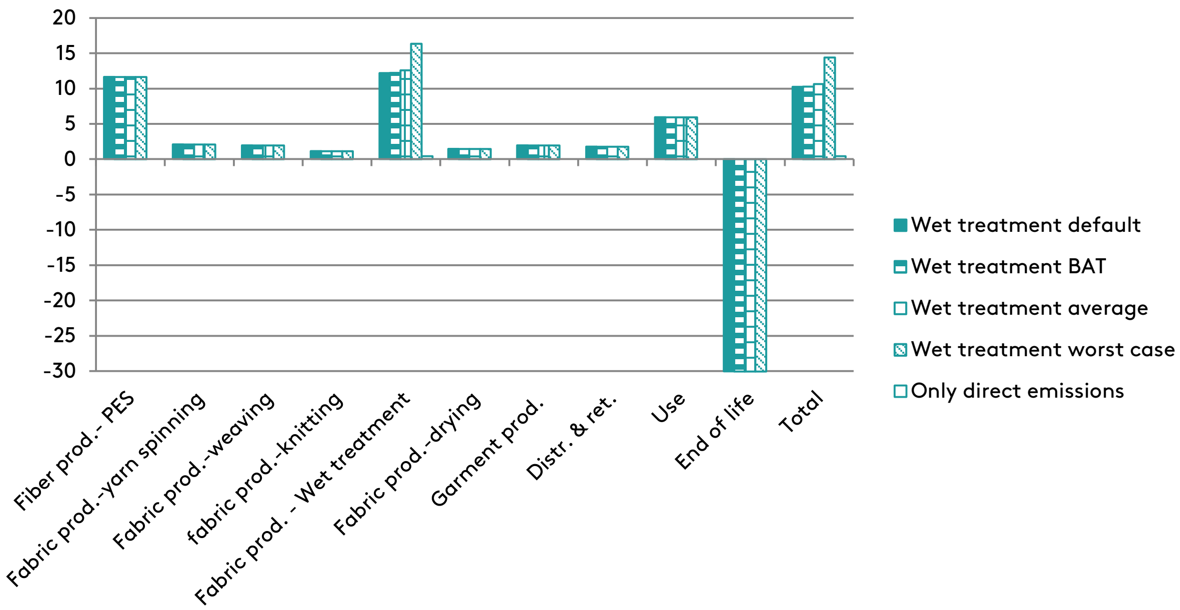

Figure 30 Results inclusion of toxicity from textile wet treatment chemicals for the dress, presented as CTUe per total life cycle of garment.

3.7.2 Toxicity of electricity production

The electricity production for the textile processes was modelled based on the electricity mixes of the three countries that contributed most to Swedish clothing imports in 2012 (Statistics Sweden 2014), in proportion to their share of imports. Thus, the mix consisted of electricity from China (65%), Bangladesh (23%) and Turkey (12%). The ecotoxicity impact result for 1 kWh of MiFuFa electricity mix is 1.99 CTUe.

The Chinese electricity dominates the ecotoxicity impact result, contributing with 89%, mainly from three disposal processes: Disposal, hard coal ash, 0% water, to residual material landfill/PL, Disposal, spoil from coal mining, in surface landfill/GLO and Disposal, tailings from hard coal milling, in impoundment/GLO. In the figure below, the main contributing emissions from these processes are displayed.

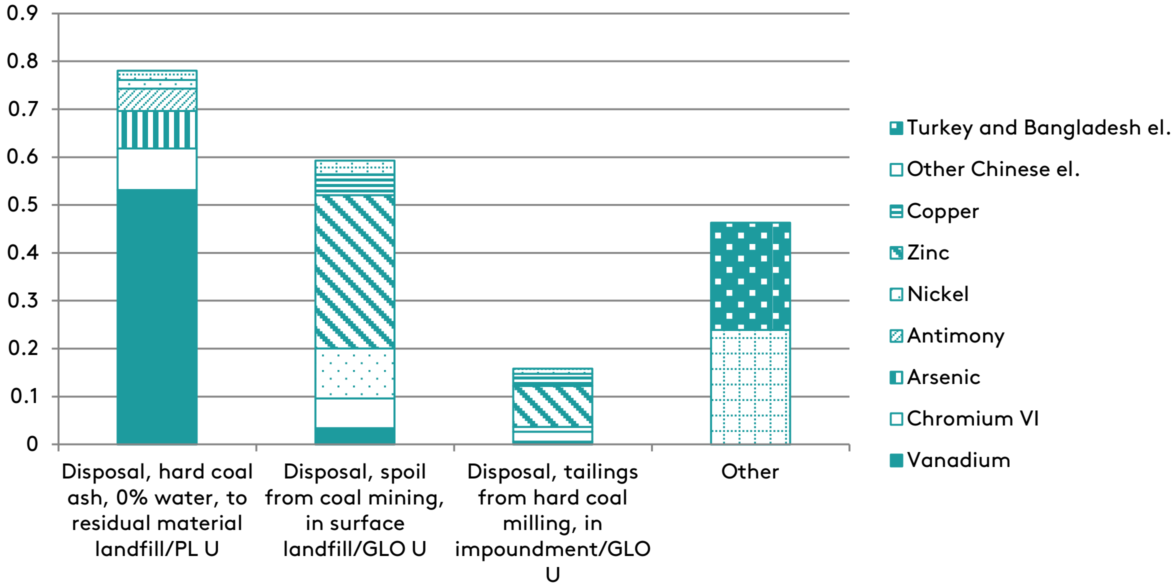

Figure 31 Ecotoxicity impact results from the three most dominant processes for the MiFuFa electricity production.

The disposal of hard coal ash in Chinese electricity production is modeled with a process from 2000, valid for Poland. Here the emission of 0.35 mg Vanadium per kg disposed ash contributes to around 25% of the toxicity, with 0.53 CTUe per kWh MiFuFa electricity mix. This is a very large estimation. In 2012, China produced 3 785 TWh[8] electricity from coal (IEA 2014). This would mean that in China 0.35 tonnes of Vanadium would leak out of hard coal ash landfills each year. This figure can be compared with the total US production in 2012 of 106 tonnes of Vanadium (U.S. Geological Survey 2015). The real Chinese electricity production is probably less toxic that what this database data suggests, and the results in Figure 29. Results for inclusion of toxicity from textile wet treatment chemicals for the jeans, presented as CTUe per total life cycle of garment. above where toxicity from energy systems and transports are included (scenario 1-4) have therefore high uncertainty.

The same problem was encountered with the modeling of the municipal waste incineration in the end of life phase of the garments. Here each kg incinerated textiles lead in the model to a water emission of 0.05 mg copper, and 0.2 mg of zinc in bioavailable form. These numbers are high, and the credits from the municipal waste incineration should probably be much lower.

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[8] 1 TWh = 1 E^{09} kWh

3.8 Implications of the choice of software

The calculations were performed in two different LCA software packages for practical reasons: GaBi v 6.0 (PE International 2014) and SimaPro v 8.0 (PRé Consultants 2014). An interesting and unforeseen consequence of this has been that the softwares and underlying databases could be compared.

GaBi and SimaPro are two broadly used LCA software packages and both have implemented common commercial LCI databases such the Ecoinvent database (Hischier 2003) and common LCIA methods, such as the ILCD recommended LCIA models (European Commission 2011), ReCiPe (Goedkoop et al. 2008) and CML (CML 2013). The output from the tools using the same database for LCI and the same model for LCIA should therefore be the same.

However, for some processes included in our study, the results differed between using GaBi and SimaPro. For example, results differed when using cotton cultivation data from the recent Cotton Inc. study (Cotton Incorporated 2012), which was available both in GaBi and SimaPro. In GaBi the carbon dioxide uptake per kg fibre was 1.54 kg whereas in SimaPro the figure was 2.99 kg. In GaBi the land area occupied to produce 1 kg cotton fibre was 11.4 m^2a whereas in SimaPro the figure was 6.84 m^2a, and also other figures differed without explanation. We therefore had to handle this dataset manually in order to get compatibility for the five garments.

Another database-related difference was that the Ecoinvent 3 data, where among other novelties the attributional or consequential approach can be chosen explicitly, had not yet been implemented in GaBi. Therefore we used Ecoinvent 2 data consistently.

We could also see a difference in the LCIA modelling, where the Swiss ecoscarcity model (Frischknecht & Büsser Knöpfel 2013) for calculation of freshwater resource depletion gave different results for GaBi and SimaPro, and adjustments to the GaBi results needed to be made, see Appendix 1.

4 Results and discussion – intervention scenarios

The sections below (4.1.1-4.1.4) show the environmental potential of a range of interventions: new business models for collaborative consumption, new technologies (Tencel fibres and spin dye technique) and changed consumer behaviour (extended service life and improved laundry practices). Next, in section 4.1.5, there is a discussion on the environmental potential of recycling of textile fibres, an intervention not studied quantitatively in the present study.

4.1.1 Business models for collaborative consumption

Below are the results for the collaborative consumption scenarios: Figure 32. shows results for the T-shirt with medium impact consumer transportation (i.e. the same transportation as assumed in the baseline). Figure 33 shows the climate impact results for one of the collaborative consumption scenarios compared to the baseline, thus providing a clear example of problem shifting. Figure 34 and Figure 35 show the results for the T-shirt with low and high impact consumer transportation, respectively. Figur 30 shows results for the jeans with medium impact consumer transportation.

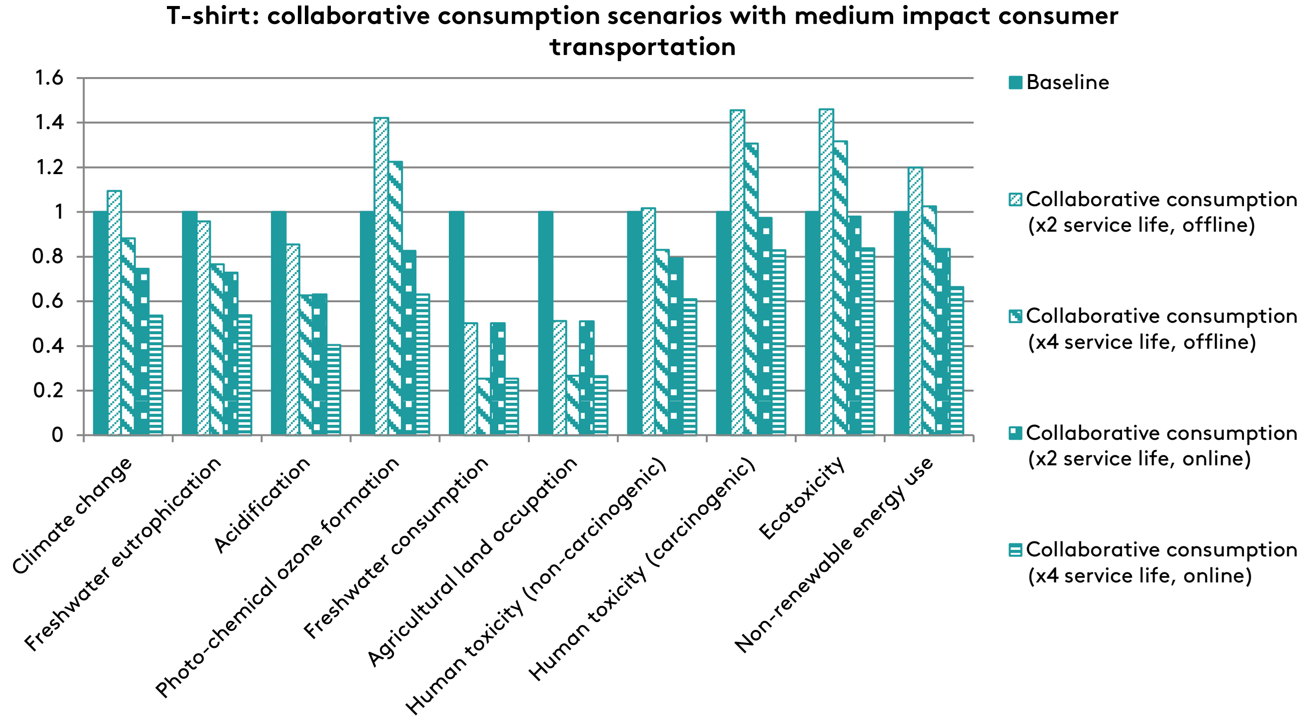

Figure 32 Environmental impacts of collaborative consumption scenarios for one (1) use of the T-shirt, with medium impact consumer transport (50% car/50% bus), normalised to the baseline scenario. Scenarios correspond to scenario 1-5 in Table 6.

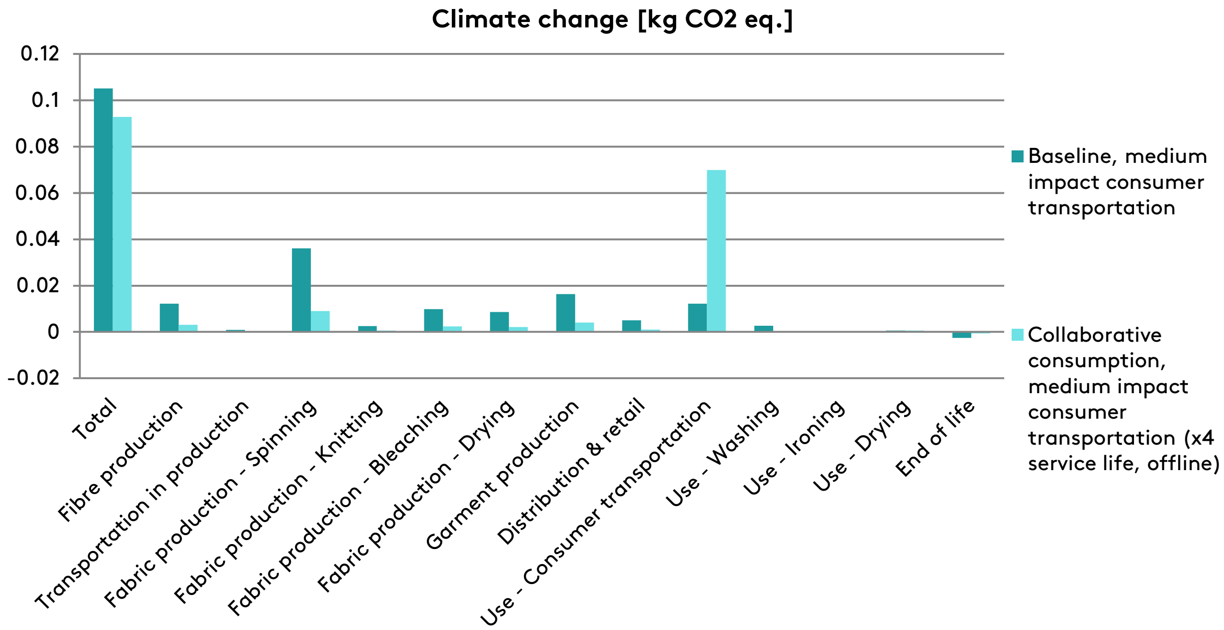

Figure 33 Climate impact of the baseline vs. the collaborative consumption scenario (x4 service life, offline solution)for one (1) use of the T-shirt, with medium impact consumer transport (50% car/50% bus).

The results for one use of T-shirt with medium impact consumer transport (Figure 34) shows that cultivation-related impacts are reduced (freshwater consumption and agricultural land occupation) in all collaborative consumption scenarios. The results for offline scenarios raise the question whether there are always environmental benefits with collaborative consumption: in many cases increased consumer transportation offset the benefits gained from reduced production, so-called problem shifting (as showed clearly in Figure 33Figure 34). This highlights the need for accounting for the logistics when implementing a collaborative consumption business model, for example by locating a physical rental service or clothing library in locations close to consumers and/or public transportation. The online scenarios show more environmental benefits compared to other scenarios since the package pickup-point is, on average, assumed to be closer to the consumer (one third of the distance) compared to an offline solution. Overall, the results show that, the more the service life is prolonged the better, and to achieve a substantial increase of service life is important for collaborative consumption to reduce the environmental impacts per garment use.

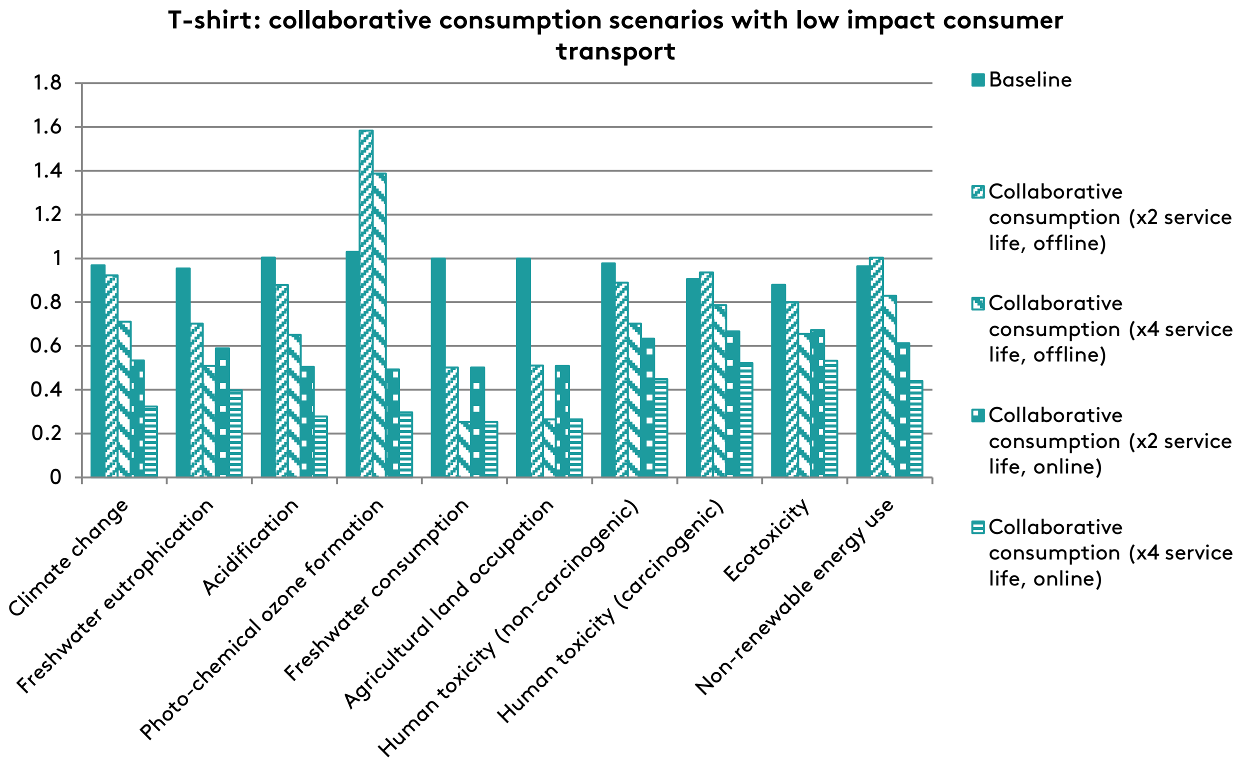

Figure 34 Environmental impacts of collaborative consumption scenarios for one (1) use of the T-shirt, with low impact consumer transport (100% bus), normalised to the baseline scenario for medium impact consumer transport. Scenarios correspond to scenario 6-10 in Table 6.

