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Environmental benefits of second hand-shopping

- environmental impacts of clothes and the benefits of the Emmaus Björkå second-hand business

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Summary

This thesis explores possible environmental benefits from second-hand shopping, focusing on used clothes sold at the second-hand stores run by Emmaus Björkå. Information was gathered through online literature searches and also received directly from Emmaus Björkå. Swedish textile consumption trends in net inflow and economic terms are presented. Figures for consumption of energy and resources such as chemicals and water, along with subsequent emissions from textile production are provided. Sales figures from Emmaus Björkå was processed and compared to production figures of clothes, and estimations on annually saved energy and avoided emissions were made. Conclusions drawn from this study are among others that the sales of used clothes at Emmaus Björkå saves 7 GWh of energy and 1 500 tonnes of CO_2 emissions annually (2013–2014), and contribute to fulfilling the environmental targets of Reduced climate impact, Natural acidification only, Zero eutrophication and A non-toxic environment.

Sammanfattning

Detta arbete undersöker de möjliga miljövinsterna med second-handshopping, och fokuserar framförallt på kläder som säljs i second-handbutikerna som drivs av Emmaus Björkå. Information har samlats in genom litteratursökningar på internet, samt inhämtats direkt från Emmaus Björkå. Svenska textilkonsumtionstrender i nettoinflöde och ekonomiska termer presenteras. Förbrukning av energi och resurser som kemikalier och vatten, tillsammans med påföljande utsläpp från textilproduktion har sammanställts. Försäljningssiffror från Emmaus Björkå behandlades och jämfördes med siffror från klädproduktion, och uppskattningar om årligen sparad energi och undvikna utsläpp gjordes. Slutsatser från studien är bland andra att försäljningen av begagnade kläder på Emmaus Björkå sparar 7 GWh energi och 1 500 ton CO_2-utsläpp årligen (2013–2014) och bidrar till att uppfylla miljömålen Begränsad klimatpåverkan, Bara naturlig försurning, Ingen övergödning och Giftfri miljö.

Contents

1. Introduction

Clothes and textiles can impact the environment throughout their lifecycle. In the introduction, section 1.1 describes the life cycle of a garment. Section 1.2 describes environmental and health effects of the main activities that are related to the production of textiles and clothings. Section 1.3 introduces environmental policies of Sweden and a policy instrument from the European commission on the reuse of materials. Emmaus Björkå, the company that was in focus of this study is introduced in section 1.4 and lastly the aim, objectives and delimitations of this thesis are given in section 1.5.

1.1 The life cycle of a garment

Most of the apparel (the terms *clothes*, *garments* and *apparel* in this thesis implies pieces of clothing) consumed in Sweden are manufactured elsewhere (Carlsson et al., 2011), a garment that is used in Sweden is therefore usually at the end of its life cycle. The concept of the life cycle of a product is used in a Life Cycle Assessment (LCA), which is a comprehensive tool to evaluate the environmental impacts associated with a product or a service. An LCA takes all the life stages of a product into account, in other words it takes on a cradle to grave perspective. The life cycle phases of a garment can be divided into *production*, *use*, *disposal or end of life* and *other impacts*. The production stage includes impacts associated with everything from the acquisition of raw materials to the completion of the product. Impacts from the use phase are typically due to washing, drying and ironing. The impacts from the disposal or end of life phase are due to the item being landfilled, incinerated or reused or recycled. Other impacts account for everything that is not included in other stages such as transports, storage and retail (Chapman, 2010). Other distinctions of the life cycle are common, e.g. *raw materials*, *manufacturing*, *packaging and distribution*, *use*, and *disposal* (Farrant et al., 2010). In the case of reuse or recycling instead of disposal, an LCA can be said to take on a cradle to cradle perspective.

1.2 Environmental and health effects

Environmental impacts from clothes and textiles (the term *textiles* in this thesis implies clothes and household textiles – curtains, towels, bed linen, table cloths etc.) are mostly due to energy consumption and greenhouse gas emissions; consumption of raw materials, water and chemicals; and generation of waste (Chapman, 2010).

The most abundant greenhouse gas in the atmosphere is CO_2 (carbon dioxide). The Earth needs the greenhouse effect to a certain extent, but the anthropogenic emissions of greenhouse gases since the industrial revolution has caused the globally averaged atmospheric concentration of CO_2 to rise from 280 ppm (parts per million) in 1850 to almost 390 ppm in 2010. Over the period from 2002 to 2011 the rate of change for atmospheric CO_2 was 2 ppm per year. If the emissions are not abated there is risk for a rise in the global average surface temperature of 4°C by 2100, compared to preindustrial temperatures. Increases in the global mean temperature can have many effects such as floods and rising sea levels, undermined food security, spread of vector and water borne diseases, decimated ecosystems and increased wildfires. Some changes are global while others appear at a regional scale. The regions that are most vulnerable to climate change have often contributed the least to greenhouse gas emissions (IPCC, 2014).

Additional important greenhouse gases are CH_4 (methane) and N_2O (nitrous oxide). Although not as abundant as CO_2, they are both more potent. The GWP (Global warming potential) is an index for the efficiency of a greenhouse gas, namely the change in net inflow of radiation at the top of the troposphere, about 10 km above the Earth surface. The GWP is the ratio of the efficiency of 1 kg of a certain gas to that of 1 kg of CO_2. Gases have very different retention times in the atmosphere, and therefore the GWP must also consider a time-span (Houghton, 2009). GWP_{20} and GWP_{100} are two common variations of the index, giving the ratio of change for 20 and 100 years, respectively. The GWP_{20} and GWP_{100} for methane is 84 and 28, and for nitrous oxide 264 and 265, respectively (IPCC, 2013).