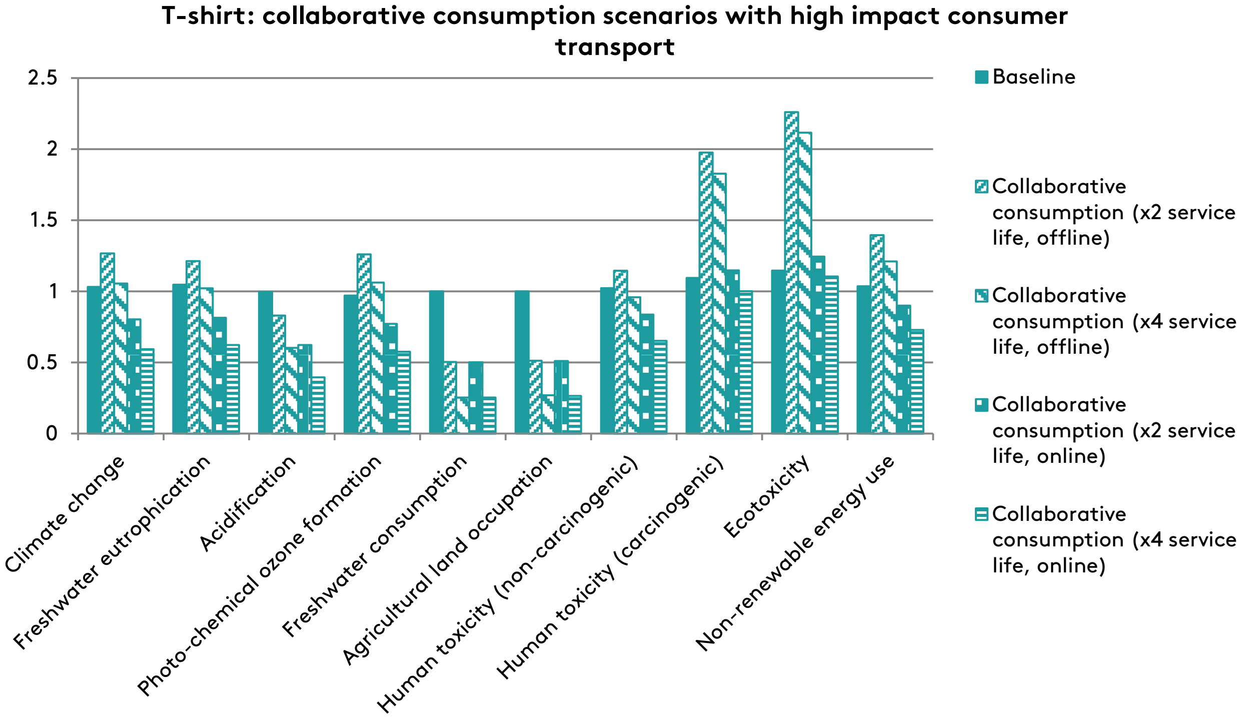

Figure 35 Environmental impacts of collaborative consumption scenarios for one (1) use of the T-shirt, with high impact consumer transport (100% bus), normalised to the baseline scenario for medium impact consumer transport. Scenarios correspond to scenario 11-15 in Table 6.

The results in Figure 34 shows significant environmental benefits in low impact consumer transport scenarios compared to the medium impact consumer transportation scenarios, and the results of Figure 35 shows the opposite effect for high impact consumer transportation scenarios. These results underline the importance of the locations of stores and/or that pickup points are close to consumers or accessible by public transportation.

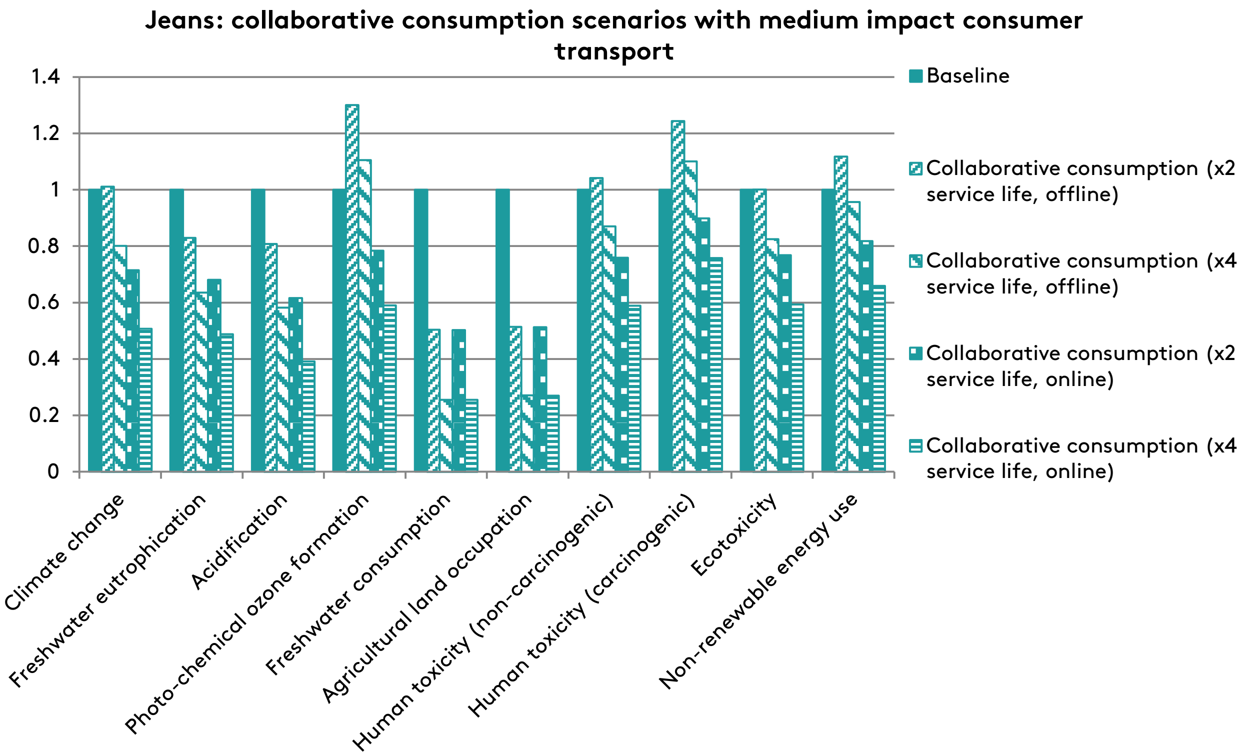

Figure 36 *Environmental impacts of collaborative consumption scenarios for one (1) use of the jeans, with medium impact consumer transport (100% bus), normalised to the baseline scenario for medium impact consumer transport. Scenarios correspond to scenario 1-5 in Table 6.*

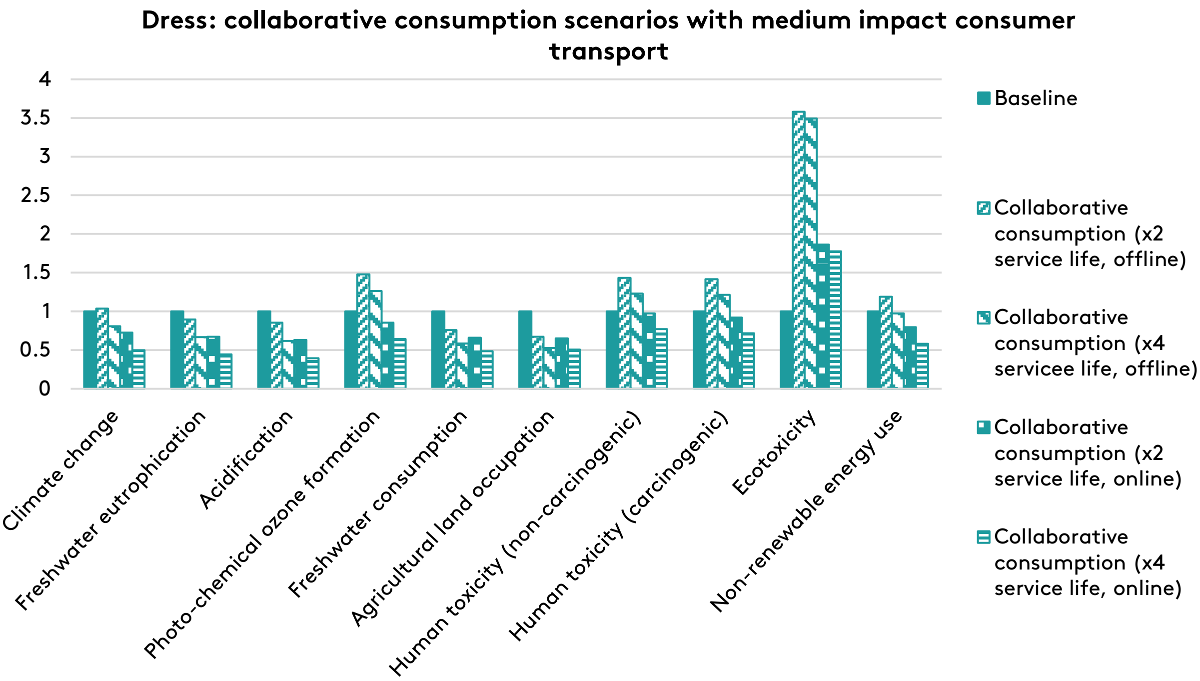

Figure 37 Environmental impacts of collaborative consumption scenarios for one (1) use of the dress, with medium impact consumer transport (50% car/50% bus), normalised to the baseline scenario. Scenarios correspond to scenario 1-5 in Table 6.

Results for the collaborative consumption scenario for the jeans (Figure 36) and the dress (Figure 37) are similar as for the T-shirt scenarios. Also the results of the low and high impact scenario follow the same patterns as corresponding T-shirt scenarios, thus they are not showed here.

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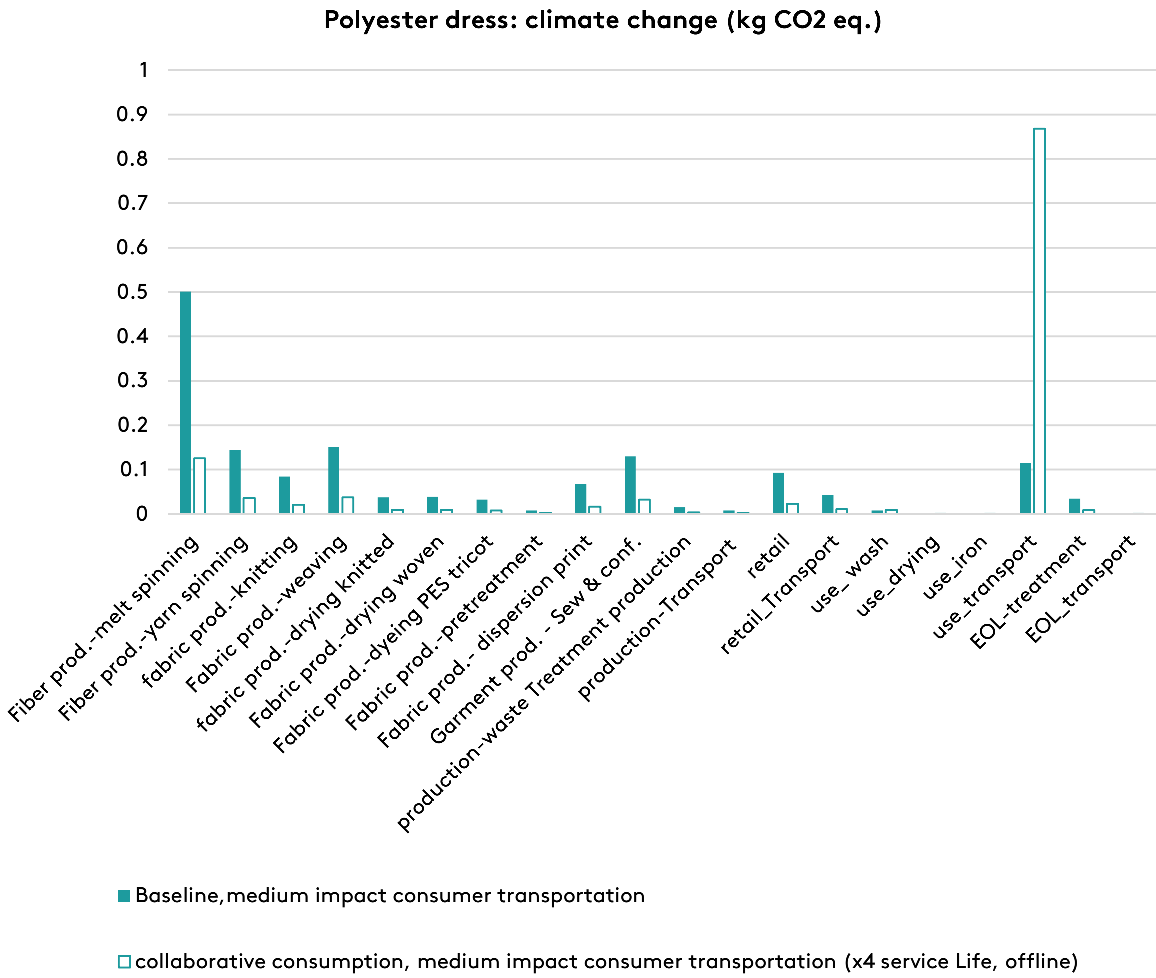

Figure 38 Climate impact of the baseline vs. the collaborative consumption scenario (x4 service life, offline solution)for one (1) use of the T-shirt, with medium impact consumer transport (50% car/50% bus).

4.1.2 Alternative fibres

Figure 39 shows the implications for the environmental impact of the T-shirt from changing from cotton fibres to fibres from forest cellulosics. A change of fibres for the T-shirt leads to improvements in terms of freshwater consumption. The differences in other impact categories are negligible in relation to uncertainties. It should be noted that intensive forestry is, according to the characterisation method, classified as agricultural land occupation. With another classification, a change of fibre from cotton to tencel would considerably reduce also agricultural land occupation. From Figure 40Figure 41, it is clear that for the dress, the pattern is similar to the T-shirt.

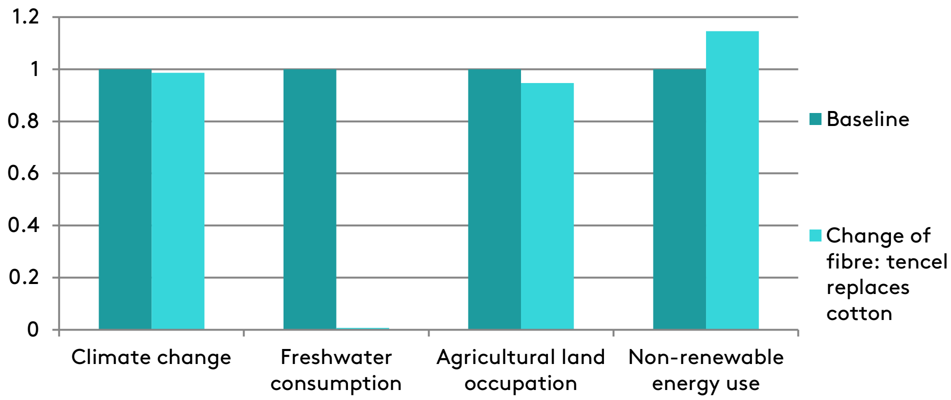

Figure 39 *Environmental impacts of one (1) use of the T-shirt, in the baseline scenario vs. the the scenario in which tencel replaces cotton. Results are showed in the impact categories for which the inventorying supports the life cycle impact assessment. Results are normalised to the baseline scenario.*

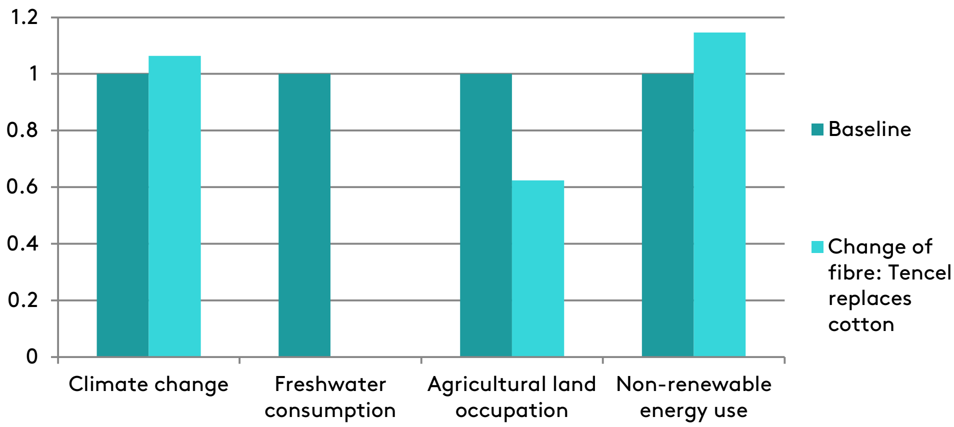

Figure 40 *Environmental impacts of one (1) use of the hospital uniform, in the baseline scenario vs. the scenario in which tencel replaces cotton. Results are showed in all the impact categories selected in the LCA. Results are normalised to the baseline scenario.*

In Roos (2012), a change of fibre was studies also for the hospital uniform, using some other impact assessment methods and modelling assumptions than in the present study. Figure 41 below shows a graph from the report Roos (2012), in which it is clear that the results are similar as in the present study: water consumption is the impact category that is improved the most with a change of fibres from cotton to Tencel.

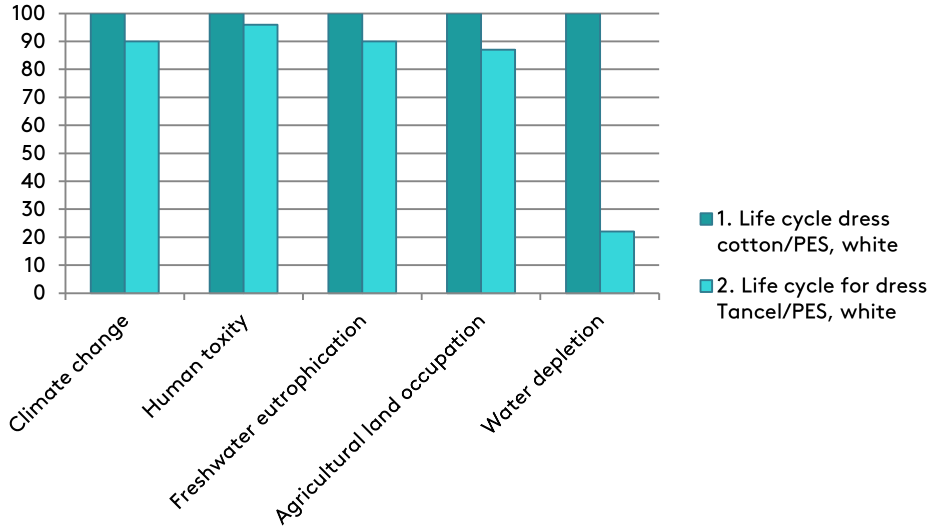

Figure 41 Comparing 1 p '1.Life cycle dress cotton/PES, white' with 1 p '2.Life cycle for dress Tencel/PES, white'; Method: ReCiPe Midpoint (H) V1.06/World ReCiPe H/Characterization. Environmental impacts for cotton/PES uniform (1) and Tencel/PES uniform (2), in terms of climate change, human toxicity, freshwater eutrophication, freshwater ecotoxicity, agricultural land occupation and water depletion, from (Roos 2012)*.*

4.1.3 From wet to dry

Spin dye is a technique that totally removes the need for wet dyeing as is shown in the graph below.

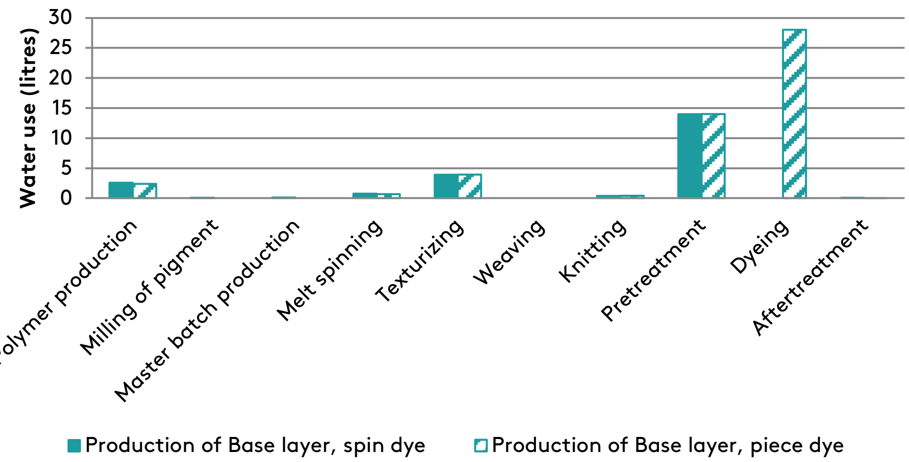

Figure 42 Direct water use in the production processes of spun dyed fabrics.

4.1.4 Changed consumer behaviour

The figure below shows results from the "your favourite T-shirt" and "conscious T-shirt consumer" scenarios (results would be similar also for the other garments). It is clear that consumer behaviour in terms of modes of transportation to and from the story and laundry practices do matter, but that prolonged service life is a much more effective way for the consumer to reduce the impact of his/her clothing consumption.

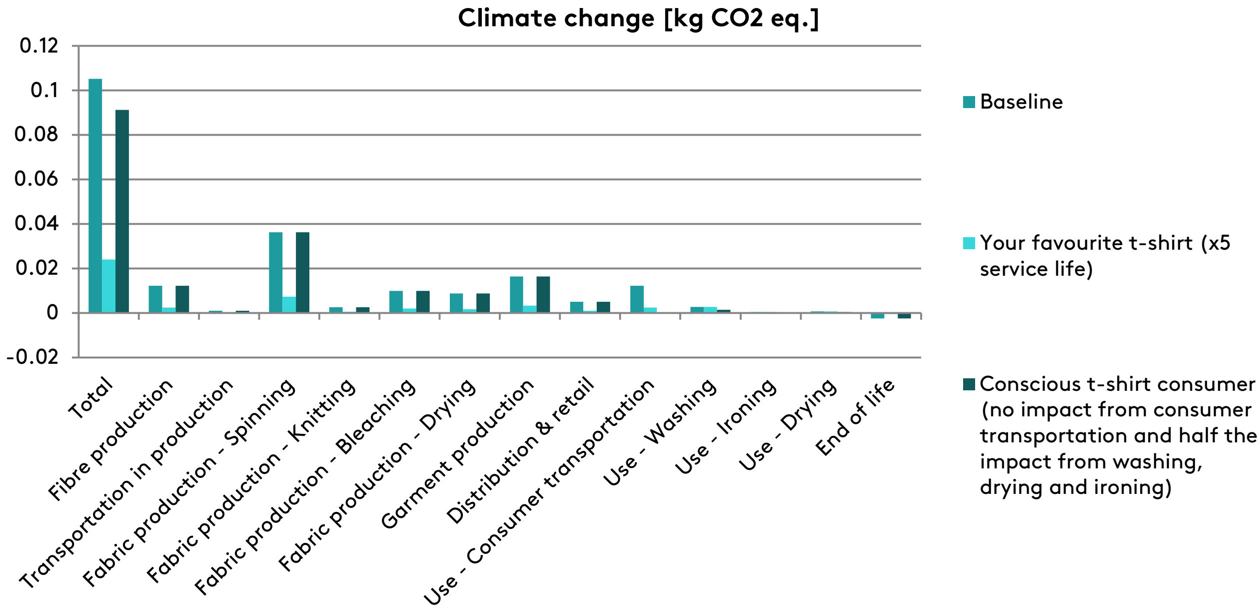

Figure 43 Environmental impacts of one (1) use of the T-shirt, in the baseline scenario vs. "the your favourite T-shirt" scenario (with prolonged service life) and the "conscious T-shirt consumer" scenario (with no impact from consumer transportation and half the impact from washing, drying and ironing).

4.1.5 Recycling

Recycling of textile fibres was not among the studied interventions in the present study due to a lack of commercial-scale recycling technologies and the associated uncertainty of LCI data. However, there are numerous recycling technologies under development, for cotton and regenerated cellulose fibres as well as for synthetic fibres. The environmental potential of such solutions were estimated in a separate report (Östlund et al. n.d.) carried out in collaboration with P2 in Mistra Future Fashion. The main conclusions of Östlund et al. (n.d.) are summarised in the below paragraph.

There are potentially considerable environmental benefits with both chemical and mechanical recycling processes in comparison with conventional energy recovery (i.e. municipal incineration, as assumed in the present study), assuming that the recycled fibres replace virgin fibres (Zamani et al. 2014). For example, recycling can reduce the climate impact with 0.5-3 CO_2 eq. per kg recycled materials, compared to energy recovery (compare with climate impact per garment service life in Figure 6, ranging from 2 to 17 kg CO_2 eq.). There are, however, several scenarios studied in Östlund et al. (n.d.) that considerably increase the climate impact, which emphasises the need for efficient recycling processes. Also, if recycling merely causes increased production, and the production of virgin fibres is not replaced, then there appears to be no environmental benefits with recycling. Furthermore, the benefits are strongly dependent on the type of fibre that is assumed to be replaced; for example, if cotton is replaced, there are potentially considerable benefits in the impact categories associated with cotton production (e.g. water consumption and toxic impacts from pesticide use).

5 Conclusions

This study aimed to provide knowledge to the Swedish fashion industry and its stakeholders about the environmental impact of fashion consumption from a life cycle perspective. To achieve this, five key garments were examined using LCA: a T-shirt, a pair of jeans, a dress, a jacket and a hospital uniform. Apart from the baseline scenarios for each garment, the potential benefits of a range of interventions for impact reduction were studied: business models for collaborative consumption, alternative fibres, changed dyeing technology and changed consumer behaviour. Furthermore, the results of the baseline were scaled up to the national level, to represent the environmental impact of Swedish national clothing consumption for one year. This permitted the study of the relative importance of different garments and the national-level potential of some of the studied interventions for impact reduction.

The environmental impact of the garments was expressed using indicators for freshwater use, non-renewable energy use, agricultural land occupation, contributions to climate change (also called "carbon footprint"), freshwater ecotoxicity, freshwater eutrophication, human toxicity (carcinogenic and non-carcinogenic), photochemical oxidant formation, and acidification.

For freshwater use, the fibre production stage dominates the whole life cycle completely, whereas the other environmental impacts are more evenly spread among the life cycle phases. Three aspects of the result profile may come as a surprise. One is the significance of the consumer's transportation to and from the retail outlet, which has generally been ignored in previous studies. We found this to be a surprisingly significant component of the overall life cycle. The next surprises were the relatively large contribution of the fabric production stage, and the relatively small contribution from the laundry phase. These results suggest that intervention aiming at reducing the pre-user environmental burden of clothing will be most worthwhile. This is notwithstanding the potential to increase garment lifespans by interventions in laundry habits that reduce damage to garment fibres.

When scaling up the results to the national level, it was shown that the carbon footprint from Swedish fashion consumption is about 0.25 tonnes CO_2 equivalents per capita and year. The average carbon footprint for a Swedish person is about 10 tonnes of CO_2-equivalents per year, which means that the carbon footprint from fashion consumption is only about 2.5% of the total carbon footprint. However, as science and political goals imply that the carbon footprint per capita must be drastically reduced, it is clear that the climate impact from fashion consumption needs to be reduced considerably in a sustainable future.

Increasing the practical lifespan of garments is an interesting scenario considering that so much clothing is discarded before the end of its technical lifespan, and so much of the fashion industry's current output is directed towards "fast fashion" – rapidly produced garments with shorter technical and practical lifespans. The environmental gains from increased lifespan were studied through the collaborative consumption scenarios and the consumer behavior scenarios. The collaborative consumption scenarios showed that there are potential environmental benefits of clothing libraries, second hand stores and rental services, but also a risk of problem shifting: increased consumer transportation can offset the benefits gained from reduced production. This highlights the need for accounting for the logistics when implementing collaborative consumption business models, for example by locating a physical rental service or clothing library in locations close to consumers and/or public transportation, or by implementing internet solutions that require less consumer transportation. At the national level, it was shown that if the practical lifespan of the average garment is increased by a factor of three, the carbon footprint and freshwater use are reduced by 65 and 66 percent respectively. Increasing the practical lifespan of garments is a challenge both to manufacturers, to make and market more durable garments, and consumers, to buy fewer of them.

The results of the scenarios for changed consumer behaviour clearly show that consumer behaviour in terms of modes of transportation to and from the store and laundry practices do matter, and that prolonged practical lifespan is a much more effective way for the consumer to reduce the impact of his/her clothing consumption

The change of fibre scenarios show that replacing cotton with Tencel leads to reduced freshwater use impacts on account of using a biomass resource from non-water stressed regions. This supports increased investments in forest cellulosic fibres by the textile industry.

The potential to do the kind of environmental evaluation presented in this report is continuously improving, with the publication of new data on fibre, fabric and garment production and the improvement in life cycle impact assessment methods (e.g. Kounina et al. 2013). Further work remains to be done on the refinement of data collection methods. For example, the growth of product category rules offers the promise of greater consistency between life cycle assessments, but such rules must properly encompass the garment lifespan if the assessments are to provide useful guidance.

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Appendix 1. Descriptions of impact categories and characterisation methods

Climate change

Climate change refers to the consequences of increased average temperatures of the earth's atmosphere and oceans. This increase is mainly because of emissions of greenhouse gases (GHGs; e.g. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs)) from anthropogenic sources such as the combustion of fossil fuels and deforestation (IPCC 2013).

For characterising climate impact, in this report we used the Global Warming Potential (GWP) with a 100 year perspective (GWP_{100}) expressed in kg CO_2 equivalents (IPCC 2013), and assumed that biogenic CO_2 emissions are climate neutral. This was done because these are the most common LCA practices and recommended in the ILCD handbook (European Commission 2010). The latter assumption presumes that within relevant spatial system boundaries (e.g. at a landscape or national level) or within a reasonable time horizon (e.g. within one rotation period: the time period from harvest to harvest), the forestry or agriculture that generates the extracted biomass is carbon neutral. This means that the land management practices ensure that as much carbon is sequestered (above and below ground) as is harvested. In other words, the land is sustainably used with regard to carbon extraction. It should be noted that this may not always be the case and new, non-established LCIA methods can capture the effects from non-sustainable land management practices. Also, methods can increasingly capture climate effects not related to the carbon cycle, e.g. changes in the land's capacity to reflect solar radiation (the so-called albedo effect). Using such methods can significantly change the characterised results from biobased products, both positively and negatively (Røyne et al. n.d.). Thus, from a climate perspective, it is important to ensure that biobased textile fibres are extracted from land uses that do not contribute to the long-term increase of atmoshperic GHGs – if this is not the case, the climate impact results of the present study does not hold.

Acidification

Precipitation (rain, snow, fog, etc.) deposit acidifying substances from antropogenic sources (e.g. sulphur dioxide (SO_2) and nitrogen oxides (NO_X) released in combustion) to terrestrial and aquatic ecosystems which may increase pH levels (the concentration of hydrogen ions, H^+). This may damage freshwater and coastal ecosystems and soils, with consequences such as forest decline, increased fish mortality and damages to buildings (Guinée et al., 2002). Also, heavy metals released due to increased pH levels can damage freshwater resources. For characterising acidification impact, we used the accumulated exceedance method developed by Seppälä et al. (2006), with characterisation factors expressed as mole H^+ equivalents.

Freshwater eutrophication

Nutrients like phosphorus (P) or nitrogen (N) released to freshwater systems may cause increased biological productivity, such as production of planktonic algae. The algae sink to the bottom and are broken down with consumption of oxygen in the bottom layers, causing a dead environment and (among others) increased fish mortality. The most significant sources of nutrient enrichment are the agricultural use of fertilizers, the emissions of nitrogen oxides from combustion and wastewater from households and industry. For characterising freshwater eutrophication impact, we used the accumulated exceedance method developed by Seppälä et al. (2006), with characterisation factors expressed as mole H^+ equivalents.

Toxicity

The toxicity has been evaluated with the LCA method USEtox (Rosenbaum et al. 2008), which is the recommended method by the European Commission (European Commission 2011). USEtox calculates characterization factors for human toxicity and freshwater ecotoxicity at midpoint level. USEtox uses the unit CTU (Comparative Toxic Unit) which is an indirect measure of the number of cases per year caused by toxic effects.

The ILCD handbook (European Commission 2010) recommends that the LCA practitioner should complement the methods with missing characterisation factors if they can have impact on the results. This can be done for processes that are modelled within a project but it is impossible to compensate for missing data in database data.Human toxicity, carcinogenic and non-carcinogenic

The characterization factor for human toxicity impacts (human toxicity potential) is expressed in comparative toxic units (CTUh), and is the estimated increase in morbidity in the total human population, per unit mass of a chemical emitted, assuming equal weighting between cancer and non-cancer due to a lack of more precise insights into this issue. The result is calculated as [CTUh per kg emitted] = [disease cases per kg emitted].

All cases of non-mortal human toxicity impacts, which do not lead to death but to disability and illness, are weighted against their relative severity compared to death.

Freshwater ecotoxicity

The characterization factor for freshwater ecotoxicity impacts (ecotoxicity potential) is expressed in comparative toxic units (CTUe), and is an estimate of the potentially affected fraction of species (PAF) integrated over time and volume, per unit mass of a chemical emitted. The result is calculated as [CTUe per kg emitted] = [PAF × m^3 × day per kg emitted].

One CTUe equals thus one cubic meter of freshwater where the species in the ecosystem are exposed daily to a concentration above their no-observed effect concentration (NOEC). An environmental concentration is considered to present an acceptable risk if not more than 5% of all species is exposed above their no-observed effect concentration (NOEC).

Photochemical ozone formation

Increased levels of ozone at ground level arise through the reaction of volatile organic compounds (VOCs), for example ethene, with oxygen compounds or oxides of nitrogen in air and under the influence of sunlight, so called photochemical oxidation. The effects on human health are, amongst others, irritation of eyes and mucous membranes as well as impaired respiratory function. Ground level ozone also has severe effects on vegetation, resulting in agricultural production losses (Guinée et al. 2002). For characterising photochemical ozone formation, we used the LOTOS-EUROS model with characterisation factors expressed as kg NMVOC equivalents (Van Zelm et al. 2008).

Agricultural land occupation

Agricultural land is increasingly seen as a limited resource, e.g. as manifested in the "peak farmland" debate (Ausubel et al. 2013). Competition for remaining agricultural land can have severe environmental consequences, including intensification of agriculture (e.g. associated with increased nutrient emissions) and habitat change (Millennium Ecosystem Assessment 2005). In the present study, we have used an LCI-level indicator – the area of agricultural land occupation and the duration of that use, expressed in m^2 times years – and not characterised the impacts of agricultural land occupation further down the cause-effect chain. For a discussion on impacts further down the cause-effect chain, and impacts from transformation of non-agricultural land, see below paragraph on biodiversity loss.

Freshwater consumption

The use of freshwater in water-scarce areas can cause water depletion with numerous environmental impacts, including effects on aquatic organisms and terrestrial ecosystems as well as malnutrition among humans (Pfister et al. 2011. For characterising water use, we used the Swiss Ecoscarcity (Frischknecht and Knöpfel 2013) method recommended by ILCD (European Commission 2010). This method accounts for consumptive water use, which is water embodied in products, water evaporated due to plants or industrial processes, and water extracted from one water catchment and released to another. In terms of the LCI inventory, this is lake water, river water and rain water used in the product system, minus water returning from the product system to natural systems, e.g. waste water, cooling water and turbine water. The method multiplies the amount of consumptive water use with a country-specific weighting factor accounting for water scarcity. As this is not done automatically within one of the LCA softwares used in the present study (GaBi), and as it is not feasible to identify the country of location for all background processes, we have (in the modelling made in GaBi) only applied country-specific weighting factors for the major flows of consumptive water use.

To exemplify, let us look at the calculation procedure for the T-shirt baseline. Cotton cultivation was identified as the only major flow of consumptive water use in the T-shirt life cycle (1652 out of 1682 l, or 98%). Therefore, the consumptive water use of cotton cultivation was multiplied with the average scarcity factor of the countries of cultivation. As the cotton cultivation dataset is based on the average production of China (46%), India (30%) and USA (24%), the scarcity factors of these countries (0.952, 3.343 and 0.607, respectively) were extracted from Frischknecht and Knöpfel (2013) and an average scarcity factor was calculated (1.6). The remaining water use (30 l, 2%) was, however, not weighted based on water scarcity (i.e., a scarcity factor of 1 was assumed). In the end, the 1652 litres of water consumed due to cotton cultivation was multiplied by 1.6 and added to the 30 litres of water consumed elsewhere, to yield a final scarcity-weighted water consumption of 2667 litres for the T-shirt (per garment life cycle, not per use)

Non-renewable energy use

Non-reneweable energy use is an impact category that reflect concerns about society’s dependency on limited, non-renewable (i.e. fossil) energy resources, e.g. as manifested in the "peak oil" debate (Owen et al. 2010). There are ecological as well as human consequences of depletion of fossil resources; e.g., because of socio-economic effects of limited access to energy or unconventional oil and gas extraction (Giacchetta et al. 2015). In the present study, we have used an LCI-level indicator – the primary non-renewable energy use, expressed in MJ – and not characterised the impacts of the depletion of non-renewable energy resources further down the cause-effect chain. "Primary" means that it is the energy content extracted from nature before further processing, i.e. the energy content in hard coal or crude oil (Øvergaard 2008).

Excluded impact category: biodiversity loss

Most environmental impacts covered in the present study influences biodiversity, but in this paragraph we specifically discuss biodiversity loss of land use (LU) and land use change (LUC), which has been identified as major drivers of biodiversity loss globally (Millennium Ecosystem Assessment 2005). The biodiversity loss of LU and LUC depends heavily on the specific geographic location of the impacted land and several site-dependent attributes (species richness, land vulnerability, other activities in the region, land management practices, etc.), which are difficult to describe in an LCA on generic garments with raw material derived from numerous regions. This site-dependency is also the reason for why the LCIA methodology of this impact category lags behind the LCIA methodology of most other impact categories, and why there is no consensus in the LCA community of LCIA methods. These are the reasons why the biodiversity loss of LU and LUC were not studied in the present study. Among the studied impact categories, agricultural land occupation is the one closest resembling a proxy for the biodiversity loss of LU, but none of the studied impact categories can be seen as a proxy for biodiversity loss of LUC. However, based on previous research, two conclusions can be made with regard to the biodiversity loss of LU and LUC in the context of garment production. First, it seems that if LUC takes place in the production of cellulosic textile fibres (e.g. as the transformation of a natural forest to a tree plantation or a cotton plantation), this causes much higher biodiversity impact than the impact of LU (Sandin et al. 2013). This suggests that in terms of biodiversity impact, it is highly important to ensure that natural, biodiversity-rich land is not transformed as a consequence of the product life cycle. This is supported by the planetary boundaries framework, which says that humanity has already transgressed the planetary boundary for land-system change, emphasising the need to prevent further deforestation (Steffen et al. 2015), and Millennium Ecosystem Assessment (2005,) which pinpoint deforestation as a major driver behind biodiversity loss. Secondly, the latitude and altitude of the location of LU and LUC seem to matter less: regions at low latitudes and altitudes experience a higher biodiversity loss per hectare in case of LU and LUC disturbances, but this is largely counteracted by the fact that less land is required for producing a given amount of biomass (Sandin et al. 2013). It should be noted that these findings were derived using non-established LCIA methods; further research is thus needed to verify these findings.

Appendix 2. Modelling of processes

The table below gives an overview of which processes that were included in the modelling of each of the five garments. The amount of each process per kg garment service life is displayed, which means that waste from each step (mainly spinning and fabric construction) is accounted for.

Table 9 Included processes for each of the five garments, and amount of each process per kg garment.