NO_x (NO and NO_2 – nitric oxide and nitrogen dioxide) and SO_2 (sulfur dioxide) are emitted due to many activities in the society such as transports, power generation and industries. A process known as acidification is caused by the presence of NO_x or SO_2 in non-calcareous soils. One effect of the resulting low pH-value is leaching of inorganic aluminum which is toxic to many organisms, particularly to fish. The aluminum and low pH-water leaks to the ground water and can cause acidification of lakes (Grennfelt & Pleijel, 2007).

Nitrogen is normally the limiter to growth in an ecosystem, therefore emissions of nitrogen can cause a nutrient imbalance in ecosystems. The condition of ecosystems being overwhelmed with nutrients is known as eutrophication (Grennfelt & Pleijel, 2007). Eutrophicated water environments result in algal blooming. Subsequent hypoxic conditions may cause large numbers of animals and plants to die.

Chemicals are often used in the process of textile and apparel manufacturing. Depending on their mode of introduction into the material, chemicals can be divided into *functional* chemicals, *process* chemicals and chemical substances that are *not intentionally added.* Functional chemicals are added to give the material certain characteristics and are intended to remain in the material in order for the garment to exhibit a desired property, e.g. a color. Process chemicals are used in order for the production process to function and are not intended to remain in the final article. Chemicals that are not intentionally added have no planned function in neither the process nor the final product. These substances are usually degradation products or contaminants and can remain in the final product, but in a much lower concentration than functional chemicals. Examples of unintended chemicals are formaldehyde from resins or heavy metals from impure raw materials (Swedish Chemicals Agency, 2014).

Chemicals that are still present in materials that enter the use phase can be released in different ways and ultimately end up in aquatic or agricultural soil ecosystems or human organs. The primary exposure path for humans is dermal contact, while the environment is exposed mainly through leaching during laundry, textile fiber release due to wear and tear, and textile waste (Swedish Chemicals Agency, 2014).

Most research about health effects from chemicals in textiles concern textile dermatitis, skin problems – typically itching, redness or inflammation. The most common causes of textile allergy are the so called disperse dyes, which are used to stain synthetic fibers. A study shows that of all the patients suffering from contact allergy, 3.6% are allergic to disperse dyes, but not all of them are allergic to the actual dye molecule. Most studies concerning the carcinogenic effects of chemicals in textiles report risks of cancer from work related exposure in the textile industry. Studies has connected reprotoxicity – mainly from endocrine disruptors – to the use of i.a. brominated flame retardants and antibacterial agents (Swedish Chemicals Agency, 2014).

Concerning the environmental effects due to chemicals in textiles, there is one study that found a significantly higher toxicity for the *Daphnia magna* (a water flea) of released chemicals from printed cotton/linen garments than from unprinted, but the findings for synthetic textiles were the opposite (Dave & Aspegren, 2010). Biocides are used in textiles e.g. to prevent bacterial growth and eliminate odor in sport clothing. There is concern of bacterial resistance being developed due to the increased use of antibacterial substances in textiles. Silver can be used as a biocide, and a study has showed that around 60 percent of the silver in textiles has been released after 10 washes. It was assumed that all silver content will be released in the first two years of a silver-treated garment (Swedish Chemicals Agency, 2014).

1.3 Environmental policies

The Swedish Environmental objectives system was initiated in 1999, and as of today the government has adopted 16 environmental objectives that describe the desired state of the environment which environmental work is to result in. The objectives refer to one or several of the areas Reduced climate impact, Waste, Biodiversity, Hazardous substances and Air pollution, and are to be met within one generation, which is by 2020. The Swedish environmental objectives reads as follows: *Reduced climate impact*; *Clean Air*; *Natural Acidification Only*; *A non-toxic environment*; *A Protective Ozone Layer*; *A Safe Radiation Environment*; *Zero Eutrophication*; *Flourishing Lakes and Streams*; *Good-Quality Groundwater*; *A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos*; *Thriving Wetlands*; *Sustainable Forests*; *A Varied Agricultural Landscape*; *A Magnificent Mountain Landscape*; *A good built environment* and *A Rich Diversity of Plant and Animal Life* (Swedish Environmental Protection Agency, 2013b).

To help achieve the environmental objectives there are one generation goal and a number of milestone targets. The generation goal sets the direction of the environmental policy in order to achieve the objectives, and reads as follows: *The overall goal of Swedish environmental policy is to hand over to the next generation a society in which the major environmental problems in Sweden have been solved, without increasing environmental and health problems outside Sweden's borders* (Swedish Environmental Protection Agency, 2013b).

The milestone targets clarify what is to be done, as they are steps to take in order to achieve the generation goal and one or several of the objectives (Swedish Environmental Protection Agency, 2013b).

Most of the textile waste that is generated in Sweden goes to incineration. The Swedish Environmental Protection Agency was commissioned in 2013 by the Swedish government to propose a new milestone target for textiles and textile waste within the Swedish environmental objectives system. Within the proposed target it was stated that by 2018 there should be accessible systems for collection that ensure the reuse of textiles, that 40 percent of the textiles put on the market shall be reused by 2020, that 25 percent of the textiles put on the market should be recycled – mainly into new textiles – and that no very hazardous substance or other substances with undesirable properties should be present in virgin textiles by 2020. This milestone target primarily fulfills the environmental objectives of *Reduced climate impact* and *A non-toxic environment* (Swedish Environmental Protection Agency, 2013a).

The Waste Framework Directive by the European commission (2008) provides a tool for EU member states to prioritize between waste management procedures. It is called *The Waste hierarchy* and places the concepts of *prevent*, *prepare for re-use*, *recycle*, *recover* and *disposal* in a hierarchical order, where the prevention of waste production is most desired, and disposal of waste is least desired, see Figure 1.

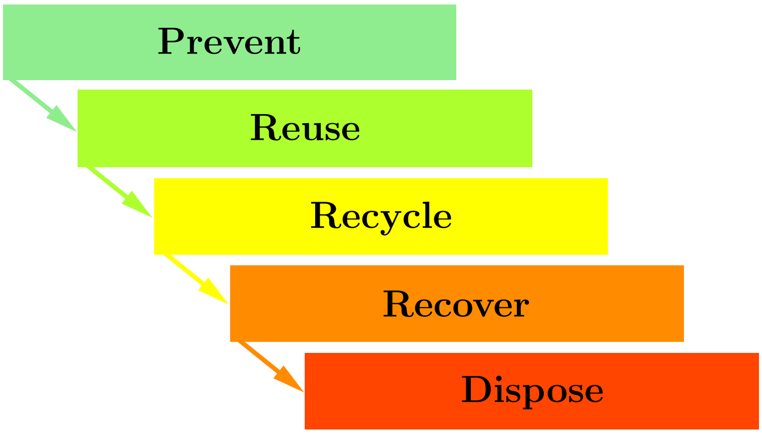

Figure 1: The Waste Hierarchy is a way to prioritize between different methods of waste disposal. On top is prevention: reduce the formation of waste, then reuse what is possible and recycle waste that can not be reused. What can not be recycled should undergo energy recovery – usually electricity production by incineration. Waste that can not be dealt with in another fashion is, as a last option, disposed of in landfills.

Among the definitions provided in the Waste Framework directive are: *Waste* is any object which the holder discards or intends to discard. *Prevention* is measures taken to reduce the amount of waste (including through re-use); adverse effects on human health or environment from waste; or the content of harmful substances in products. *Re-use* means using products or components again "for the same purpose for which they were conceived". *Preparing for re-use* means any operation by which products that have become waste are prepared to be re-used without further pre-processing. *Recycling* means any operation where waste materials are reprocessed into materials with either the same or other than the original purpose. *Recovery* means any operation where waste is replacing materials that would otherwise have been used to fulfill a particular function, e.g. energy recovery where waste is incinerated in order to produce heat or electricity. *Disposal* means any procedure that is not recovery (European Commission, 2008). Although the Waste Framework Directive only applies to governmental bodies, it provides a way of thinking that could be implemented by anyone who wants to reduce their environmental impacts.

1.4 Emmaus Björkå

The reuse of products, particularly clothes, is often facilitated by charity organizations running domestic second-hand shops or exporting clothes and other necessities abroad (Ekström & Salomonson, 2014). Emmaus Björkå is one of several large Swedish charity organizations involved in the *Ideell Second Hand* cooperation (nonprofit second-hand) aiming at facilitating reuse and second-hand activities for the purpose of social benefits

(Emmaus Björkå, 2014). Emmaus Björkå specifically supports projects working with international solidarity, sustainable development and social responsibility around the world (Emmaus Björkå, 2015b). There are seven Emmaus Björkå shops in Sweden, three of them are located in Malmö, two in Gothenburg, and one each in Borås and Halmstad. They are also cooperating with 15 second-hand shops – so called friend stores – in the southwest of Sweden (Emmaus Björkå, 2015a).

1.5 Aim, objectives an delimitations

The aim of this study was to investigate the environmental benefits of second-hand shopping and to provide information of Swedish textile consumption.

The specific objectives were to:

- investigate and quantify the environmental benefits of clothes reuse from the second-hand business of Emmaus Björkå.
- propose indicators of the reuse of clothes through second-hand shopping.

This study has been limited to the reuse of clothes in Sweden, more specifically the clothes that are sold in Emmaus Björkå's stores. Clothes collected by Emmaus Björkå but sold elsewhere or exported are not included in the assessment. Household textiles, baby clothes, underwear, shoes and accessories have been excluded where possible. The estimated environmental savings are based on the environmental burden due to production of virgin material. Recycling has not been taken into consideration, nor has any environmental impacts due to Emmaus Björkå's own activities, such as maintenance of buildings, sorting processing, transports etc. Production of clothes has also many social impacts, but in the scope of this study the environmental impacts has been the focus.

2. Methods

THE METHODS USED in this thesis are described in this chapter. In section 2.1 the literature search and approach to finding information is described. Section 2.2 contains information on how the presented data from Emmaus Björkå has been processed.

2.1 Literature search

Information for the Introduction chapter (1) and the Textiles in a broad perspective section (3.1) was found through a literature search. The scientific databases *Web of Science* and *Scopus* were used for this purpose. The reference lists of these articles were scanned for interesting titles, which were used in a subsequent Google search. A list of the used search phrases for the initial literature search can be found in Appendix A.

Websites of Swedish institutes and agencies were also searched for relevant reports and data. Searches were performed specifically at the websites of the Swedish Chemicals Agency (KemI), Statistics Sweden (SCB), The Swedish Environmental Protection Agency, The Swedish Environmental Research Institute (IVL) and Swedish Environmental Emissions Data (SMED) in order to find representative data for the Swedish market and environment. Reference lists of the found reports and publications were also searched for relevant sources of information.

The Energy Information Agency (EIA) was used to find energy consumption and CO_2 emission data for the whole world. The data from EIA had to be processed in order to compare them to data from SCB. The EIA did not provide data on the CO_2 intensity of regions, which was thus calculated.

Data on average weights for different garments was sorted in three categories: outerwear, pants etc. and sweaters etc. These categories were chosen so as to match the data from Emmaus Björkå. It was assumed that the original categories were equally frequent in the merged ones, that way the average of all the constituent categories served as the weight of the merged category.