	Amount per kg of garment (kg)				
Process	*T-shirt*	*Jeans*	*Dress*	*Jacket*	*Hospital uniform*
Production phase					
0 Cotton cultivation, ginning and baling	1.62	1.65	-	0.14	0.64
0 Polyester fibre production	-	-	1.21	0.32	0.59
0 Polyamide fibre production	-	-	-	0.49	-
0 Elastane fibre production	-	0.02	-	0.01	-
0 Yarn spinning	1.62	1.65	1.20	0.79	1.18
A2.1.7 Knitting	1.40	-	0.59	0.12	-
A2.1.8 Weaving	-	1.49	0.61	0.64	1.18
A2.1.9 Non woven process	-	-	-	0.15	-
A2.1.10 Wet treatment, dyeing and printing	1.19	1.49[9]	1.20	0.76	1.18
A2.1.11 Product assembly	1.01	1.01	1.01	1.01	1.0
Distribution & Retailing phase					
A2.2.1 T-shirt , jeans, dress and jacket, distribution and retail	1.01	1.01	1.01	1.01	-
A2.2.2 Hospital uniform, distribution	-	-	-	-	1.0
Use phase					
A2.3.1 Detergent production/kg wash	0.013	0.013	0.013	0.013	-
A2.3.2 Residential washing/kg wash	1.0	1.0	1.0	1.0	-
A2.3.3 Residential drying (% of washing cycles)	34%	29%	19%	21%	-
A2.3.4 Residential ironing (% of washing cycles)	15%	15%	18%	5%	-
A2.3.5 Use of T-shirt	1.0	-	-	-	-
A2.3.6 Use of jeans	-	1.0	-	-	-
A2.3.7 Use of dress	-	-	1.0	-	-
A2.3.8 Use of jacket	-	-	-	1.0	-
A2.3.9 Use of hospital uniform	-	-	-	-	1.0

[9] Please note that the wet treatment for jeans material is made on yarn, and is performed prior to the weaving.

	Amount per kg of garment (kg)				
A2.3.11 Industrial laundry	-	-	-	-	1.0
End of life phase					
A2.4.1 Incineration	1.0	1.0	1.0	1.0	1.0

The tables below shows how each of the processes have been modelled. The background information behind the modelling, such as selected data sources and assumptions is found in chapter 2.3.

A2.1 Production phase

A2.1.1 Electricity mix in production

Based on respective countries' share of the three biggest contributors to Swedish clothing imports in 2012: China, Bangladesh and Turkey (Statistics Sweden 2014), a "MiFuFa" electricity mix was created used for all production processes.

A2.1.1.1 MiFuFa electricity mix

The Chinese electricity mix dataset is from Ecoinvent (Frischknecht & Faist Emmenegger 2007).

Inputs	Datasets	Share of electricity mix
China's electricity mix	CN: electricity, medium voltage, at grid	65%
Bangladesh electricity mix	Model described below	23%
Turkey's electricity mix	Model described below	12%

A2.1.1.2 Electricity mix, Bangladesh

Mixes and losses are based on IEA statistics for Bangladesh (IEA 2011). All processes are from Ecoinvent (Dones 2007).

Inputs	Datasets	Share of electricity mix
Electricity from natural gas	GLO: electricity, natural gas, at turbine, 10MW	91.5%
Electricity from oil	UCTE: electricity, oil, at power plant	4.8%
Electricity from hydro power	RER: electricity, hydropower, at reservoir power plant, non alpine regions	2.0%
Electricity from coal and peat	CN: electricity, hard coal, at power plant	1.8%

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Losses		10.3%

A2.1.1.3 Electricity mix, Turkey

Mixes and losses are based on IEA statistics for Turkey (IEA 2011). All processes are from Ecoinvent (Dones 2007).

Inputs	Datasets	Share of electricity mix
Electricity from natural gas	GLO: electricity, natural gas, at turbine, 10MW	45.8%
Electricity from coal and peat	UCTE: electricity, hard coal, at power plant	29.1%
Electricity from hydro power	RER: electricity, hydropower, at reservoir power plant, non alpine regions	23.0%
Electricity from wind power	RER: electricity, at wind power plant	2.1%
Losses		14.2%

A2.1.2 Cotton cultivation, ginning and baling, per kg cotton fibre

For the draft report, the Cotton Inc. data as implemented in GaBi v6.0 has been used without any modifications (Cotton Incorporated 2012). For SimaPro, the results from the same dataset differed so the GaBi results were inserted manually.

A2.1.3 Polyester fibre production, per kg

Polyester fibre production is modelled from the Ecoinvent dataset "Polyethylene terephthalate, granulate, amorphous, at plant/RER" and a model of melt spinning of PES to fibres, see below.

A2.1.3.1 Polyester fibre production, per kg

Materials/fuels	Amount	Unit
Polyethylene terephthalate, granulate, amorphous, at plant/RER S	1	kg
Melt spinning of PES to fibers	1	kg

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A2.1.3.2 Melt spinning of PES fibres, per kg

Melt spinning is modelled from a mixture of data from the BAT (Best Available Techniques) Reference Document (BREF) for the Textiles Industry (European Commission 2003), Fimreite et al. (Fimreite & Blomstrand 2009) and EDIPTEX (Laursen et al. 2007).

Materials/fuels		Amount	Unit	Comments
Lubricating oil, at plant/RER S		0.01	kg	BREF quantity - spinning oil
Manganese, at regional storage/RER S		0.0001	kg	BREF
Cobalt, at plant/GLO S		0.0001/2	kg	BREF
Antimony, at refinery/CN S		0.0001/2	kg	BREF
Phosphoric acid, industrial grade, 85% in H2O, at plant/RER S		0.0001	kg	Polyphosphric acid/BREF
Electricity/heat				
Electricity mix modelled according to A2.1.1		4.9	kWh	Fimreite et al. 8.04 for both fiber and spinning. Spinning to yarn takes about 3.14 kWh/kg material according to EDIPTEX.
Emissions to air				
Terephthalate, dimethyl	Indoor	0.0001	kg	

A2.1.4 Polyamide fibre production, per kg

Polyamide fibre production is modelled from the Ecoinvent dataset "Nylon 6, at plant/RER" (Hischier 2003) and a model of melt spinning of PA6 to fibres, see below.

A2.1.4.1 Polyamide fibre production, per kg

Materials/fuels	Amount	Unit
Nylon 6, at plant/RER S	1	kg
Melt spinning of PA6 to fibers	1	kg

A2.1.4.1 Melt spinning of PA6 fibres, per kg

Melt spinning is modelled from a mixture of data from the BAT (Best Available Techniques) Reference Document (BREF) for the Textiles Industry (European Commission 2003), Fimreite et al. (Fimreite & Blomstrand 2009) and EDIPTEX (Laursen et al. 2007).

Materials/fuels		Amount	Unit
Lubricating oil, at plant/RER S		0.01	kg
Manganese, at regional storage/RER S		0.0001	kg
Cobalt, at plant/GLO S		0.0001/2	kg
Antimony, at refinery/CN S		0.0001/2	kg
Phosphoric acid, industrial grade, 85% in H2O, at plant/RER S		0.0001	kg
Electricity/heat			
MiFuFa electricity mix		1.5	kWh
Heat, light fuel oil, at boiler 10kW, non-modulating/CH S		2.2	MJ
Emissions to air			
Caprolactam	indoor	0.0001	kg
Caprolactam	high. pop.	0.0009	kg

A2.1.5 Elastane fibre production, per kg

Elastane fibre production is modelled from the Ecoinvent dataset "Polyurethane, flexible foam, at plant/RER" and a model of dry spinning of elastane fibres from the BAT (Best Available Techniques) Reference Document (BREF) for the Textiles Industry (European Commission 2003), see below.

A2.1.5.1 Elastane fibre production, per kg

Materials/fuels	Amount	Unit
Polyurethane, flexible foam, at plant/RER S	1	kg
Dry spinning of elastane fibres	1	kg

A2.1.5.2 Dry spinning of elastane fibres, per kg

Materials/fuels		Amount	Unit	Comments
Lubricating oil, at plant/RER EcoInvent System		0.06	kg	BREF quantity - silicon oil 6-7%
Dimethylacetamide, at plant/GLO S		0.02	kg	BREF; 1% may be found on the fibre.
Electricity/heat				
Electricity mix modelled modelled according to A2.1.1		4.9	kWh	Assumed similar to melt spinning
Emissions to air				
N,n'-dimethylacetamide	indoor	0.02/100	kg	1% to air assumed

A2.1.6 Yarn spinning, per kg

Yarn spinning is modelled based on data from Wendin et al. (Wendin 2007) for electricity consumption from cotton spinning and EDIPTEX (Laursen et al. 2007) from synthetics spinning, and on inventory data from (Olsson et al. 2009) for consumption of spinning oil and from (Roos 2012) for waste.

A2.1.6.1 Ring spinning to cotton yarn, 250 dtex, per kg, in SimaPro

Materials/fuels	Amount	Unit	Comments
Lubricating oil, at plant/RER S	0.4*0.004	kg	BREF quantity - spinning oil
Electricity/heat			
Electricity mix	4.72	kWh	Modelled according to A2.1.1
Waste to treatment			
Waste incineration of textile fraction in municipal solid waste (MSW), EU-27 S	0.08	kg	8% waste from cotton yarn spinning according to (Roos 2012).

A2.1.6.2 Ring spinning of yarn for T-shirt, per kg, in GaBi

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comments
Cotton fibers packed	(from fibre production process)	1.14025	kg	Amount based on 13.8% waste (Cotton Incorporated 2012), whereof 1.5% in knitting (Laursen et al. 2007, p. 83)
Heat	RER: lubricating oil, at plant	0.05	kg	
Electricity	Electricity mix	20.5	MJ	Modelled according to A2.1.1
Outputs				
Spinned cotton	(to knitting process)	1	kg	
Waste to treatment	CH: disposal, textiles, soiled, 25% water, to municipal incineration	0.14025	kg	
Mineral oil (emission to indoor air)	Mineral oil (tetradecane) [Group NMVOC to air]	0.0005	kg	

A2.1.6.3 Ring spinning of white cotton/elastane yarn for jeans, per kg

Flows	Dataset/flow used in Gabi	Amount	Unit	Comment
Inputs				
Cotton fibers packed	(from fibre production process)	1.076	kg	Amount based on 96% cotton, and 13.8% waste (Cotton Incorporated 2012), whereof 1.5% in knitting (Laursen et al. 2007, p. 83)
Elastane fibres	(from fibre production process)	0.04485	kg	Amount based on 4% elastane, and 13.8% waste (CottonInc), whereof 1.5% in knitting (EDIPTEX p. 83)
Heat	RER: lubricating oil, at plant	0.035	kg	
Electricity	Electricity mix	11.3	MJ	Modelled according to A2.1.1
Outputs				
Spinned cotton/elastane yarn	(to knitting process)	1	kg	
Waste to treatment	CH: disposal, textiles, soiled, 25% water, to municipal incineration	0.121	kg	
Mineral oil (emission to indoor air)	Mineral oil (tetradecane) [Group NMVOC to air]	0.0005	kg	

A2.1.6.4 Yarn spinning from filament fibres, per kg

Materials/fuels	Amount	Unit	Comments
Lubricating oil, at plant/RER S	0.0305	kg	Coining oil
Electricity/heat			
Electricity mix	2.08	kWh	Modelled according to A2.1.1
Compressed air, average generation, >30kW, 6 bar gauge, at compressor/RER S	25	M3	Ecoinvent data set
Waste to treatment			
Waste incineration of textile fraction of industrial waste	0.005	kg	

A2.1.7 Knitting to fabric, per kg

Knitting is modelled based on data from Fimreite et al. (2009) for electricity consumption of different dtex, and on inventory data from the Textile BREF document (European Commission 2003) for consumption of knitting oil and data from EDIPTEX (Laursen et al. 2007) for waste.

A2.1.7.1 Knitting to fabric, 250 dtex, per kg

Materials/fuels	Amount	Unit	Comments
Paraffin, at plant/RER S	0.01	kg	The yarn specially made for the knitting industry is lubricated or waxed (generally with paraffin wax) to allow knitting at higher speed and protect the yarn from mechanical stresses. (European Commission 2003 p 37)
Lubricating oil, at plant/RER S	0.1	kg	Like weaving, knitting is a mechanical process and involves knotting yarn together with a series of needles. Mineral oils are widely used to lubricate the needles and other parts of the knitting machinery. The quantity of oils used depends on the technology of the machine and on the speed of the needles. The value ranges between 4 and 8% of the weight of the fabric (when mineral oils are used the amount may rise to 10%). The oil and the wax that remain on the final fabric will be washed out during the finishing treatments. Their contribution to the total pollution load coming from finishing mills may be significant. BREF Textiles p 37
Electricity/heat			
Electricity mix modelled according to A2.1.1	2.854	kWh	Electricity consumption from Fimreite et al. 2,854 kWh per kg yarn (5 sources).
Disposal, textiles, soiled, 25% water, to municipal incineration/CH S	0.015	Kg	1.5% textile waste assumed (Laursen et al. 2007, page 83).

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A2.1.7.2 Knitting to fabric for T-shirt, in GaBi, per kg

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comment
Spinned cotton	(from spinning process)	1.0152	kg	Based on 1.5% waste (Laursen et al. 2007, p. 83)
Lubricating oil	RER: lubricating oil, at plant	0.1	kg	
Ethoxylated alcohols	RER: ethoxylated alcohols (AE7), petrochemical, at plant	0.004	kg	
Paraffin	RER: paraffin, at plan	0.01	kg	
Electricity	Electricity mix modelled according to A2.1.1	1.044	MJ	
Outputs				
Knitted cotton fabric	(to bleaching process)	1	kg	
Waste to treatment	CH: disposal, textiles, soiled, 25% water, to municipal incineration	0.0152	kg	

A2.1.8 Weaving to fabric, per kg

Weaving is modelled based on the IDEMAT database (Vogtländer 2012) for electricity consumption of different dtex, and on inventory data from different sources (European Commission 2003; Olsson et al. 2009; Roos 2012) for consumption of knitting oil and waste.

A2.1.8.1 Weaving, 300 dtex, based on literature data for T-shirt, jeans, dress and jacket., per kg

Materials/fuels	Amount	Unit	Comments
Modified starch, at plant/RER S	0.05	kg	Starch based sizing agent, 5% of the weave's weight.
Electricity/heat			
Electricity mix	4.93	kWh	Modelled according to A2.1.1
Waste to treatment			
Waste incineration of textile fraction in municipal solid waste (MSW), EU-27 S	0.015	kg	BREF 2003 data

A2.1.8.2 Weaving to cotton/PES fabric for hospital uniform, per kg

Materials/fuels	Amount	Unit	Comments
Modified starch, at plant/RER S	0.05	kg	Starch based sizing agent, 5% of the weave's weight.
Electricity/heat			
Electricity mix	0.775	kWh	Modelled according to A2.1.1
Heat, light fuel oil, at boiler 10kW, non-modulating/CH S	4.15	kWh	Compressed air.

A2.1.9 Non-woven process, per kg

The modelling of the non-woven process is based on data from an anonymous supplier (Supplier 1) involved in a previous non public study at Swerea IVF.

Materials/fuels	Amount	Unit	Comments
Opening and blending for non woven process	1	kg	0.872 kWh/kg
Carding for non woven process	1	kg	2.7 kWh/kg
Needle punching for non woven process	1	kg	1.05 kWh/kg
Padding for non woven process	1	kg	0.75 kWh/kg

A2.1.10 Wet treatment, dyeing and printing, per kg

All datasets for the different wet treatment processes are listed in tables below. The process descriptions for the T-shirt, jeans, dress and jacket were compiled by Kaj Otterqvist, Swerea IVF. The chemical compositions were taken from TEGEWA's International Textile Auxiliaries Buyer's Guide 2008/09 (TEGEWA 2008). Electricity consumption and heat consumption for jet dyeing machines were provided by an equipment manufacturer. For the emissions and waste water treatment, assumptions have been made. Wastewater treatment systems are able to reduce all forms of pollution in wastewater by 90% or more according to LeBlanc et al., and for most substances 99% is assumed in the modelling (LeBlanc et al. 2008). For the hospital uniform, the wet treatment was inventoried at Lauffenmühle, a vertical textile mill in Germany. An overview is found in the table below (Table 3 in the report).

Processes included in wet treatment	T-shirt	Jeans	Dress	Jacket	Hospital uniform
A2.1.10.1 Bleaching of fabric for T-shirt	X	-	-	-	-
A2.1.10.2 Drying of cotton fabric	X	X	-	-	-
A2.1.10.3 Dyeing of blue cotton yarn for jeans	-	X	-	-	-
A2.1.10.4 Bleaching of white cotton/elastane yarn for jeans	-	X	-	-	-
A2.1.10.5 Dyeing PES tricot black in jet dyeing machine	-	-	X	-	-
A2.1.10.6 Pretreatment in jet machine of PES weave before printing	-	-	X	-	-
A2.1.10.7 Dispersion print of PES weave on rotation printer	-	-	X	-	-
A2.1.10.8 Dyeing polyamide weave black and green in jet dyeing machine	X	-	-	X	-
A2.1.10.10 Dyeing PES weave black in jet dyeing machine	-	-	-	X	-
A2.1.10.10 Dyeing CO/EL tricot green in jet dyeing machine	-	-	-	X	-
A2.1.10.11 Dyeing CO/PES weave blue in jet dyeing machine	-	-	-	-	X
A2.1.10.12 Drying and fixation of cellulosics in stenter frame	X	X	-	-	X
A2.1.10.13 Drying and fixation of synthetics in stenter frame	-	-	X	X	-

A2.1.10.1 Bleaching of fabric for T-shirt, per kg

Resources	Amount	Unit	Comment
Water, river	6*10/1000	m3	6 baths, 1:10, no recirculation is made
Materials/fuels			
Lubricant, average	0.004*10*2	kg	
Detergent/Wetting agent, average	0.002*10*2	kg	
Acid (formic acid), average	0.001*10	kg	
Peroxide stabilizer, average	0.0002*10	kg	
Base (alkali) (NaOH), average	0.0025*10	kg	
Bleach (H2O2), average	0.007*10	kg	
Optical brightener, average	0.06	kg	6% of fabric weight
Acid (sulphuric acid), average	0.001*10*2	kg	
Softener, average	0.03	kg	3% of fabric weight
Electricity/heat			
MiFuFa electricity mix	0.0933*0.8	kWh	
Heat, light fuel oil, at boiler 10kW, non-modulating/CH S	123/350	kWh	
Air emissions			
Air emissions from 1 kg Lubricant, average	0.08	kg	
Air emissions from 1 kg Detergent/Wetting agent, average	0.04	kg	

Resources	Amount	Unit	Comment
Air emissions from 1 kg Acid (formic acid), average	0.01	kg	
Air emissions from 1 kg Peroxide stabilizer, average	0.002	kg	
Air emissions from 1 kg Bleach (H2O2), average	0.07	kg	
Air emissions from 1 kg Acid (sulfuric acid), average	0.02	kg	
Water emissions			
Water emissions from 1 kg Lubricant, average	0.08	kg	
Water emissions from 1 kg Detergent, average	0.04	kg	
Water emissions from 1 kg Acid (formic acid), average	0.01	kg	
Water emissions from 1 kg Peroxide stabilizer, average	0.002	kg	
Water emissions from 1 kg Base (NaOH), average	0.025	kg	
Water emissions from 1 kg Bleach (H2O2), average	0.07	kg	
Water emissions from 1 kg Optical brightener, average	0.06	kg	
Water emissions from 1 kg Acid (sulfuric acid), average	0.02	kg	
Water emissions from 1 kg Softener, average	0.03	kg	
COD, Chemical Oxygen Demand	0.0002	kg	
Waste to treatment			
Disposal, sludge from pulp and paper production, 25% water, to sanitary landfill/CH EcoInvent System	0.5	kg	

A2.1.10.2 Drying of cotton fabric in stenter frame, per kg

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comments
Bleached cotton fabric	(from bleaching process)	1	kg	
Electricity	Electricity mix	5.04	MJ	Modelled according to A2.1.1
Outputs				
Dried cotton fabric	(to confectioning process)	1	kg	