Distribution of the textile fiber production of the world was used to distinguish between environmental impacts from cotton and polyester.

2.2 Emmaus Björkå data

Information for the Clothes at Emmaus Björkå section (3.2.1) was received directly from Elisabeth Ahlström at Emmaus Björkå in Gothenburg. The information consisted of the total number of sold units of clothes divided in different categories, and the total amount (by weight) of the same categories that had been delivered to any of their seven stores, in both 2013 and 2014. Some information on how the business is conducted was also collected during a study visit to the sorting facility in Gothenburg.

The data of sold pieces of clothing at Emmaus Björkå was sorted in the categories women's, men's, retro, sports and children's wear. The clothes in these categories were also labeled as outerwear, tops ("överdel"), bottoms ("nederdel"), exclusive, XL, campaign, clearance sale or bargains. The retro category was labeled with women's, men's, children's, jeans or outerwear. In order to compare the data to the literature, clothes were sorted into the categories *outerwear*, *pants etc.* and *sweaters etc*, where all clothes labeled outerwear was put in the outerwear category. Jeans and bottoms were put in the pants etc. category while tops were put in sweaters etc. The mutual distribution by sold unit of these three categories was calculated. The amount of clothes that were labeled exclusive, XL, campaign, clearance sale, bargains and most of the retro was distributed among outerwear, pants and sweaters according to the mutual distribution.

Using the data on average weights for different garments, the total weight of the sold amount was estimated. This quantity was divided among *cotton and other natural fibers* and *polyester and other synthetic fibers* using figures of production ratio.

Figures of emissions and energy consumption etc. for production of cotton and polyester clothes were used to evaluate the maximum and the likely environmental benefit from the estimated amount of clothes sold at Emmaus Björkå. The production figures for cotton and polyester garments was applied to all natural and synthetic fibers, respectively. When data from more than one source was available, the average of these was used. Some data only concerned production of textile fiber instead of an entire garment. These data were used only when it could be assumed that the clothing production would not contribute further to the figure, or when they closely resembled data from production of entire garments.

In order to find the CO_2 emissions from clothing production energy consumption was divided between regions in proportion to their share of total imports to Sweden. The figures were then multiplied by the intensity of CO_2 emissions from energy consumption in respective region.

It was assumed that a garment sold at Emmaus Björkå replaces the production of a new garment in the maximum scenario, while the likely scenarios took the replacement rate (how many new garments that are replaced by the purchase of a reused garment) into consideration.

Transport and administration such as sorting, maintenance of buildings etc. has not been assessed. However, these activities are present for both new and reused clothes, and the assumption has been that it is possible to simply call it even between the two.

3. Results

THIS CHAPTER conveys a picture of textiles in a broad perspective in section 3.1. Information on textiles and clothes such as Swedish consumption and energy use for production is provided. This information is compared to data from Emmaus Björkå in section 3.2, landing in estimations of saved energy and resources owing to the reuse of clothes sold at Emmaus Björkå.

3.1 Textiles in a broad perspective

Section 3.1.1 describes the Swedish textile consumption. Energy use and resource consumption from textile production is presented in section 3.1.2, and in section 3.1.3 are data and assessments of the reuse of textiles.

3.1.1 Swedish textile consumption

The annual Swedish consumption of clothes and shoes has increased over the last decade. In Table 1 are figures for the Swedish consumption of clothes and shoes from 2006 to 2013 presented.

Table 1: Trends in Swedish consumption of clothes and shoes from 2006 to 2013 (Holmberg, 2007, 2009; Mankila, 2008; Roos, 2010, 2011, 2012, 2013, 2014).

Year	Change compared to ten years prior (real value)	Change compared to one year prior (real value)	Money spent (billion SEK, nominal value)	Change compared to one year prior (nominal value)
2006	57%	5.4%	67	-
2007	64%	3.2%	71	6.0%
2008	60%	2.3%	72	1.4%
2009	53%	2.1%	75	4.2%
2010	50%	4.2%	80	6.7%
2011	42%	-0.8%	79	-1.3%
2012	37%	1.7%	80	1.3%
2013	31%	-0.1%	79	-1.3%

The consumption of shoes and clothes in Table 1 represented about 5 percent of the total average household consumption. Real prices means that inflation has been taken into account, while nominal prices reflects the actual price payed at the moment of the purchase.

There has been a high overall increase in consumption of clothes and shoes over the period (1996-2013), but the increase itself has been decreasing. In some of the latest years the consumption has even decreased compared to the previous year (Holmberg, 2007, 2009; Mankila, 2008; Roos, 2010, 2011, 2012, 2013, 2014).

The domestic production of textiles in Sweden is small compared to the import and export and can therefore be neglected. The net inflow thus equals import minus export, and is assumed to represent the Swedish textile consumption. Table 2 shows the net inflow of clothes and household textiles to Sweden in 2008 and the amount of textiles that ended up in household waste.

Table 2: Swedish import and net inflow of textiles and clothes in 2008 and the amount that ended up in the household waste (Carlsson et al., 2011).

Category	**Net inflow (tonnes)**	**Net inflow (kg per capita)**	**Amount in household waste (kg per capita)**
Textiles	131 800	14.7	7.9 **
Clothes *	95 620	10.5	

* Clothes are included in the textile category, but also listed separately
** Clothes and rags were reported, no other distinction was available

The amount of textiles found in household waste in Table 2 is a result of sorting analyses performed in the years 2004-2010. The estimated amount of clothes in the waste constitutes more than half of the annual consumed amount of textiles. No information was given about the condition of waste textiles, if they seemed fit for reuse or were actual garbage. Shoes and furniture textiles were not included in the study. It was assumed that some amount of textiles was directly discarded as bulky waste, e.g. in the combustible waste containers at recycling centers, but this amount had not been investigated.

The Clothes category in Table 2 is divided into subcategories and is shown in Table 3.

Table 3: Net inflow categories of clothing to Sweden in 2008 (Carlsson et al., 2011).

Category	**Net inflow (tonnes)**	**Original category**	**Net inflow (tonnes)**
Outerwear	11 700	Outerwear	11 700
Pants	20 580	Pants	20 580
		Sweaters	11 980
		Blazers	1 400
Sweaters etc.	39 090	Shirts	7 420
		T-shirts	13 690
		Dresses, skirts etc. *	4 600
Total	71 370		71 370

* The original data did not distinguish between dresses and skirts, skirts are therefore included in the sweaters category

In Table 3, the subcategories sportswear, suits, underwear, baby clothes and gloves/hats etc. have been omitted to make the data comparable to those from Emmaus Björkå. The latter have been further divided into outerwear, pants etc. and sweaters etc. in Table 15. The average weights of garments of similar categories are compiled in Table 4.

Table 4: Average weights of the most common clothing categories, both original and average for the same merged categories as in Table 3 (Elander et al., 2014).

Category	**Average weight (kg)**	**Original categories (average weight in kg)**
Outerwear	0.60	Outerwear (0.6)
Pants etc.	0.38	Pants (0.3), jeans (0.7), skirts (0.2), shorts (0.3)
Sweaters etc.	0.36	Dresses (0.3), blouses (0.25), blazers (0.6), shirts (0.3), sweaters (0.5), t-shirts etc. (0.2)

Table 4 contains the average weights of garments divided by category. Some categories have been merged to make the data comparable to that from Emmaus Björkå. For this merge of data it has been assumed that the garments in the original categories are equally frequent in the merged category.

The total import of clothes to Sweden over the years 2010 to 2014 is broken down by region of origin and presented in Table 5.

Table 5: Import of clothes to Sweden in the years 2010 to 2014 (Statistics Sweden, 2015)

From	**Import 2010-2014 (tonnes)**	
China	238 512	33%
Rest of Asia	243 834	33%
Europe	238 050	33%
America, Africa and Oceania	4 094	1%
Total	724 490	100%

As can be seen from Table 5, two thirds of the clothes imported to Sweden between 2010 and 2014 originated Asia, and one third came from Europe. The clothes imported from the rest of the world can be ignored as they constitute only 1% of the total import of clothes.

Almost 1500 respondents answered a questionnaire on how they get rid of clothes that they no longer wish to use. The study was performed by Gustafsson and Ekström (2012) and the outcome is presented in Table 6.

Table 6: Data from a study investigating the routes by which consumers get rid of usable clothes (Gustafsson & Ekström, 2012).

How do you get rid of whole clothes (not socks/underwear) that you no longer use?				
Option	**Never**	**Sometimes**	**Quite/Very often**	**Always**
Donate to charity	13%	35%	32%	20%
Sell to second-hand store	89%	8%	1%	1%
Sell online	89%	8%	2%	1%
Sell on flea market	88%	10%	1%	1%
Give to family and friends	26%	49%	22%	4%
Throw in garbage	38%	46%	12%	4%
Trade with someone else	90%	8%	1%	1%

The overall picture provided in Table 6 is that (1) much usable clothes end up in the garbage which is often used for energy production, (2) that exchange between family and friends is frequently occurring, and (3) that donating is favored over selling. Two answers "Quite often" and "Very often" have been merged into one. The percentages for the rows "Sell to second-hand store" and "Give to family and friends" do not add up to 100 percent, however the data is copied directly from the source (Gustafsson & Ekström, 2012).

3.1.2 Energy use and resource consumption

Energy production methods differ around the world and some production methods have higher CO_2 emission rates than others. The intensity of CO_2 emissions per unit of consumed energy from the regions of the world between 2008 and 2012 is shown in Table 7.

Table 7: Average density of CO_2 emissions energy consumption from each continent and China in the years 2008 to 2012. Combined data from (U.S. Energy Information Administration, 2015a, 2015b).

	kg of emitted CO_2 per MWh of energy consumed						
Year	**North America**	**C. & S. America**	**Europe**	**Africa**	**China**	**Rest of Asia**	**Oceania & Antarctica**
2008	195	162	185	241	267	211	235
2009	190	160	183	241	270	214	233
2010	190	165	182	241	266	215	234
2011	186	163	184	239	268	219	226
2012	185	167	183	237	261	222	229
Average	189	163	183	240	266	216	231

The data in Table 7 are divided into continents, but since a third of the clothes imported to Sweden 2010 to 2014 originated in China (see Table 5), this country is presented separately. There are fluctuations between the years, but the pattern reveals that Central and South America emit the least amount of CO_2 per unit of energy consumption, followed by Europe and then North America. Africa, Asia, Oceania and Antarctica are the regions with CO_2 emissions above the world average of 210 kg/MWh.

In Table 8 is a compilation of energy and resource consumption and sequential emissions from three different LCAs distinguishing between cotton and polyester production and a mapping of chemical consumption during the life cycle of garments. Two of the LCAs assessed the impacts of the production of ready made garments (Woolridge et al., 2006; Steinberger et al., 2009), while the third assessed the impact just from fiber production (Kalliala & Nousiainen, 1999). The chemicals consumption mapping assessed the consumed amounts of both hazardous and non-hazardous chemicals during the life cycle of garments. No estimation of the quantities released into air, water or soil was made, but merely the amounts used (Olsson et al., 2009).