A2.1.10.3 Dyeing denim blue yarn for jeans warp yarn, per kg

Resources	Amount	Unit	Comment
Water, river	0.005	m3	1:5 ratio assumed
Materials/fuels			
Detergent/Wetting agent, average	2*5	g	
Peroxide stabilizer, average	0.2*5	g	
Base (alkali) (NaOH), average	2.5*5+1.5*5	g	
Bleach (H2O2), average	7*5	g	
Antifoaming agent, average	4*5	g	

Resources	Amount	Unit	Comment
Blue VAT dyestuff (indigo), average	4*5	g	
Reducing agent, average	3*5	g	
Wetting/Penetrating agent, cellulosic, average	1*5	g	
Conducting salt (NaSO4), average	30*5	g	
Acid (sulphuric acid), average	10*5	g	
Detergent/Wetting agent, average	2*5	g	
Base/Soda ash (Na2CO3), average	2*5	g	
Sizing agent, average	0.1	kg	10% fabric weight
Oxidizing agent (H2O2), average	4*5	g	
Electricity/heat			
MiFuFa electricity mix	0.0933*0.8	kWh	
Heat, light fuel oil, at boiler 10kW, non-modulating/CH S	123/350	kWh	
Emissions to air			
Ethylene oxide	0.010*0.001*0.1	kg	0.1% content in detergent. 10% emitted to air
Magnesium chloride	0.001*0.005*0.1	kg	0.1% content in peroxide stabilizer. 10% emitted to air
Hydrogen peroxide	(0.020+0.035)*0.1	kg	10% emitted to air
Indigo	0.020*0.1	kg	10% emitted to air
Thiosulfate	0.015*0.9*0.1	kg	0.1% content in reduction agent. 10% emitted to air
Nonylphenol ethoxylate (NPEO)	0.005*0.1*0.1	kg	0.1% content in penetrating agent. 10% emitted to air
Sulfuric acid	0.050*0.01	kg	1% emitted to air
Sodium carbonate	0.010*0.1	kg	1% emitted to air
Emissions to water			
Oxirane, methyl-, polymer with oxirane, decyl ether	(0.010+0.010)*0.25*0.9*0.01	kg	25% content in detergent, assumed 10% reacted and 99% separated in water treatment facility
Alcohols, c12-14, ethoxylated	(0.010+0.010)*0.10*0.9*0.01	kg	10% content in detergent, assumed 10% reacted and 99% separated in water treatment facility
Polyacrylic acid, sodium salt	(0.010+0.010+0.001)*0.10*0.9*0.01	kg	10% content in detergent and 10% in peroxide stabilizer, assumed 10% reacted and 99% separated in water treatment facility
Formaldehyde	9.9E-6*0.01	kg	common breakdown product of

Resources	Amount	Unit	Comment
			acrylamides (assumed 1%), assumed 99% separated in water treatment facility
Sodium mono(2-ethylhexyl)estersulfate	(0.010+0.010)*0.05*0.1*0.01	kg	5% content in detergent, assumed 10% reacted and 99% separated in water treatment facility
Phosphonic acid	0.001*0.10*0.9*0.01	kg	10% content in peroxide stabilizer, assumed 10% reacted and 99% separated in water treatment facility
Magnesium chloride	0.001*0.005*0.01	kg	0.5% content in peroxide stabilizer, assumed 0% reacted and 99% separated in water treatment facility
Sodium hydroxide	0.020*0.01	kg	assumed no salt is reacted, and 99% separated in water treatment facility
Hydrogen peroxide	(0.020+0.035)*0.5*0.01*0.01	kg	assumed 99% reacted, and 99% separated in water treatment facility
Dimethyl siloxane, reaction product with silica	0.020*0.05*0.9*0.99	kg	5% content in defoamer, assumed 10% reacted and 99% separated in water treatment facility
Sodium lauryl sulfate	0.020*0.001*0.9*0.99	kg	0.1% content in defoamer, assumed 10% reacted and 99% separated in water treatment facility
5-chloro-2-methyl-4-isothiazolin-3-one	0.020*0.001*0.9*0.99	kg	0.1% content in defoamer, assumed 10% reacted and 99% separated in water treatment facility
2-methyl-4-isothiazolin-3-one	0.020*0.001*0.9*0.99	kg	0.1% content in defoamer, assumed 10% reacted and 99% separated in water treatment facility
Indigo	0.020*0.1*0.99	kg	assumed 90% reacted and 99% separated in water treatment facility
Sodium	0.015*0.98*0.5*0.01	kg	assumed 50/50 sodium and sulfite in sodium dithionite, assumed no salt is reacted, and 99% separated in water treatment facility
Sulfite	0.015*0.98*0.5*0.01	kg	assumed 50/50 sodium and sulfite in both sodium dithionite ($Na_2S_2O_4$) and sodium sulfite (Na_2SO_3), assumed no salt reacted, and 99% separated in water treatment facility
Thiosulfate	0.015*0.9*0.01*0.01	kg	assumed 1% from sodium dithionite, assumed no salt is reacted, and 99% separated in water treatment facility
Fatty methylester sulfonates	0.005*0.60*0.9*0.01	kg	60% content in wetting agent, assumed 10% reacted and 99% separated in water treatment facility
Isooctyl alcohol	0.005*0.20*0.9*0.01	kg	20% content in wetting agent, assumed 10% reacted and 99%

Resources	Amount	Unit	Comment
			separated in water treatment facility
Nonylphenol ethoxylate (NPEO)	0.005*0.10*0.9*0.01	kg	10% content in wetting agent, assumed 10% reacted and 99% separated in water treatment facility
Nonylphenol	0.005*0.10*0.01*0.9*0.01	kg	common breakdown product of NPEO (assumed 1%), assumed 99% separated in water treatment facility
Sodium sulfate	0.150*0.01	kg	assumed no salt is reacted, and 99% separated in water treatment facility
Sulfuric acid	0.050*0.5*0.01	kg	assumed 50% reacted, and 99% separated in water treatment facility
sodium carbonate	0.010*0.01	kg	assumed no salt is reacted, and 99% separated in water treatment facility
COD, Chemical Oxygen Demand	0.0002	kg	EU ecolabel criteria assumed to be passed.
Waste to treatment			
Disposal, sludge from pulp and paper production, 25% water, to sanitary landfill/CH EcoInvent System	0.5	kg	

A2.1.10.4 Bleaching of white cotton/elastane yarn for jeans weft yarn, per kg

Resources	Amount	Unit	Comments
Water, river	4*6/1000	m3	4 baths, 1:6, no recirculation is made
Materials/fuels			
Sequestering agent, average	0.0010*6	kg	
Detergent/Wetting agent, average	0.0010*6	kg	
Wetting/Penetration agent (synthetic), average	0.0005*6	kg	
Peroxide stabilizer, average	0.0005*6	kg	
Sodium hydroxide, 50% in H2O, production mix, at plant/RER S	0.0025*6	kg	
Hydrogen peroxide, 50% in H2O, at plant/RER S	0.010*6*19/50	kg	19% H2O2
Acetic acid, 98% in H2O, at plant/RER S	0.001*6	kg	
Electricity/heat			
Electricity, medium voltage, production CENTREL, at grid/CENTREL EcoInvent System	0.0933*0.8	kWh	
Heat, light fuel oil, at boiler 10kW condensing, non-modulating/CH EcoInvent System	123/350	kWh	

Emissions to air			
Sulfuric acid	0.001	kg	
Phosphonic acid, disodium salt	0.000001	kg	
Nonylphenol ethoxylate (NPEO)	0.00005	kg	
Magnesium chloride	5E-07	kg	
Hydrogen peroxide	0.001	kg	
Ethylene oxide	0.000001	kg	
Emissions to water			
Phosphonic acid	3.0E-04	kg	
Polyacrylic acid, sodium salt	1.0E-04	kg	
Oxirane, methyl-, polymer with oxirane, decyl ether	2.5E-04	kg	
Alcohols, c12-14, ethoxylated	1.0E-04	kg	
Sodium mono(2-ethylhexyl)estersulfate	5.0E-05	kg	
Formaldehyde	2.5E-05	kg	
Ethylene oxide	1.0E-06	kg	
Fatty methylester sulfonates	6.0E-04	kg	
Isooctyl alcohol	2.0E-04	kg	
Nonylphenol ethoxylate (NPEO)	1.0E-04	kg	
Nonylphenol	1.0E-06	kg	
Polyacrylic acid, sodium salt	1.0E-04	kg	
Phosphonic acid	1.0E-04	kg	
Magnesium chloride	5.0E-05	kg	
Formaldehyde	1.0E-05	kg	
Sodium hydroxide	1.0E-02	kg	
Hydrogen peroxide	1.0E-04	kg	
Sulfuric acid	1.0E-03	kg	
Waste to treatment			
Disposal, sludge from pulp and paper production, 25% water, to sanitary landfill/CH EcoInvent System	(0.006*3+0.003*2+0.015+0.0228)*0.99	kg	

A2.1.10.5 Dyeing PES tricot black in jet dyeing machine

Resources			
Water. river	in water	7 * 0.005	m3
Materials/fuels			
Ultravon EL	0.001*5	kg	Proxy from EcoInvent:
			25% Ethoxylated alcohols (AE7). petrochemical. at plant/RER S + 25% Acrylic acid. at plant/RER S
Invatex CS	0.001*5	kg	Proxy from EcoInvent:
			Glyphosate. at regional

Resources			
			storehouse/RER S
Soda. powder. at plant/RER S	(0.001+0.002)*5	kg	
Breviol PAM-N	0.001*5	kg	Proxy from EcoInvent:
			Acrylic dispersion. 65% in H2O. at plant/RER S
Univadine DP	0.001*5	kg	Proxy from EcoInvent:
			Ethylene glycol monoethyl ether. at plant/RER S
Ammonium sulphate. as N. at regional storehouse/RER S	0.001*5	kg	
Cibatex AR	0.002*5	kg	Anionic – methylene substituted aryl supfonic acid. Proxy from EcoInvent: Fatty alcohol sulfate. mix. at plant/RER S
Terasil Black WS-N	0.05*5	kg	Proxy from EcoInvent:
			50% Diazole-compounds. at regional storehouse/RER S IVF
Acetic acid. 98% in H2O. at plant/RER S	0.001*2*5	kg	
Sodium hydroxide. 50% in H2O. production mix. at plant/RER S	0.005*5	kg	appr. NaOH 36 grad Bé
Sodium dithionite. anhydrous. at plant/RER S	0.005*5	kg	
Cibapon OS	0.002*5	kg	Proxy from EcoInvent:
			Ethoxylated alcohols (AE7). petrochemical. at plant/RER S
Sapamine FPG	0.03*5	kg	Proxy from EcoInvent:
			25% Fatty acids. from vegetarian oil. at plant/RER S + 25% Dimethylacetamide. at plant/GLO S
Electricity/heat			
Electricity. medium voltage. production CENTREL. at grid/CENTREL EcoInvent System	0.0933*0.8+1.4	kWh	
Heat. light fuel oil. at boiler 10kW condensing. non-modulating/CH EcoInvent System	123/350	kWh	
Emissions to air			
Remazol black B	16.5/10000	kg	
Acetic acid	0.01/10000	kg	
Emissions to water			
Isobutyl acrylate	0.001*1.25*5*0.3*0.01	kg	assumed 70% reacted. and 99% separated in water treatment facility
Formaldehyde	0.001*1.25*5*0.0025*0.01	kg	common breakdown product of acrylamides. assumed 99% separated in water treatment facility
Alcohol ethoxylate	(0.001*2.	kg	assumed 70% reacted. and 99%

Resources			
	25+0.002)*5*0.3*0.01		separated in water treatment facility
Glyphosate	0.001*5*0.9*0.01	kg	assumed 10% reacted. and 99% separated in water treatment facility
Sodium. ion	(0.003+0.005)/2*5*0.01	kg	assumed 50/50 sodium and carbonate in soda. assumed no salt is reacted. and 99% separated in water treatment facility. same assumptions of sodium dithionate. see also sulfite emission below.
Carbonate	0.003/2*5*0.01	kg	assumed 50/50 sodium and carbonate in soda. assumed no salt is reacted. and 99% separated in water treatment facility
Diethylene glycol monomethyl ether	0.001*5*0.9*0.01	kg	assumed 10% reacted. and 99% separated in water treatment facility
Ammonium. ion	0.001/2*5*0.01	kg	assumed 50/50 ammonium and sulfate in salt. assumed no salt is reacted. and 99% separated in water treatment facility
Sulfate	0.001/2*5*0.01	kg	assumed 50/50 ammonium and sulfate in salt. assumed no salt is reacted. and 99% separated in water treatment facility
Alkylbenzenesulfonic acid. sodium salt c10-c13	0.002*5*0.9*0.01	kg	assumed 10% reacted. and 99% separated in water treatment facility
Remazol black B	0.25*0.1*0.01	kg	assumed 90% reacted. and 99% separated in water treatment facility
Acetic acid	0.002*5*0.3*0.01	kg	assumed 70% reacted. and 99% separated in water treatment facility
Sodium hydroxide	0.005*5*0.01	kg	assumed no salt is reacted. and 99% separated in water treatment facility
Sulfite	0.005/2*5*0.01	kg	assumed 50/50 sodium and sulfite in sodium dithionite. assumed no salt reacted. and 99% separated in water treatment facility
Fatty acids as C	0.15*0.25*5*0.3*0.01	kg	assumed 70% reacted. and 99% separated in water treatment facility
N.n'-dimethylacetamide	0.15*0.25*5*0.3*0.01	kg	assumed 70% reacted. and 99% separated in water treatment facility
Waste to treatment			
Disposal. sludge from pulp and paper production. 25% water. to sanitary landfill/CH EcoInvent System	(0.006*3+0.003*2+0.015+0.0228)*0.99	kg	estimated with 99* chemicals released

A2.1.10.6 Pretreatment in jet machine of PES weave before printing

Resources			
Water, river	6*10/1000	m3	6 baths, 1:10, no recirculation is made

Resources			
Materials/fuels			
Breviol PAM-N	0.001*5	kg	Proxy from EcoInvent:
			Acrylic dispersion, 65% in H2O, at plant/RER S
Ultravon EL	0.001*5	kg	Proxy from EcoInvent?
			25% Ethoxylated alcohols (AE7), petrochemical, at plant/RER S + 25% Acrylic acid, at plant/RER S
Invatex CS	0.001*5	kg	Proxy from EcoInvent:
			Glyphosate, at regional storehouse/RER S
Ultravon PRE	0.001*5	kg	3% of 10 kg water = 0.3 kg. Proxy from EcoInvent:
			50% Ethoxylated alcohols (AE3), petrochemical, at plant/RER S
Electricity/heat			
Electricity, medium voltage, production CENTREL, at grid/CENTREL EcoInvent System	0.0933*0,8	kWh	Undefined
Heat, light fuel oil, at boiler 10kW condensing, non-modulating/CH EcoInvent System	123/350	kWh	Undefined
Emissions to water			
Isobutyl acrylate	0.005*1.25*0.3*0.01	kg	assumed 70% reacted, and 99% separated in water treatment facility
Alcohol ethoxylate	0.005*0.75*0.3*0.01	kg	assumed 70% reacted, and 99% separated in water treatment facility
Glyphosate	0.005*0.9*0.01	kg	assumed 10% reacted, and 99% separated in water treatment facility
COD, Chemical Oxygen Demand	0.0002	kg	EU ecolabel criteria assumed to be passed
Formaldehyde	0.005*1.25*0.0025*0.01	kg	common breakdown product of acrylamides, assumed 99% separated in water

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Resources			
			treatment facility
Waste to treatment			
Disposal, sludge from pulp and paper production, 25% water, to sanitary landfill/CH EcoInvent System	(0.006*3+0.003*2+0.015+0.0228)*0.99	kg	estimated with 99% chemicals released

A2.1.10.7 Dispersion print of PES weave on rotation printer

Resources			
Water, river	0.9/1000*0.3	m3	1:5 ratio for jet machine assumed
Materials/fuels			
Alcoprint DT-CS	0.35*0.3	kg	Proxy from EcoInvent:
			Latex, at plant/RER S
Lyoprint AIR 1:1	0.10*0.3	kg	Proxy from EcoInvent?
			Acrylic dispersion, 65% in H2O, at plant/RER S
Terasil Black P-R liq.50%	0.55*0.3	kg	Proxy from EcoInvent:
			50% Diazole-compounds, at regional storehouse/RER S IVF
Cibapon OS	0.001*2*5	kg	Proxy from EcoInvent:
			Ethoxylated alcohols (AE7), petrochemical, at plant/RER S
Sodium dithionite, anhydrous, at plant/RER S	0.002*5	kg	sodium hydrosulfite = sodium dithionite, CAS RN 7775-14-6
Sodium hydroxide, 50% in H2O, production mix, at plant/RER S	0.002*5	kg	appr. NaOH 36 grad Bé
Acetic acid, 98% in H2O, at plant/RER S	0.001*5	kg	
Sapamine FPG	0.03*5	kg	Proxy from EcoInvent:
			25% Fatty acids, from vegetarian oil, at plant/RER S + 25% Dimethylacetamide, at plant/GLO S
Electricity/heat			
Electricity, medium voltage, production CENTREL, at grid/CENTREL EcoInvent System	0.0933*0,8*1,5	kWh	
Heat, light fuel oil,	123/350*1.5	kWh	

Resources			
at boiler 10kW condensing, non-modulating/CH EcoInvent System			
Emissions to air			
Remazol black B	16.5/10000	kg	
Acetic acid	0.005/10000	kg	
Emissions to water			
Isobutyl acrylate	(0.03*1.25*5)*0.3*0.01	kg	assumed 70% reacted, and 99% separated in water treatment facility
Remazol black B	0.165*0.1*0.01	kg	assumed 90% reacted, and 99% separated in water treatment facility
Formaldehyde	0.005*1.25*0.0025*0.01	kg	common breakdown product of acrylamides, assumed 99% separated in water treatment facility
Alcohol ethoxylate	0.002*0.25*5*0.3*0.01	kg	assumed 70% reacted, and 99% separated in water treatment facility
Sodium, ion	0.002/2*5*0.01	kg	assumed 50/50 sodium and sulfite in sodium dithionite, assumed no salt reacted, and 99% separated in water treatment facility
Sulfite	0.002/2*5*0.01	kg	assumed 50/50 sodium and sulfite in sodium dithionite, assumed no salt reacted, and 99% separated in water treatment facility
Sodium hydroxide	0.002*5*0.01	kg	assumed no salt is reacted, and 99% separated in water treatment facility
Acetic acid	0.001*5*0.3*0.01	kg	assumed 70% reacted, and 99% separated in water treatment facility
Fatty acids as C	0.03*0.25*5*0.3*0.01	kg	assumed 70% reacted, and 99% separated in water treatment facility
N,n'-dimethylacetamide	0.03*0.25*5*0.3*0.01	kg	assumed 70% reacted, and 99% separated in water treatment facility

Resources			
Waste to treatment			
Disposal, sludge from pulp and paper production, 25% water, to sanitary landfill/CH EcoInvent System	(0.006*3+0.003*2+0.015+0.0228)*0.99	kg	estimated with 99% chemicals released