Table 8: Energy and resource consumption and resulting emissions for production of cotton and polyester (Woolridge et al., 2006; Steinberger et al., 2009; Kalliala & Nousiainen, 1999; Olsson et al., 2009)

Parameter	**Woolridge et al. 2006**		**Steinberger et al. 2009**		**Kalliala et al. 1999**		**Olsson et al. 2009**	
(per kg of textile)	**cotton**	**polyester**	**cotton**	**polyester**	**cotton**	**polyester**	**cotton**	**polyester**
Energy consumption (kWh)	66	92	62.8	61.4	16.6	27.1		
CO_2 emissions (kg) (1)			14.6	15.0				
Calculated CO_2 (kg) (2)	14.6	20.4	13.9	13.6				
NO_x emissions (g)			126	61.7	22.7	19.4		
SO_2 emissions (g)			84.8	82.6	4	0.2		
Water consumption (l)					22 200	17.2		
Fertilizers (g)					457		535	
Pesticides (g)					16		18.7	
Raw material (kg)						1.53 (3)		1.15 (4)
Chemicals (kg)							3.04 (5)	2.76 (5)
Scope of study	From fiber production (incl. raw materials) to garment		From fiber production (incl. raw materials) to garment		Fiber production (incl. raw materials)		Chemical consumption from fiber production to garment	

Empty space indicates that the information was not provided or that the piece of information is not relevant for the current fiber.
(1) Stated by the reference. (2) Based on energy consumption and intensity of CO_2 emissions from Asia, China and Europe in Table 7. (3) Raw material – in this case natural gas, crude oil and coal – are already included in the energy consumption for polyester, but is listed separately to illustrate the input material. (4) In this case dimethylephthalate, which is produced from crude oil. (5) Fertilizers, pesticides and raw material are already included in these figures

In Table 8 is a collection of data from three LCAs and a chemical consumption mapping of cotton and polyester production. Cotton is estimated to consume from 40 percent less up to equal amounts of the energy consumed by polyester production. Most emissions to air consists of CO_2, but smaller amounts of NO_x and SO_2 are also emitted. It appears that emissions of NO_x from fiber production is fairly equal, but when the whole production chain is taken into account, the emissions from the cotton garment production is higher. Concerning the SO_2 emissions it seems that the fiber production of cotton emit more than the fiber production of polyester, but when the garment production is being considered as well the emissions of SO_2 are quite similar between cotton and polyester. Cotton require pesticides, fertilizers and huge amounts of water, and is in some cases cultivated in water scarce areas, thus being very irrigation demanding (Kalliala & Nousiainen, 1999). Around 11 percent of the world pesticide use is for cotton cultivation (Tekie et al., 2013). The different figures of fertilizers, pesticides and raw material input are consistent. The amount of used chemicals only indicates the consumed quantity, no information is provided regarding the potential release of these chemicals into the environment.

The division of cotton, polyester and other fiber types produced in the world in 2010 is presented in Table 9.

Table 9: World production of textile fibers in 2010 (Palm et al., 2013).

Cotton	**Other natural fibers**	**Polyester**	**Other synthetic fibers**
36%	7%	45%	12%

Table 9 illustrates that the most produced textile fiber in the world 2010 was polyester. The synthetic fibers make up almost 60 percent of the world production, while cotton and other natural fibers represent just over 40 percent (Palm et al., 2013).

3.1.3 Reuse of textiles

The amount of reused textiles is compared to the net inflow to Sweden in 2011 and 2013 in Table 10.

Table 10: Net inflow and reused amount of textiles in Sweden in 2011 and 2013 (Elander et al., 2014).

Year	**Net inflow of textiles to Sweden (tonnes)**	**Reused amount compared to net inflow**	**Amount reused in Sweden compared to net inflow**
2011	133 000	18%	6%
2013	121 000	19%	7%

The net inflow of textiles in Table 10 is assumed to be the consumed amount. Among the reused amount, a third is reused in Sweden while the rest is reused abroad. The total reuse was estimated by assessing the reuse carried out through charity organizations, e-commerce and second-hand businesses (Elander et al., 2014). The net import is consistent with the figures for 2008, presented in Table 2. Interesting to note is that the net import appears to decrease, but the figures of consumption in Table 1 exhibits no such apparent trend. The figures provides some indication of where we are in relation to the proposed milestone target of reusing 40% of the textiles put on the market by 2020 (Swedish Environmental Protection Agency, 2013a).

Clothes that are diverted from the waste stream through reuse could to some degree replace the production of new clothes. In an LCA from 2010 the life cycle impacts of clothes that were collected and sorted for the purpose of being reused was compared to that of clothes that were disposed of by incineration after the first consumer use stage. A questionnaire was performed within the LCA in second-hand shops in Sweden and Estonia to determine the replacement rate, which indicates how many brand new purchases the purchase of a second-hand garment replaces. A replacement rate of 25 percent indicates that the purchase of four second-hand items replace the purchase of one new item. High replacement rates were found with customers searching for clothes they need, with the intention of buying an item brand new when instead buying a similar second-hand item. Low replacement rates were found with customers looking for additional goods in the second-hand shop, with no intention of buying a similar one new. The questionnaire study revealed that the average replacement rate in Sweden was 60 percent and 75 percent in Estonia. Some results from the LCA are compiled in Table 11.

Table 11: Reduction of environmental impacts of the life cycle of garments that are reused compared to those of the life cycle of garments that are disposed of by incineration after first consumer use. The garments are 100% cotton t-shirts and 65/35% polyester/cotton trousers (Farrant et al., 2010).