A2.1.10.8 Dyeing polyamide weave black and green in beam dyeing machine, per kg

Resources			
Water. river	10+8+3*10+3*10+10	m3	Beam dyeing with desizing in cold pad batch. water ratio 1:10.
Materials/fuels			
Detergent/Wetting agent. average	0.010*10	kg	25% Ethoxylated alcohols (AE3). petrochemical. at plant/RER S. 15% Ethoxylated alcohols (AE7). petrochemical. at plant/RER S. 10% Acrylic acid. at plant/RER S
Sequestering agent. average	0.004*10	kg	
Antifoaming agent. average	0.0003*10	kg	
Base (alkali) (NaOH). average	0.001*10	kg	
Acid (formic acid). average	0.001*10*2+0.03	kg	
Wetting/Penetration agent (synthetic). average	0.0004*10+0.005	kg	
Lubricant. average	0.002*10	kg	
Black disperse dyestuff PA. BAT	0.05	kg	
Yellow disperse dyestuff PA. BAT	0.01	kg	
Blue disperse dyestuff PA. BAT	0.0015	kg	
Soda (CaCO3). average	0.001*10	kg	
DWR agent	0.050*10	kg	
Electricity/heat			
MiFuFa electricity mix	0.0933*0.8	kWh	Dyeing
Heat. light fuel oil. at boiler 10kW. non-modulating/CH S	123/350	kWh	
MiFuFa electricity mix	1.25	kWh	Drying/fixation
Air emissions			
Air emissions from 1 kg Detergent/Wetting agent. average	0.1	kg	
Air emissions from 1 kg Sequestering agent. average	0.04	kg	
Air emissions from 1 kg Acid (formic acid). average	0.05	kg	
Air emissions from 1 kg Lubricant. average	0.02	kg	

Resources			
Water emissions			
Water emissions from 1 kg Detergent. average	0.1	kg	
Water emissions from 1 kg Sequestering agent. average	0.04	kg	
Water emissions from 1 kg Antifoaming agent. average	0.003	kg	
Water emissions from 1 kg Base (NaOH). average	0.01	kg	
Water emissions from 1 kg Acid (formic acid). average	0.05	kg	
Water emissions from 1 kg Wetting/Penetration agent (synthetic). average	0.009	kg	
Water emissions from 1 kg Lubricant. average	0.02	kg	
Water emissions from 1 kg Black disperse dyestuff. BAT	0.05	kg	
Water emissions from 1 kg Yellow disperse dyestuff. BAT	0.01	kg	
Water emissions from 1 kg Blue disperse dyestuff. BAT	0.0015	kg	
Water emissions from 1 kg Soda (CaCO3). average	0.01	kg	
Water emissions from 1 kg DWR agent. average	0.5	kg	
COD. Chemical Oxygen Demand	0.0002	kg	
Waste to treatment			
Disposal. sludge from pulp and paper production. 25% water. to sanitary landfill/CH EcoInvent System	0.5	kg	

A2.1.10.9 Dyeing PES weave orange in jet dyeing machine, per kg

Resources			
Water. river	10+8+2*10+3*10+10	m3	Beam dyeing with desizing in cold pad batch. water ratio 1:10.
Materials/fuels			
Detergent/Wetting agent. average	0.010*10+0.005*10	kg	
Sequestering agent. average	0.004*10	kg	
Antifoaming agent. average	0.0003*10	kg	
Base (alkali) (Na2CO3). average	0.0005*10	kg	
Acid (formic acid). average	0.001*10*3	kg	
Wetting/Penetration agent (synthetic). average	0.001*10+0.005	kg	
Dispergent. average	0.003*10	kg	
Decalcifier ((NH4)2SO4). average	0.002*10	kg	
Antireduction agent (H2O2). average	0.003*10	kg	

Resources			
Yellow disperse dyestuff PES. average	0.0006	kg	
Red disperse dyestuff PES. average	0.013	kg	
Base (alkali) (NaOH). average	0.005	kg	
Reducing agent. average	0.005	kg	
Soda (CaCO3). average	0.002*10	kg	
Detergent/Wetting agent. BAT	0.002*10	kg	
Softener. average	0.020*10	kg	
Electricity/heat			
MiFuFa electricity mix	0.0933*0.8	kWh	
Heat. light fuel oil. at boiler 10kW. non-modulating/CH S	123/350	kWh	
MiFuFa electricity mix	1.25	kWh	
Air emissions from 1 kg Detergent/Wetting agent. average	0.15	kg	
Air emissions from 1 kg Sequestering agent. average	0.04	kg	
Air emissions from 1 kg Acid (formic acid). average	0.03	kg	
Water emissions from 1 kg Detergent. average	0.15	kg	
Water emissions from 1 kg Sequestering agent. average	0.04	kg	
Water emissions from 1 kg Antifoaming agent. average	0.003	kg	
Water emissions from 1 kg Base (NaOH). average	0.005	kg	
Water emissions from 1 kg Acid (formic acid). average	0.03	kg	
Water emissions from 1 kg Wetting/Penetration agent (synthetic). average	0.015	kg	
Water emissions from 1 kg Soda (CaCO3). average	0.02	kg	
Water emissions from 1 kg Black disperse dyestuff. BAT	0.019	kg	
COD. Chemical Oxygen Demand	0.0002	kg	
Waste to treatment			
Disposal. sludge from pulp and paper production. 25% water. to sanitary landfill/CH EcoInvent System	0.5	kg	

A2.1.10.10 Dyeing CO/EL tricot green in jet dyeing machine, per kg

Resources			
Water. river	15*4	l	15 baths. no recirculation is made

Resources			
Materials/fuels			
Acrylic dispersion. without water. in 65% solution state {RER}| acrylic dispersion production. product in 65% solution state | Alloc Def. S	2*0.001*1400/350	kg	Breviol PAM-N. acrylic copolymer. dyeing agent. förtvätt + färgning
Ethoxylated alcohol (AE7) {RER}| ethoxylated alcohol (AE7) production. petrochemical | Alloc Def. S	0.001*1400/350	kg	Foryl JA ; vätmedel
Organophosphorus-compound. unspecified {RER}| production | Alloc Def. S	0.0015*1400/350	kg	Securon 540. organic phosphorous compound; förbehandlingsmedel
Sodium hydroxide. 50% in H2O. production mix. at plant/RER S	3*0.002*1400/350	kg	NaOH. förtvätt + PES färgning + CO färgning
Acetic acid. without water. in 98% solution state {RER}| acetic acid production. product in 98% solution state | Alloc Def. S	0.013*1400/350	kg	HAC 60%. PES färg + CO färg + mjuk
Ethoxylated alcohol (AE7) {RER}| ethoxylated alcohol (AE7) production. petrochemical | Alloc Def. S	0.002*1400/350	kg	H2O2 35%Osimol OV. triglyceride ethoxylated
Alkylbenzene sulfonate. linear. petrochemical {RER}| production | Alloc Def. S	0.001*1400/350	kg	Lamepon N. sodium lignin sulfonate
N.N-dimethylformamide {RER}| production | Alloc Def. S	0.003*1400/350	kg	Lorinol R. formamidinesulfinic acid
Acrylic acid {RER}| production | Alloc Def. S	0.0015*1400/350	kg	Locanit S. Polyacrylic acid. sodium salt. CO färg + tvålning
Esterquat {RER}| treatment of tallow to | Alloc Def. S	1400*0.03/350	kg	Belsoft 200 = Amides. tallow. hydrogenated. N-[2-[(2-hydroxyethyl)amino]ethyl]. glycolates(salts); R41. R51/53; EC 271-658-6; and Tallow alkyl polyglycol ether;
Electricity/heat			
MiFuFa electricity mix	0.0933*0.2	kWh	Data for Then-airflow. used due to lack of data from Tirupur/7H. only mechanical energy. no warming of water. 20% for bleach (4 loops).
Heat. light fuel oil. at boiler 10kW. non-modulating/CH S	524/350	kWh	Oil furnace/bolier at the factory heating steam that heats the airjet machine.
Emissions to water			
Isobutyl acrylate	0.008*0.3*0.01	kg	assumed 70% reacted 1% emitted
Fatty alcohol ethoxylate	0.012*0.3*0.01	kg	assumed 70% reacted 1% emitted
Phosphorus compounds. unspecified	0.006*0.3*0.01	kg	assumed 70% reacted 1% emitted

Resources			
Sodium hydroxide	0.024*0.01	kg	assumed no salt is reacted 1% emitted
Acetic acid	0.052*0.3*0.01	kg	assumed 70% reacted 1% emitted
Sodium 1-octanesulfonate	0.004*0.3*0.01	kg	assumed 70% reacted 1% emitted
N-[4-(5-Nitro-2-furyl)-2-thiazolyl]formamide	0.012*0.1*0.01	kg	assumed 90% reacted 1% emitted
Acrylic acid	0.006*0.3*0.01	kg	assumed 70% reacted 1% emitted
Glycol ethers	0.12*0.3*0.01	kg	assumed 70% reacted 1% emitted
COD. Chemical Oxygen Demand	0.0002	kg	from cotton bleach/scouring
Waste to treatment			
Disposal. sludge from pulp and paper production. 25% water. to sanitary landfill/CH S	0.58	kg	Approximately the same amount as non-emitted chemicals

A2.1.10.11 Dyeing CO/PES weave blue in jet dyeing machine, per kg

Resources			
Water. river	15*4	l	15 baths. no recirculation is made
Materials/fuels			
Acrylic dispersion. without water. in 65% solution state {RER}| acrylic dispersion production. product in 65% solution state | Alloc Def. S	2*0.001*1400/350	kg	Breviol PAM-N. acrylic copolymer. dyeing agent. förtvätt + färgning
Ethoxylated alcohol (AE7) {RER}| ethoxylated alcohol (AE7) production. petrochemical | Alloc Def. S	0.001*1400/350	kg	Foryl JA ; vätmedel
Organophosphorus-compound. unspecified {RER}| production | Alloc Def. S	0.0015*1400/350	kg	Securon 540. organic phosphorous compound; förbehandlingsmedel
Sodium hydroxide. 50% in H2O. production mix. at plant/RER S	3*0.002*1400/350	kg	NaOH. förtvätt + PES färgning + CO färgning
Acetic acid. without water. in 98% solution state {RER}| acetic acid production. product in 98% solution state | Alloc Def. S	0.013*1400/350	kg	HAC 60%. PES färg + CO färg + mjuk
Ethoxylated alcohol (AE7) {RER}| ethoxylated alcohol (AE7) production. petrochemical | Alloc Def. S	0.002*1400/350	kg	H2O2 35%Osimol OV. triglyceride ethoxylated
Alkylbenzene sulfonate. linear. petrochemical {RER}| production | Alloc Def. S	0.001*1400/350	kg	Lamepon N. sodium lignin sulfonate
N.N-dimethylformamide {RER}| production | Alloc Def. S	0.003*1400/350	kg	Lorinol R. formamidinesulfinic acid
Acrylic acid {RER}| production | Alloc Def. S	0.0015*1400/350	kg	Locanit S. Polyacrylic acid. sodium salt. CO färg + tvålning
Esterquat {RER}| treatment of	1400*0.03/350	kg	Belsoft 200 = Amides. tallow.

Resources			
tallow to | Alloc Def. S			hydrogenated. N-[2-[(2-
			hydroxyethyl)amino]ethyl]. glycolates
			(salts); R41. R51/53; EC 271-658-6; and Tallow alkyl polyglycol ether; R22. R41; mjukgörare
Electricity/heat			
Electricity. high voltage. at grid/DE S	0.0933*0.2	kWh	Data for Then-airflow. used due to lack of data from Tirupur/7H. only mechanical energy. no warming of water. 20% for bleach (4 loops).
Heat. central or small-scale. other than natural gas {CH}| heat production. light fuel oil. at boiler 10kW condensing. non-modulating | Alloc Def. S	524/350	kWh	Oil furnace/bolier at the factory heating steam that heats the airjet machine.
Emissions to water			
Isobutyl acrylate	0.008*0.3*0.01	kg	assumed 70% reacted 1% emitted
Fatty alcohol ethoxylate	0.012*0.3*0.01	kg	assumed 70% reacted 1% emitted
Phosphorus compounds. unspecified	0.006*0.3*0.01	kg	assumed 70% reacted 1% emitted
Sodium hydroxide	0.024*0.01	kg	assumed no salt is reacted 1% emitted
Acetic acid	0.052*0.3*0.01	kg	assumed 70% reacted 1% emitted
Sodium 1-octanesulfonate	0.004*0.3*0.01	kg	assumed 70% reacted 1% emitted
N-[4-(5-Nitro-2-furyl)-2-thiazolyl]formamide	0.012*0.1*0.01	kg	assumed 90% reacted 1% emitted
Acrylic acid	0.006*0.3*0.01	kg	assumed 70% reacted 1% emitted
Glycol ethers	0.12*0.3*0.01	kg	assumed 70% reacted 1% emitted
COD. Chemical Oxygen Demand	0.0002	kg	from cotton bleach/scouring
Waste to treatment			
Sludge from pulp and paper production {CH}| treatment of. sanitary landfill | Alloc Def. S	0.58	kg	approximerat med 99*kemikalier utsläppta

A2.1.10.12 Drying and fixation of cellulosics in stenter frame

Electricity/heat		
Electricity, high voltage, at grid/DE S	1.4	kWh

A2.1.10.13 Drying and fixation of synthetics in stenter frame

Electricity/heat		
MiFuFa electricity mix	1.25	kWh

A2.1.11 Product assembly, per kg

The material composition of the garments was acquired by cutting the garments to pieces and weighing the components by hand for all garments except the hospital uniform, where this data was given by the supplier. The individual packaging of the garments has been weighed by hand, it is then assumed that the garments are packed in cardboard boxes, assumed to weigh 60 g/kg garment. Below is described the components included in the product assembly, and also the modelling of the manufacturing of each such component.

A2.1.11.1 T-shirt product assembly, per kg product

The T-shirt includes only one component, the fabric, except for thread, labels and packaging materials.

T-shirt sewing and finishing, per kg product

Input	Dataset/flow used in Gabi	Amount	Unit	Comment
Dried cotton fabric	(from drying process)	1.176	kg	15% waste assumed
Water	RER: tap water, at user	10.35	kg	Supplementary
Confectioning template	RER: paper, recycling, with deinking, at plant	0.05	kg	Assumed to be 5% of the material's weight, several layers cut at once
Cardboard box and trims	RER: solid unbleached board, SUB, at plant	0.06	kg	Packaging
Plastic bag	RER: packaging film, LDPE, at plant	0.02	kg	Packaging
Electricity	Electricity mix modelled according to A2.1.1	2.628	kWh	Sewing
Heating	RER: heat, natural gas, at boiler condensing modulating <100kW	3.6	MJ	Supplementary
Electricity	Electricity mix modelled according to A2.1.1	0.05	kWh	Ironing
Material to threads	GLO: Cotton fiber (bales after ginning) CottonInc	0.0035	kg	Assumed the same thread-to-mass ratio as for the jacket
Production of threads	Ring spinning to yarn, cotton 250 dtex (mix)	0.003	kg	
Production of threads	Dyeing cotton/PES weave (mix)	0.003	kg	
Production of threads	Drying PA6 in stenter frame (mix)	0.003	kg	
Output				
Textile waste	EU-27: Waste incineration of textile fraction in municipal solid waste (MSW) ELCD/CEWEP <p-agg>	0.176	kg	Adjusted according to biogenic carbon content
T-shirt	(to distribution and retail process)	1	kg	

White cotton tricot manufacturing, per kg product

Process	Amount (kg)
Inputs	
A2.1.1 Cotton cultivation, ginning and baling	1.176*1.087 = 1.279
A2.1.5 Yarn spinning	1.176
A2.1.6 Knitting	1.176
A2.1.10.1 Bleaching cotton tricot with optical brightener in jet machine	1.176
A2.1.10.10 Drying and fixation of cellulosics in stenter frame	1.176

A2.1.11.2 Jeans product assembly, per kg product

The jeans consist of blue warp and white weft yarn that undergo wet treatment before the fabric production step.

Jeans sewing and finishing, per kg product

Input	Dataset/flow used in Gabi	Amount	Unit	Comment
Dried cotton/elastane fabric	(from drying process)	1.25	kg	20% waste assumed
Water	RER: tap water, at user	11.5	kg	Supplementary
Confectioning template	RER: paper, recycling, with deinking, at plant	0.05	kg	Assumed to be 5% of the material's weight, several layers cut at once
Cardboard box and trims	RER: solid unbleached board, SUB, at plant	0.06	kg	Packaging
Plastic bag	RER: packaging film, LDPE, at plant	0.02	kg	Packaging
Electricity	Electricity mix modelled according to A2.1.1	2.92	kWh	Sewing
Heating	RER: heat, natural gas, at boiler condensing modulating <100kW	3.6	MJ	Supplementary
Electricity	Electricity mix modelled according to A2.1.1	0.05	kWh	Ironing
Material to buttons	CH: brass, at plant	0.019	kg	
Production of buttons	RER; steel product manufacturing, average metal wokrking	0.019	kg	
Material to zippers	RER; steel, low-alloyed, at plant	0.013	kg	
Production of zippers	RER: metal product manufacturing, average metal working	0.013	kg	
Material to threads	GLO: Cotton fiber (bales after ginning) CottonInc	0.0035	kg	Assumed the same thread-to-mass ratio as for the jacket
Production of threads	Ring spinning to yarn, cotton 250 dtex (mix)	0.003	kg	
Production of threads	Dyeing cotton/PES weave (mix)	0.003	kg	
Production of threads	Drying PA6 in stenter frame (mix)	0.003	kg	
Output				
Textile waste	EU-27: Waste incineration of textile fraction in municipal solid waste (MSW) ELCD/CEWEP <p-agg>	0.25	kg	Adjusted according to biogenic carbon content
Jeans	(to distribution and retail process)	1	kg	

Denim weave manufacturing, per kg product

Process	Amount (kg)
A2.1.1 Cotton cultivation, ginning and baling	1.33
A2.1.4 Elastane fibre production	1.25*1.005*0.02=0.025
A2.1.5 Yarn spinning	1.25
A2.1.7 Weaving	1.25
A2.1.10.2 Yarn bleaching of cotton/elastane yarn in OBEM machine	1.25
A2.1.10.3 Denim batch dyeing	1.25
A2.1.10.10 Drying and fixation of cellulosics in stenter frame	1.25

Zippers, buttons, threads and packaging, per kg product

Process	Amount (kg)
A2.1.10.4.4 Threads	0.003
Steel zippers	0.013
Brass buttons	0.019
Confectioning template	0.050
Paper packaging	0.060
Plastic packaging	0.020

A2.1.11.3 Dress product assembly, per kg product

The printed fabric is woven, pretreated in jet machine before drying and printing. The black liner is knitted, dyed and dried.

Dress sewing and finishing, per kg product

Input	Dataset/flow used in Gabi	Amount	Unit	Comment
Dried cotton/elastane fabric	(from drying process)	1.2	kg	20% waste assumed
Water	RER: tap water, at user	11.5	kg	Supplementary
Confectioning template	RER: paper, recycling, with deinking, at plant	0.05	kg	Assumed to be 5% of the material's weight, several layers cut at once
Cardboard box and trims	RER: solid unbleached board, SUB, at plant	0.06	kg	Packaging
Plastic bag	RER: packaging film, LDPE, at plant	0.02	kg	Packaging
Electricity	Electricity mix modelled according to A2.1.1	2.23	kWh	Sewing and ironing
Heating	RER: heat, natural gas, at boiler condensing modulating <100kW	3.6	MJ	Supplementary
Material to threads	GLO: Cotton fiber (bales after ginning) CottonInc	0.0035	kg	Assumed the same thread-to-mass ratio as for the jacket
Production of threads	Ring spinning to yarn, cotton 250 dtex (mix)	0.003	kg	
Production of threads	Dyeing cotton/PES weave (mix)	0.003	kg	
Production of threads	Drying PA6 in stenter frame (mix)	0.003	kg	
Output				
Textile waste	EU-27: Waste incineration of textile fraction in municipal solid waste (MSW) ELCD/CEWEP <p-agg>	0.2	kg	Adjusted according to biogenic carbon content
Dress	(to distribution and retail process)	1	kg	

Printed polyester weave manufacturing, per kg product

Process	Amount (kg)
A2.1.2 Polyester fibre production	0.61*1.005
A2.1.5 Yarn spinning	0.61
A2.1.7 Weaving	0.61
A2.1.10.5 Pretreatment in jet machine of PES weave before printing	0.61
A2.1.10.6 Dispersion print of PES weave on rotation printer	0.61
A2.1.10.10 Drying and fixation of synthetics in stenter frame	0.61

Black polyester tricot manufacturing, per kg product

Process	Amount (kg)
A2.1.2 Polyester fibre production	0.59*1.005
A2.1.5 Yarn spinning	0.59
A2.1.6 Knitting	0.59
A2.1.10.4 Dyeing PES tricot black in jet dyeing machine – will be added	0.59
A2.1.10.10 Drying and fixation of synthetics in stenter frame	0.59

A2.1.11.4 Jacket product assembly, per kg product

The black and green polyamide weaves are modelled exactly the same way except for the dyestuffs added in the dyeing process. The measured yarn weight was for the black weave 202 dtex for the warp and 94 dtex for the weft. The green weave had very similar constitution with a measured yarn weight of 209 dtex for the warp and 80 dtex for the weft. The measured yarn weight of the orange weave was 71 dtex for the warp and 70 dtex for the weft. The black and green cotton/elastane gussets are modelled exactly the same way except for the dyestuffs added in the dyeing process.

Jacket sewing and finishing, per kg product

Materials/fuels			
Weave PA (mix)	0.504	kg	20% cutting waste is assumed for all fabrics
Weave PES	0.107	kg	
Non woven PES for lining for jacket	0.231	kg	
Gussets in cotton/elastane tricot	0.195	kg	gussets
Zippers jacket	0.115	kg	zippers - 2% waste is assumed for all non textile materials and the thread
Buttons. jacket	0.0133	kg	Buttons
Cotton thread. black 50	0.0069	kg	Thread modelled as yarn
Paper labels	0.0039	kg	paper labels
Confectioning of jacket. per kg	1.0	kg	includes confectioning template and packaging

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Black and green polyamide weave manufacturing (for the shell), per kg product

Process	Amount (kg)
A2.1.3 Polyamide fibre production	0.167*1.25*1.04
A2.1.10 Filament DTY yarn, synthetic 100 dtex	0.167*1.25*1.02
A2.1.7 Weaving to fabric 150 dtex	0.167*1.25
A2.1.10.7 Dyeing and drying PA6 weave black and olive in beam dyeing machine, average	0.167*1.25

Orange polyester lining weave manufacturing, per kg product

Process	Amount (kg)
A2.1.2 Polyester fibre production	0.059*1.25*1.04
A2.1.10 Filament DTY yarn, synthetic 100 dtex	0.059*1.25*1.02
A2.1.7 Weaving to fabric 150 dtex	0.059*1.25
A2.1.10.4 Dyeing PES tricot orange in jet dyeing machine	0.059*1.25
A2.1.10.11 Drying and fixation of synthetics in stenter frame	0.059*1.25

Polyester non woven padding manufacturing, per kg product

Process	Amount (kg)
A2.1.2 Polyester fibre production	0.085*1.25*1.005
A2.1.8 Non woven process	0.085*1.25

Black and green cotton/elastane gussets manufacturing, per kg product

Process	Amount (kg)
A2.1.1 Cotton cultivation, ginning and baling	0.065*1.25*1.08
A2.1.4 Elastane fibre production	0.007*1.25*1.005
A2.1.5 Yarn spinning	0.072*1.25
A2.1.6 Knitting	0.072*1.25
A2.1.10.8 Dyeing CO/EL tricot black and green in jet dyeing machine	0.072*1.25
A2.1.10.10 Drying and fixation of cellulosics in stenter frame	0.072*1.25

Zippers, buttons, labels and packaging, per kg product

Process	Amount (kg)
Steel zippers	0.0503
Brass buttons	0.0058
Paper labels	0.0017
A2.1.10.4.4 Threads	0.0030
Retail packaging	0.0113
Plastic consumer bag	0.0262

Zippers jacket manufacturing, per kg

Materials/fuels		
Steel, low-alloyed, at plant/RER S	1	kg
Steel product manufacturing, average metal working/RER S	1	kg

Buttons jacket manufacturing, per kg

Materials/fuels		
Brass, at plant/CH S	1	kg
Metal product manufacturing, average metal working/RER S	1	kg

Paper labels manufacturing, per kg

Materials/fuels		
Paper, recycling, with deinking, at plant/RER S	1	kg

Cotton thread manufacturing, per kg

All threads have been modelled as cotton thread.

Materials/fuels		
Cotton fibre {CN}| cotton production | Alloc Def, S	1.18	kg
Ring spinning to yarn, cotton 250 dtex (mix)	1	kg
Dyeing cotton/PES weave (mix)	1	kg
Drying PA6 in stenter frame (mix)	1	kg

Confectioning of jacket, per kg

Materials/fuels			
Tap water. at user {RoW}| market for | Alloc Def. S	0.115*100	kg	Supplementary
Paper. recycling. with deinking. at plant/RER S	0.05	kg	The confectioning template is assumed to be 5% of the material's weight. several layers cut at once.
Packaging film. LDPE. at plant/RER S	0.0113/0.444	kg	Plastic bag. measured weight for a jacket of 444 g.
Solid unbleached board {GLO}| market for | Alloc Def. S	0.06	kg	Cardboard box and trims.
Electricity/heat			
Electricity mix modelled according to A2.1.1	0.0292*100	kWh	Sewing
Heat. natural gas. at boiler modulating <100kW/RER S	0.00105*100	MJ	Supplementary
MiFuFa electricity mix	0.05	kWh	Ironing
Waste to treatment			
Disposal. inert waste. 5% water. to inert material landfill/CH S	0.2	kg	Odefinierad

A2.1.11.5 Hospital uniform product assembly, per kg product

The material composition was given by the producer for the hospital uniform. Weight of plastic buttons and thread is based on assumptions.

Hospital uniform sewing and finishing, per kg product

Materials/fuels			
Cotton/PES weave per squaremeter	1.15	kg	15% waste during confectioning in Latvia
Processes			
Wet processing of cotton/PES weave, light blue	1.15	kg	15% waste during confectioning in Latvia
Confectioning of hospital uniform, Latvia, per kg	1	kg	Includes packaging material

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Blue cotton/polyester weave manufacturing, per kg product

Process	Amount (kg)
A2.1.1 Cotton cultivation, ginning and baling	0.169*1.1765*1.08
A2.1.2 Polyester fibre production	0.169*1. 1765*1.005
A2.1.5 Yarn spinning	0.169*1. 1765
A2.1.7 Weaving	0.169*1. 1765
A2.1.10.9 Dyeing CO/PES weave blue in jet dyeing machine	0.169*1. 1765
A2.1.10.10 Drying and fixation of cellulosics in stenter frame	0.169*1. 1765

Buttons, thread, labels and packaging, per kg product

Process	Amount (kg)
Buttons	0.007
Threads	0.002
Cardboard box	0.02
Rubber band	0.004

Confectioning of jacket, per kg

Materials/fuels		
Electricity, high voltage, at grid/PL S	239690/9045801*28	kWh
Natural gas, at long-distance pipeline/RER S	9510/9045801*28	m3
Tap water {Europe without Switzerland}| market for | Alloc Def, S	1043/9045801*28	ton
Waste to treatment		
Disposal. inert waste. 5% water. to inert material landfill/CH S	0.15	kg

A2.2 Distribution & Retailing phase

A2.2.1 T-shirt, jeans, dress and jacket

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comment
Garment	(from fabric production process)	1.01	kg	The waste in retailing (1%) is an assumption based on a survey among Swedish retailers indicating that there is almost no waste due to sales and outlet stores (Carlsson et al 2011).
Transport (from manufacturing country to Sweden)	OCE: transport, transoceanic freight ship [Water]	18.88	tkm	Distance according to Sea-Distances.org (2015) from Shanghai to Gothenburg (empty return trip not included)
Transport (distribution to store)	RER: transport, lorry 16-32t, EURO5 [Street]	2.85	tkm	
Transport (distribution to store)	RER: transport, lorry 3.5-7.5, EURO5 [Street]	0.32	tkm	
Transport (retail staff)	CH: transport, regular bus [Street]	0.1	pkm	
Transport (retail staff)	RER: transport, aircraft, passenger, intercontinental [Air]	0.0008	pkm	
Transport (retail staff)	RER: transport, passenger car [Street]	0.19	pkm	

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comment
Electricity (store and credit)	SE: electricity, low voltage, at grid	6.858	MJ	Including credit for electricity production in waste treatment of packaging and textile waste.
Heat (credit)	2.4.1.1 District heating MiFuFa, Swedish average	-0.299	MJ	Credit for heat production in waste treatment of packaging and textile waste
Outputs				
Garment	(to use process)	1	kg	
Waste to treatment	CH: disposal, packaging paper, 13.7% water, to municipal incineration [municipal incineration]	0.13	kg	
Waste to treatment	EU-27: Waste incineration of textile fraction in municipal solid waste (MSW) ELCD/CEWEP <p-agg>	0.01	kg	Modified according to specific fraction (cellulosics or polyester). Modified factors include: heating value (which influence the heat and electricity credits) and the origin of CO_2 emissions (biogenic for cellulosing, fossil for polyester)

A2.2.2 Hospital uniform, distribution per kg

Materials/fuels	Amount	Unit	Comments
Transport, freight, sea, transoceanic ship (GLO)| processing | Alloc Def, S	0.001*357*1.85	tkm	1.85 nautic mile/km, 357 nautic miles
Transport, freight, lorry 16-32 metric ton, EURO5 (RER)| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Def, S	0.001*200	tkm	200 km transport from production site to Riga harbour and from Stockholm harbour-Norrköping (164 km) assumed.

A2.3 Use phase

The use phase includes transport from the store to the home of the buyer and washing, drying and ironing of garments. A2.3.1-14 show inventory data for general processes (detergent, washing, drying and ironing), then follows garment-specific inventory data in subsections.

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A2.3.1 Detergent production

Inventory for detergent are from Table 5, and energy use and emission data is from Table 6, in Saouter & van Hoof (2002).

Inventory	% of ingredients, or mass/mass detergent	Chosen dataset	Amount for 887 g detergent	Comment
Inputs				
AE11-PO	2%	RER: ethoxylated alcohols (AE11), palm oil, at plant	20 g	Amount is based on "1 kg recipe". This amount is then assumed for 887 of detergent output, as we did not find LCI data for 113 g of the 1 kg recipe. The ingredients we found LCI data for are assumed to be representative for the ingredients we did not find LCI data for.
AE7-pc	4%	RER: ethoxylated alcohols (AE7), petrochemical, at plant	40 g	
LAS-pc	7.8%	RER: ethoxylated alcohols, unspecified, at plant [Surfactants (tensides)]	78 g	As LAS-pc this has been phased out in Sweden, we instead assume ethoxylated alcohols.
Citric acid	5.2%	Not available in Gabi	-	
Na-Silicate powder	3%	RER: sodium silicate, spray powder 80%, at plant	30 g	
Zeolite	20.1%	RER: zeolite, powder, at plant	201 g	
Sodium carbonate	17%	GLO: sodium carbonate from ammonium chloride production, at plant	170 g	
Perborate mono hydrate	8.7%	RER: sodium perborate, monohydrate, powder, at plant	87 g	
Perborate tetra hydrate	11.5%	RER: sodium perborate, tetrahydrate, powder, at plant	115 g	
Antifoam S1.2-3522	0.5%	Not available in Gabi	-	
FWA DAS-1	0.2%	Not available in Gabi	-	
Polyacrylate	4%	Not available in Gabi	-	
Protease	1.4%	Not available in Gabi	-	
Sodium sulfate	0.4%	GLO: sodium persulfate, at plant	4 g	
Water	14.2%	GLO: water, ultrapure, at plant	142 g	
Packaging materials				
Paper woody U B250 (1998)	21.7 g/kg detergent	RER: kraft paper, unbleached, at plant	19.3 g	
Corrugated cardboard	108.2 g/kg detergent	RER: corrugated board base paper, kraftliner, at plant	96 g	
HDPE B250 (barrier)	8.1 g/kg detergent	RER: polyethylene, HDPE, granulate, at plant	7.2 g	
Process energy	0.25 GJ/1000 wash loads (100 kg detergents)	SE: electricity , high voltage, at grid	2.22 MJ	
Electricity (credit from package disposal)		SE: electricity, high voltage, at grid	-0.54 MJ	
Heat (credit from package disposal)		CH: heat, light fuel oil, at boiler 10kW, non-modulating	-0.41 MJ	
Outputs				
Products/byproducts				
Detergent			887 g	

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Inventory	% of ingredients, or mass/mass detergent	Chosen dataset	Amount for 887 g detergent	Comment
Disposal packaging		CH: disposal, packaging paper, 13.7% water, to municipal incineration	19.3 g	
Disposal packaging		CH: disposal, packaging cardboard, 19.6% water, to municipal incineration	96 g	
Disposal packaging		CH: disposal, plastics, mixture, 15.3% water, to municipal incineration	7.2 g	
Emissions to air				
CO2	13.30kg/100 kg		0.12 kg	
CO	6.00g/100 kg		0.000053 kg	
SOx	69.60g/100 kg		0.00062 kg	
NOx	32.90g/100 kg		0.00029 kg	
CxHx	109.00g/100 kg		0.00097 kg	
Particles/dust	17.60g/100 kg		0.00016 kg	
Emissions to water				
BOD	4.90g/100 kg		0.000043 kg	
COD	10.10g/100kg		0.000090 kg	

A2.3.2 Residential washing

A2.3.2.1 Inventory for the washing of 1 kg garment in 40 degrees

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comments
Garment	(from use phase process)	1	kg	
Water	RER: tap water, at user [Appropriation]	6.2	kg	Here we assume that the machine adjust the amount of water to the amount of load, which was standard for most machines already in 2005 (Faberi 2007). As for electricity use, we assume the most efficient machines available in 2005 (Faberi 2007). We have assumed the same water use/kg of load as a fully loaded 6 kg capacity washing machine.
Detergent	(from detergent process)	0.013	kg	According to (Granello et al. 2015), most used the recommended detergent dosage, which for the common hardness of water in Sweden is 50 ml/wash wash, which according to our own weighting is about 42 g/wash, or 13 g per kg assuming an average load of 3.2 kg (from Faberi (2007))
Electricity	SE: electricity, low voltage, production SE, at grid	0.225	kWh	Average load in Sweden is 3.2 kg (out of an average full load of 5.4 kg, i.e. 59%) (Faberi 2007). Assuming a 6 kg capacity washing machine (most common machine capacity according to Faberi (2007), the average load can thus be assumed to be 3.6 kg. The average washing machine in 2005 was 5.6 years old (Faberi 2007). We assume that today's average 6 kg capacity washing machine corresponds to the most energy efficient 6 kg capacity washing machine in 2005, this is reduced by 25-29% in case of an average load (Faberi 2007); we assume a 27% reduction. Standby and other low power modes correspond to 4-8% of energy use for washing machines (Faberi 2007); we assume 6%.
Outputs				
Garment	(to use phase process)	1	kg	

Washing water	CH: treatment, sewage, from residence, to wastewater treatment, class 2 [wastewater treatment]	6.2	kg	This is a simplification. In reality, some of this amount will enter the wastewater system during the drying process

A2.3.3 Residential drying

A2.3.3.1 Inventory for the drying of 1 kg garment in tumble dryer

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comments
Garment	(from use phase process)	1	Kg	
Electricity	SE: electricity, low voltage, production SE, at grid	0.67	kWh	Assuming condenser tumble dryer adhering to A classification in European energy label, including standby modes (Lefèvre 2009)
Outputs				
Garment	(to use phase process)	1	Kg	

A2.3.4 Residential ironing, 1 minute

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comments
Garment	(from use phase process)	1	Kg	
Electricity	SE: electricity, low voltage, production SE, at grid	0.027	kWh	Wolf et al. (2012): assumes an average iron power of 1600 kW, corresponding to 0.027 kWh/min
Outputs				
Garment	(to use phase process)	1	Kg	

A2.3.5 Use of T-shirt

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comments
T-shirt	(from distribution and retail process)	0.11	kg	
Transport (from store to buyer´s home)	RER: transport, passenger car [Street]	0.94	pkm	Based on an assumption of 17 person-km/kg garment, which is based on (Granello et al. 2015): 66% of the respondes answered 2-15 km for the distance to the store; the middle of this interval is 8.5, thus 17 km for both ways. Most consumers purchase 2-3 garments each trip (Granello et al. 2015), which (considering the weight of our garments) is in the order of 1 kg. Also, 50% car transportation and 50% public transportation was assumed; this is a simplified assumption based on (Granello et al. 2015), in which by foot and bicycle also are common transportation modes (28%), but as these modes probably are mainly used for shorter distances, we assume these are comparably insignificant per person-km.
Transport (from store to buyer´s	CH: transport, regular bus	0.94	pkm	See above

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comments
home)	[Street]			
Washing of garment (40 degrees)	(from washing process)	1.32	kg	11 washing cycles per functional unit. This is, based on net import in 2008 and assumption on weight/garment: ~9 T-shirts/person/yr. Assuming that the amount of T-shirts in our wardrobe is constant and that T-shirts are used 200 days/yr (based on (Granello et al. 2015)), then the average T-shirt is worn 22 days before end of life. Then assuming that a T-shirt in average is used about 2 times before wash (based on Gwozdz et al. 2013 and (Granello et al. 2015). Washing temperature of 40 degrees is assumed, based on most common temperature according to Gwozdz et al. 2013 (77.8%) and for Sweden according to Faberi (2007) (the average temperature for Swedes is ~48 degrees, but that includes washing of linen, underwear and towels).
Drying of garment	(from drying process)	0.41	kg	Assumed to be dried after 34% of the washes (Granello et al. 2015)
Ironing of garment	(from ironing process)	5	min	We have assumed 3 minutes of ironing per T-shirt (Wolf et al. 2012) and that ironing is done after 15% of washing cycles (Granello et al. 2015)
Outputs				
T-shirt	(to end of life process)	0.11	kg	

A2.3.6 Use of jeans

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comments
Jeans	(from distribution and retail process)	0.477	kg	
Transport (from store to buyer´s home)	RER: transport, passenger car [Street]	4.05	pkm	Based on an assumption of 17 person-km/kg garment, see Table 0 for reference.
Transport (from store to buyer´s home)	CH: transport, regular bus [Street]	4.05	pkm	Based on an assumption of 17 person-km/kg garment, see Table 0 for reference.
Washing of garment (40 degrees)	(from washing process)	9.54	kg	20 washing cycles per functional unit. This is based on net import in 2008 and assumption on weight/garment: ~1 jeans/person/yr. Assuming that the amount of jeans in our wardrobe is constant and that jeans are used 200 days/yr (Granello et al. 2015), then the average jeans is worn 200 days before end of life. Then assuming that jeans are washed every 20th time (Granello et al. 2015). Washing temperature of 40 degrees is assumed, based on most commontemperature according to Gwozdz et al. (2013) (77.8%) and for Sweden according to Faberi (2007) (the average temperature for Swedes is ~48 degrees, but that includes washing of linen, underwear and towels).
Drying of garment	(from drying process)	2.77	kg	Assumed to be dried after 29% of the washes (Granello et al. 2015).
Ironing of garment	(from ironing process)	5	min	We have assumed 6 minutes of ironing for jeans (Wolf et al. 2012) and that ironing is done in 15% of washing cycles (Granello et al. 2015).