Impact category	**Cotton t-shirt**	**Cotton/polyester trousers**
Global warming	14%	23%
Acidification	28%	28%
Eutrophication	25%	25%
Resources (natural gas & crude oil)	15%	20%
Waste	30%	25%

The data in Table 11 illustrates the decrease of the environmental burden from the life cycle of 100 percent cotton t-shirts and 65/35 percent polyester/cotton trousers when the clothes are being reused instead of disposed of by incineration. The estimations were performed by comparing the impacts of reusing 100 garments to the impacts of not reusing the same amount of. It was assumed that all reused apparel were fit for use, i.e. any unfit garments have already been disposed of. A replacement rate of 75 percent was used, taking into account the amount of avoided production of new clothes. The burden for some categories did not decrease by much, e.g. global warming for the cotton t-shirts. This is due to the fact that most of the contribution to global warming from the t-shirt (65 percent of the total impact) come from the use stage where the t-shirts were assumed to be tumble dried after laundry, where the trousers were not. Acidification and eutrophication were estimated to decrease by equal percentages. The resource use for the trousers was expected to decrease by more percentages than for the t-shirt, which can be explained by polyester requiring these resources as raw material. The conclusion from the LCA was that the environmental impacts of collecting, processing and transporting second-hand clothing are insignificant compared to the environmental impacts of new clothes. The possibly different lifetimes between new and reused garments was not investigated, but if the reused garment would have a shorter lifetime, the replacement rate would be lowered (Farrant et al., 2010).

Palm et al. (2013) performed an LCA of Swedish textile consumption, using a textile mix based on the figures presented in Table 9. Although it was not calculated but rather a consequence of the LCA methodology, numbers for the environmental impact of producing textiles were presented. The decrease of the environmental burden from some impact categories can be seen in Table 12.

Table 12: Ease of the environmental impacts from reusing cotton and polyester textiles instead of storing them (Palm et al., 2013).

Impact category	**Cotton**	**Polyester**
Acidification	55%	56%
Eutrophication	60%	56%
Greenhouse effect	58%	59%

Table 12 presents the ease of the environmental burden from reusing textiles. The numbers are based on comparing the reuse of one kg of textiles to not reusing the same amount. A replacement rate of 60 percent was assumed, taking into account the avoided production of new textiles (Palm et al., 2013).

There is a major discrepancy between the numbers in Tables 11 and 12. The decrease of the environmental burden is lower in Table 11 even though it is based on a higher replacement rate. It seems that the ease of he environmental impacts when reusing clothes is difficult to assess.

3.2 Reuse of clothes at Emmaus Björkå

Section 3.2.1 holds an introduction to clothes sold at Emmaus Björkå and the results of the assessment of the data from Emmaus Björkå is presented in section 3.2.2.

3.2.1 Clothes at Emmaus Björkå

All goods sold in Emmaus Björkå's stores are donated. When the donated goods first arrive at Emmaus Björkå they are separated into two categories: hard and soft. Items such as books, toys, glass, electrical appliances and furniture are hard, while all clothing, shoes and other textiles are soft. The soft category is sorted into women's wear, men's wear, retro, sportswear, children's wear, textiles, accessories, shoes and a summer mix. Clothes categorized as retro can be women's, men's or children's wear, but bearing a touch of vintage. Textiles are mostly household textiles, e.g. sheets, curtains, towels etc. The summer mix consists of clothes that are believed to be unsaleable in Sweden, and is exported to Africa to be sold in second-hand markets. Clothes that are assumed to be salable in Sweden are price labeled and boxed. The boxes are stored until they are delivered to stores, where the clothes are unpacked and sold. Waste is discarded from all sorting instances, in the year 2014 a total of 95 tonnes of textiles went to incineration (Elisabeth Ahlström, personal communication).

3.2.2 Data and assessment

The annual revenue from sales of clothes between 2010 and 2014 in all seven Emmaus Björkå stores is presented in Table 13.

Table 13: Annual revenue from sales of clothes at the Emmaus Björkå stores. Textiles, shoes and accessories are not included.

Year	Million SEK	Increase from previous year (nominal value)
2010	20.6	
2011	21.5	4.4%
2012	24.6	14.4%
2013	27.7	12.6%
2014	29.6	6.9%

From the figures in Table 13 it appears that the sales of clothes at Emmaus Björkå increased at a higher rate than the sales of clothes and shoes in the whole of Sweden during the same period, as presented in Table 1.

The total amount of sold units and the amount of clothes that were delivered to Emmaus Björkå's stores in 2013 and 2014 are collected in Table 14.

Table 14: The total weight of clothes delivered to and the amount of sold clothes at all seven Emmaus Björkå stores in 2013 and 2014.

Category	2013		2014	
	Sent to stores (kg)	Units sold	Sent to stores (kg)	Units sold
Women's	65 304	229 509	74 640	199 414
Men's	26 664	36 075	35 556	56 369
Retro	32 472	50 800	28 356	67 179
Sports	6 540	13 180	8 208	16 858
Children's	20 844	65 622	21 132	67 423
Bargains	8 220	27 962	804	4 955
Total	160 044	423 148	168 696	412 198

As can be seen in Table 14, women's wear make up more than half of the sales of clothes at Emmaus Björkå's stores. The sent to stores column is the total weight of clothes that has been delivered to all seven stores during the year. This column does not completely correspond to the amount of sold clothes, since sold clothes could have been delivered previous years or that all delivered clothes might not be sold. These data were also divided by type of garment in Table 15.

Table 15: The total amount of sold clothes in all seven Emmaus Björkå stores in 2013 and 2014 divided by type of garment and their respective ratio, and also their disbtribution among the net inflow to Sweden in 2008 of the same categories (Carlsson et al., 2011).