Outputs				
Jeans	(to end of life process)	0.477	kg	

A2.3.7 Use of dress

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comments
Dress	(from distribution and retail process)	0.478	kg	
Transport (from store to buyer´s home)	RER: transport, passenger car [Street]	4.06	pkm	Based on an assumption of 17 person-km/kg garment, see Table 0 for reference.
Transport (from store to buyer´s home)	CH: transport, regular bus [Street]	4.06	pkm	Based on an assumption of 17 person-km/kg garment, see Table 0 for reference.
Washing of garment(40 degrees)	(from washing process)	1.59	kg	3.33 washing cycles per functional unit. This is based on net import in 2008 and assumption on weight/garment: ~5 dresses/woman/yr,aAssuming that the amount of dresses in our wardrobe is constant, and that a woman uses a dress 50 days/year (Granello et al. 2015). Each dress is thus used: 10 times before end of life. Assuming a dress is washed after third second use (Survey 2015), yields: 3.33 washing cycles per service life. Washing temperature of 40 degrees is assumed, based on most common temperature according to Gwozdz et al. (2013) (77.8%) and for Sweden according to Faberi (2007) (the average temperature for Swedes is ~48 degrees, but that includes washing of linen, underwear and towels).
Drying of garment	(from drying process)	0.30	kg	Assumed to be dried after 19% of the washes (Granello et al. 2015)
Ironing of garment	(from ironing process)	3.6	min	Assumed to be itroned after 18% of the washes, based on data from Lefèvre (2009) on synthetic materials. According to Wolf (2012), it is reasonable to assume that a dress (excluding knitted and crocheted) are ironed for 6 minutes.
Outputs				
Dress	(to end of life process)	0.478	kg	

A2.3.8 Use of jacket

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comments
Jacket	(from distribution and retail process)	0.444	kg	
Transport (from store to consumer´s home)	RER: transport, passenger car [Street]	3.77	pkm	Based on an assumption of 17 person-km/kg garment, see Table 0 for reference.
Transport (from store to buyer´s home)	CH: transport, regular bus [Street]	3.77	pkm	Based on an assumption of 17 person-km/kg garment, see Table 0 for reference.
Washing of garment (40 degrees)	(from washing process)	0.444	kg	1 washing cycles per functional unit. This is based on net import in 2008 and assumption on weight/garment: ~3.25 jackets/person/yr. Assuming that the

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comments
				amount of jackets in our wardrobe is constant and that jackets are worn 325 days/yr, then the average jacket is worn 100 days before end of life. Then assuming that a jacket is washed in average once during 100 days of use. Washing temperature of 40 degrees is assumed, based onmost common temperature according to Gwozdz et al. (2013) (77.8%) and for Sweden according to Faberi (2007) (the average temperature for Swedes is ~48 degrees, but that includes washing of linen, underwear and towels).
Drying of garment	(from drying process)	0.0.93	kg	Assumed to be dried after 21% of the washes (Granello et al. 2015).
Ironing of garment	(from ironing process)	0.20	min	Assumed to be dried after 5% of the washes (Granello et al. 2015). According to Wolf (2012), it is reasonable to assume that a jacket is ironed for 3-5 minutes, so we assumed 4.
Outputs				
Jacket	(to end of life process)	0.444	kg	

A2.3.9 Use of hospital uniform

Materials/fuels	Amount	Unit
Industrial washing and drying SE electricity	0.340*75	kg
Wearing of hospital uniform, LC	0.340*75	kg
Heavy vehicle, per litre RME	1.17E-06	m3

A2.3.10 Industrial laundry, per kg garments

Materials/fuels	Amount	Unit
Tap water, at user {Europe without Switzerland}| market for | Alloc Def, S	12	kg
Washing detergent S	0.009	kg
Electricity, medium voltage, at grid/SE S	0.4	kWh
Heat, future {CH}| wood pellets, burned in stirling heat and power co-generation unit, 3kW electrical, future | Alloc Def, S	1.9	kWh
Waste to treatment		
Treatment, sewage, from residence, to wastewater treatment, class 2/CH S	0.012	m3

A2.4 End of life phase

A2.4.1 Incineration, per kg garment

The below heat and electricity are in average; these numbers have then been adjusted to the textile content of each garment (see section 2.7.1).

Waste to treatment	Amount	Unit
EU-27: Waste incineration of textile fraction in municipal solid waste (MSW)	1	kg
Transportation of waste to treatment: RER: transport, lorry 3.5-7.5t, EURO5	0.03	tkm
Heat credit: A2.4.1.1 Distring heating MiFuFa, Swedish average	-5.29	MJ
Electricity credit: SE: elecitricity, low voltage, production SE, at grid	-1.78	MJ

A2.4.1.1 District heating MiFuFa, Swedish average

Products	Amount	Unit
District heating MiFuFa, Swedish average	1	MJ
Electricity/heat		
Heat, softwood chips from forest, at furnace 1000kW/CH S	0.47	MJ
Heat from waste, at municipal waste incineration plant with emissions	0.2	MJ
Heat, light fuel oil, at boiler 100kW condensing, non-modulating/CH EcoInvent System	0.04	MJ
Heat, natural gas, at industrial furnace >100kW/RER S	0.05	MJ
Hard coal, burned in industrial furnace 1-10MW/RER S	0.05	MJ
Peat, burned in power plant/NORDEL S	0.04	MJ

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Appendix 3. Statistics for import of garments to Sweden

The EU common Combined Nomenclature (CN) is used by the Swedish Statistics for import and export of commodities, including garments. When declared to customs in the European community, goods must generally be classified according to the CN. Imported and exported goods have to be declared stating under which subheading of the nomenclature they fall. This determines which rate of customs duty applies and how the goods are treated for statistical purposes. The CN is a method for designating goods and merchandise which was established to meet, at one and the same time, the requirements both of the Common Customs Tarif and of the external trade statistics of the Community. The CN is also used in intra-Community trade statistics. The CN is comprised of the Harmonized System (HS) nomenclature with further Community subdivisions. The HS is run by the World Customs Organisation (WCO).

Below is shown the statistics for consumption of garments (import + production – export) in Sweden 2012 and what type of garment that has been chosen to represent each category according to CN (European Commission 2013).

CN code	Description	Consumption in Sweden 2012 (ton)	MiFuFa garment representation
6101	Men's or boys' overcoats, car coats, capes, cloaks, anoraks (including ski jackets), windcheaters, wind-jackets and similar articles, knitted or crocheted, other than those of heading 6103:	320	dress
6102	Women's or girls' overcoats, car coats, capes, cloaks, anoraks (including ski jackets), windcheaters, wind-jackets and similar articles, knitted or crocheted, other than those of heading 6104:	939	dress
6103	Men's or boys' suits, ensembles, jackets, blazers, trousers, bib and brace overalls, breeches and shorts (other than swimwear), knitted or crocheted:	1036	jeans
6104	Women's or girls' suits, ensembles, jackets, blazers, dresses, skirts, divided skirts, trousers, bib and brace overalls, breeches and shorts (other than swimwear), knitted or crocheted:	5234	jeans
6105	Men's or boys' shirts, knitted or crocheted:	1079	T-shirt

CN code	Description	Consumption in Sweden 2012 (ton)	MiFuFa garment representation
6106	Women's or girls' blouses, shirts and shirt-blouses, knitted or crocheted:	926	dress
6107	Men's or boys' underpants, briefs, nightshirts, pyjamas, bathrobes, dressing gowns and similar articles, knitted or crocheted:	1996	T-shirt
6108	Women's or girls' slips, petticoats, briefs, panties, nightdresses, pyjamas, négligés, bathrobes, dressing gowns and similar articles, knitted or crocheted:	2220	T-shirt
6109	T-shirts, singlets and other vests, knitted or crocheted:	10441	T-shirt
6110	Jerseys, pullovers, cardigans, waistcoats and similar articles, knitted or crocheted:	10672	dress
6111	Babies' garments and clothing accessories, knitted or crocheted:	1573	T-shirt
6112	Tracksuits, ski suits and swimwear, knitted or crocheted:	689	T-shirt
6113	Garments, made up of knitted or crocheted fabrics of heading 5903, 5906 or 5907:	229	jacket
6114	Other garments, knitted or crocheted:	948	T-shirt
6115	Pantyhose, tights, stockings, socks and other hosiery, including graduated compression hosiery (for example, stockings for varicose veins) and footwear without applied soles, knitted or crocheted:	5567	dress
6116	Gloves, mittens and mitts, knitted or crocheted:	1525	dress
6117	Other made-up clothing accessories, knitted or crocheted; knitted or crocheted parts of garments or of clothing accessories:	726	T-shirt
6201	Men's or boys' overcoats, car coats, capes, cloaks, anoraks (including ski jackets), windcheaters, wind-jackets and similar articles, other than those of heading 6203:	1874	jacket
6202	Women's or girls' overcoats, car coats, capes,	2960	jacket

CN code	Description	Consumption in Sweden 2012 (ton)	MiFuFa garment representation
	cloaks, anoraks (including ski jackets), windcheaters, wind-jackets and similar articles, other than those of heading 6204:		
6203	Men's or boys' suits, ensembles, jackets, blazers, trousers, bib and brace overalls, breeches and shorts (other than swimwear):	9489	jeans
6204	Women's or girls' suits, ensembles, jackets, blazers, dresses, skirts, divided skirts, trousers, bib and brace overalls, breeches and shorts (other than swimwear):	10023	jacket
6205	Men's or boys' shirts:	2642	uniform
6206	Women's or girls' blouses, shirts and shirt-blouses:	2012	uniform
6207	Men's or boys' singlets and other vests, underpants, briefs, nightshirts, pyjamas, bathrobes, dressing gowns and similar articles:	403	uniform
6208	Women's or girls' singlets and other vests, slips, petticoats, briefs, panties, nightdresses, pyjamas, négligés, bathrobes, dressing gowns and similar articles:	547	uniform
6209	Babies' garments and clothing accessories:	379	jeans
6210	Garments, made up of fabrics of heading 5602, 5603, 5903, 5906 or 5907:	3173	jacket
6211	Tracksuits, ski suits and swimwear; other garments:	1703	jacket
6212	Brassières, girdles, corsets, braces, suspenders, garters and similar articles and parts thereof, whether or not knitted or crocheted:	976	jacket
6213	Handkerchiefs:	15	dress
6214	Shawls, scarves, mufflers, mantillas, veils and the like:	536	dress
6215	Ties, bow ties and cravats:	75	jacket
6216	Gloves, mittens and mitts	376	jacket

CN code	Description	Consumption in Sweden 2012 (ton)	MiFuFa garment representation
6217	Other made-up clothing accessories; parts of garments or of clothing accessories, other than those of heading 6212:	129	jacket

Appendix 4. Details of the scenario modelling

A4.1 Details for the collaborative consumption scenarios

	T-shirt	Jeans	Dress	Jacket
Baseline scenarios (1, 6 and 10) – the basis for modelling the rental service setups				
Number of uses before disposal	22	200	10	100
Number of washes before disposal	11	20	3.33	1
Number of uses per wash	2	10	3	100
Number of consumers before disposal	1	1	1	1
Consumer transportation	17 person-km/kg. Scenario 1: 50% car/50% bus; Scenario 6: 100% car; Scenario 11: 100% bus (the car and bus datasets are shown in Tables 0-0) Appendix 2)			
person-km/garment life cycle	1.87	8.11	8.13	7.55
person-km/garment use	0.085	0.041	0.813	0.0.075
Mass of garment (kg)	0.11	0.477	0.478	0.444
Collaborative consumption scenarios – twice (x2) and four times (x4) the garment service life as of the baseline scenarios				
Number of uses before disposal (x2)	44	400	20	200
Number of uses before disposal (x4)	88	800	40	400
Number of washes before disposal (x2)	22	40	6.66	2
Number of washes before disposal (x4)	44	80	13.32	4
Number of consumers before disposal (x2)	11	10	15	4
Number of consumers before disposal (x4)	22	20	30	8
Number of uses per consumer (x2 and x4)	4	40	1.33	50
Comment 1: Today, washing practices differ a lot between rental services (based on questionnaire, see A4.2). Here, we assume the garment is washed, dried and ironed in the same manner as in the baseline. One could imagine both advantegous and disadvantageous of washing in a rental service setup: the store could take be responsible for some of the washing and thus do this more efficiently, but there could be more frequent washes compared to baseline scenarios (e.g. the consumer washes the garment before handing it back to the store, the store washes the garment, and then the consumer washes it before use).				
Comment 2: Differences in transportation of staff and electricity use at store (or, e.g., more electricity use due to servers) are ignored, as energy use in the store was insignificant contributors to the life cycle impact in the baseline scenarios (see Chapter 40)				

	T-shirt	Jeans	Dress	Jacket
Transportation for x2 scenarios (6 scenarios; the car and bus datasets are shown in Tables 0-0)Appendix 2)				
Scenario 2: Offline (baseline consumer transportation) Difference from baseline scenario: more consumer transports				
Consumer transportation: 17 person-km/kg garment, 50% car/50% bus				
person-km/garment life cycle	20.6	81.1	122	30.2
person-km/garment use	0.468	0.203	6.09	0.151
Scenario 7: Offline (low impact consumer transportation) Difference from baseline scenario: more consumer transports				
Consumer transport distances as in scenario 2, but the means of transportation is 100% bus				
Scenario 12: Offline (high impact consumer transportation) Difference from baseline scenario: more consumer transports				
Consumer transport distances as in scenario 2, but the means of transportation is 100% car				
Scenario 3: Online (baseline consumer transportation) Differences from baseline scenario: more consumer transports, mail distribution transportation (from central warehouse) and consumer transportation to pickup-point (e.g. postal office)				
No distribution to store, i.e. minus 0.32 tkm/kg garment/consumer of "RER: transport, lorry 3.5-7.5, EURO5"				
tkm/garment life cycle	-0.0352	-0.153	-0.153	-0.142
Distribution from central warehouse to/from postal service: +0.32 tkm/kg garment, in each direction, of "RER:transport, lorry3.5- 7.5t, EURO5"				
tkm/garment life cycle	0.774	3.05	4.59	1.14
tkm/garment use	0.0176	0.00763	0.229	0.00568
Consumer transportation to/from home to pickup-point (e.g. postal office): 5.67 person-km/kg garment/consumer (i.e. one third of the distance/kg as for transportation to/from store), 50% car/50% bus				
tkm/garment life cycle	6.86	27.0	40.7	10.1
tkm/garment use	0.156	0.0.68	2.03	0.050
Scenario 8: Online (low impact consumer transportation) Differences from baseline scenario: more consumer transports, mail distribution transportation (from central warehouse) and consumer transportation to pickup-point (e.g. postal office)				
Distribution to/from postal office and consumer transport distance as in scenario 3, but the consumerconsumer's means of transportation is by walk/bike				
Scenario 13: Online (high impact consumer transportation) Differences from baseline scenario: more consumer transports, mail distribution transportation (from central warehouse) and transportation to pickup-point (e.g. postal office)				
Distribution to/from postal office and consumer transport distance as in scenario 3, but the consumer's means of transportation is by car				
Transportation for x4 scenarios (6 scenarios; the car and bus datasets are shown in *Tables 0-0)*Appendix 2*)*				
Scenario 4: Offline (baseline consumer transportation) Difference from baseline scenario: more consumer transports				

	T-shirt	Jeans	Dress	Jacket
Consumer transportation: 17 person-km/kg garment/consumer, 50% car/50% bus				
person-km/garment life cycle	41.1	162	244	60.3
person-km/garment use	0.468	0.203	6.09	0.151
Scenario 9: Offline (low impact consumer transportation) Difference from baseline scenario: more consumer transports				
Consumer transport distances as in scenario 4, but the means of transportation is 100% bus				
Scenario 14: Offline (high impact consumer transportation) Difference from baseline scenario: more consumer transports				
Consumer transport distances as in scenario 4, but the means of transportation is 100% car				
Scenario 5: Online (baseline consumer transportation) Differences from baseline scenario: more consumer transports, mail distribution transportation (from central warehouse) and consumer transportation to pickup-point (e.g. postal office)				
No distribution to store, i.e. -0.32 tkm/kg garment of "RER: transport, lorry 3.5-7.5, EURO5"				
tkm/garment life cycle	-0.04	-0.15	-0.15	-0.14
Distribution from central warehouse to/from postal service: +0.32 tkm/kg garment/consumer, in each direction, of "RER:transport, lorry 3.5-7.5, EURO5"				
tkm/garment life cycle	1.59	5.95	9.02	2.13
tkm/garment use	0.0176	0.00744	0.226	0.00533
Consumer transportation to/from home to postal office: 5.67 person-km/kg/consumer (i.e. one third of the distance/kg as for transportation to/from store), 50% car/50% public transport				
tkm/garment life cycle	13.7	54.1	81.3	20.1
tkm/garment use	0.156	0.068	2.03	0.050
Scenario 10: Online (low impact consumer transportation) Differences from baseline scenario: more consumer transports, mail distribution transportation (from central warehouse) and transportation to pickup-point (e.g. postal office)				
Distribution to/from postal office and consumer transport distance as in scenario 5, but the consumer's means of transportation is by walk/bike				
Scenario 15: Online (high impact consumer transportation)				
Differences from baseline scenario: more consumer transports, mail distribution transportation (from central warehouse) and transportation to pickup-point (e.g. postal office)				
Distribution to/from postal office and consumer transport distance as in scenario 5, but the consumer's means of transportation is by car				

A4.2 Details for the fibre replacement scenario

A4.2.1 Fibre recycling, per kg

Modelling the tencel/lyocell process:

Inputs	Dataset/flow used in Gabi	Amount	Unit	Comments
Pulp	scenario A: RER: sulphate pulp, TCF bleached, at plant	1	Kg	
Pulp	scenario B: TH: sulphate pulp, from eucalyptus ssp. (SFM), unbleached, at pulpmill	1	Kg	
NMMO	NMMO	0.03	Kg	electricity mix of production countries (the MiFuFa mix) and CH: heat, natural gas, allocation exergy, at micro gas turbine used
Heat	CH: heat, at cogen 160kWe lambda=1, allocation exergy	5	kWh	
Heat	CH: heat, at cogen with biogas engine, allocation exergy	3	kWh	
Water	CH: tap water, at user	0.02	Kg	
Outputs	*Dataset/flow used in Gabi*	*Amount*	*Unit*	*Comments*
Tencel fibres	-	1	Kg	
NMMO	NMMO	0.03	Kg	to water (not characterised)

A4.3 Questionnaire to clothing libraries

The questionnaire was carried out in the fall of 2014. It was sent out to five different clothing libraries in Sweden. Replies were received from Klädoteket in Gothenburg (respondent A) and Lånegarderoben in Stockholm (respondent B). The questionnaire and the answers have been translated from Swedish to English by the authors.

Question 1: Which garment type is most popular among your customers?

Respondent A: Varies with season. In the spring/summer, dresses, blouses and tops are popular. In the winter, jackets and heavier shirts are more popular. Jeans/troconsumers are not as popular as it can be difficult to find a pair that fits the customer.

Respondent B: Every-day garments of different kinds.

Question 2: Do you have the following garments in your supply: T-shirts, jeans, dresses and jackets?

Respondent A: Yes, all of them, as well as skirts, troconsumers, blouses, shoes and some accesseries.

Respondent B: Yes, all of them

Question 3: For how long time, or for how many uses, do your customer usually use the different types of garments before they are returned (e.g. the garments specified in question 2)?

Respondent A: Many of our customers keep the garments for the full period (one month) to be able to use them many times, in particular for jackets. Some customers do, however, like to change garments more frequently. Often dresses and tops are changed more frequently (we have predominantly female customers). Some customers do not try out the garments but take them home directly, and then they change more often as the garment may not fit (more often the case with troconsumers/jeans). It can also be that a customer lease the garment for a special occasion (e.g. a party) and then it is leased over a shorter period of time.

Respondent B: It depends on how successful the leasing was. Sometimes the garments are used a lot and frequently, sometimes just one time. There is no general answer on this question. Sometimes they lease for a special occasion and sometimes a jacket or a coat that they used almost daily.

Question 4: Do you encourage your customers to wash the garments in any particular way (e.g. to always or never wash the garments before they are returned)?

Respondent A: Our customers wash the garments. We do not want them to use softeners and, of course, they should use environmentally friendly detergents. But this is nothing we are in control of. Garments that are new in our shop, we wash ourselves. We have looked into working with a professional laundry service (and in such case use as environmentally sound washing practices as possible, e.g. using soapnuts).

Respondent B: We always give washing advice. All garments are to be returned in a condition so they can be directly leased again.

Question 5: Do you wash all the garments after each customer turns them back and before they are leased to the next customer?

Respondent A: See above question. Today, we use regular washing machines.

Respondent B: See above question.