Category	**2013**		**2014**		**2008**
	Units sold	**of known categories**	**Units sold**	**of known categories**	**Net inflow of known categories**
Outerwear	23 789	16%	24 999	14%	16%
Pants etc.	27 681	19%	34 737	19%	29%
Sweaters etc.	97 331	65%	123 909	67%	55%
Unknown	274 347	-	228 553	-	-
Total	423 148	100%	412 198	100%	100%

The unknown category in Table 15 consists of clothes labeled as exclusive, XL, campaign, sale, retro, sports, children's wear or bargain. Included for comparison is also the share of the same categories among the net inflow in 2008, from Carlsson et al. (2011). Note that the distribution is shown only for the three known categories, it does not reflect the true distribution, but merely their mutual ratio. The distribution of clothes sold at Emmaus Björkå largely resembles the distribution of clothes over the net inflow, but clothes from the sweaters etc. category is more abundant at Emmaus Björkå than in the net inflow, at the expense of pants etc.

The clothes of unknown category has been distributed among the categories outerwear, pants etc. and sweaters etc. according to their mutual ratio. The estimated amount per category is exhibited in Table 16.

Table 16: The estimated weight of sold garments per category in all seven Emmaus Björkå stores in 2013 and 2014.

Category	**2013**	**2014**
	Estimated weight (kg)	**Estimated weight (kg)**
Outerwear	40 590	33 667
Pants etc.	29 519	29 238
Sweaters etc.	99 180	99 659
Total	169 289	162 564

In Table 16 it has been assumed that all clothes of unknown category can be distributed among the known categories, according to their respective share of the known total. The weight of the sold clothes has been calculated using data from of average weights in Table 4, and is consistent with the amounts that were delivered to stores, see Table 14. Even though the amount sent to stores does not fully correspond to the sold amount, it probably indicates that the made assumptions and estimations are reasonable.

In Table 17 the calculated weights have been distributed between *cotton and other natural fibers*, and *polyester and other synthetic fibers* according to their world production ratio as presented in Table 9.

Table 17: The estimated distribution between cotton and other natural fibers, and also polyester and other synthetic fibers of sold clothes at Emmaus Björkåin 2013 and 2014.

Year	**Cotton and other natural fibers (kg)**	**Polyester and other synthetic fibers (kg)**
2013	72 455	96 833
2014	69 577	92 987
Average	71 016	94 910

For all practical purposes, data of cotton production was applied to all natural fibers, and data of polyester production applied to all synthetic fibers. Table 18 comprises estimations of avoided environmental stressors due to the sale of reused clothes in all seven of Emmaus Björkå's stores.

Table 18: Estimated annual avoided resource and energy consumption and sequential emissions from the sale of reused clothes at Emmaus Björkå.

Parameter	**Maximum annual save (no replacement rate)**	**Likely annual save (replacement rate 60%)**
Energy consumption (GWh)	11.9	7.11
CO_2 emissions (tonnes)	2 480	1 490
NO_x emissions (tonnes)	14.8	8.89
SO_2 emissions (tonnes)	13.9	8.33
Water consumption (m^3)	1 580 000	947 000
Raw material (tonnes)	127	76.3
Fertilizers (tonnes)	35.2	21.1
Pesticides (tonnes)	1.23	0.739
Chemicals (tonnes)	469	282

In Table 18 are estimations of annual amounts of some polluters that are not emitted and also energy, water and other materials that are not consumed due to the amount of reused clothes sold at Emmaus Björkå.

The saved energy (7.11 GWh), CO_2 (1490 tonnes) and water (947 000 m^3) corresponds to:

- the energy required for hot water and heating of 425 average Swedish houses, assuming 16.7 MWh per house annually (Swedish Energy Agency, 2014).
- emissions of CO_2e from the lifestyle of 149 average Swedes, assuming 10 tonnes of CO_2e per person annually (Swedish Environmental Protection Agency, 2015).
- a shower that is 150 to 300 years long, depending on how water-saving the shower head is. This figure assumes a water consumption of 6 to 12 liters per minute (Swedish Energy Agency, 2011).

CO_2e means CO_2-equivalents, and is a recalculation of all greenhouse gases into CO_2 (Swedish Environmental Protection Agency, 2015).

4. Discussion

Among all clothes consumed in Sweden 66 percent are imported from Asia, and 33 percent from Europe. All we know from the data on import is the amounts imported from which country. Some of the clothes imported from Europe might just have gone though a European intermediary, and still be produced somewhere else in the world. It might be fair to assume that the amount produced in Asia is not lower than 66 percent, since an Asian intermediary of clothes destined for Europe would probably not handle clothes produced in Europe or America. There might be a fraction of clothes produced in Oceania that are listed as imported from Asia or China, but in this assessment it does not make a big difference since the CO_2 intensity of Oceania is closer to the one of China or the rest of Asia than that of Europe or America.

Given the assumption that a third of the clothes consumed in Sweden are produced in China, a third in the rest of Asia and a third in Europe, an even distribution of these go to reuse, and the replacement rate is 60 percent, 1 500 tonnes of CO_2 were not emitted thanks to sales of clothes at Emmaus Björkå. Reuse of clothes at Emmaus Björkå thus fulfills the environmental objective *Reduced climate impact*.

From the annual sales at Emmaus Björkå, it appears that the avoided water consumption could amount to as much as 950 000 m^3, which would be a valuable saving in areas with scarce water access. However, the figure of water consumption used in this estimation was not accompanied with information of where the production took place. The savings of NO_x and SO_2 are around 8 and 9 tonnes, respectively. This fulfills the environmental objectives *Natural Acidification Only* and *Zero Eutrophication*.

Chemicals are used in the production of textiles and clothes. An example is silver which is used as a biocide. It is estimated that all silver will be released in the first two years of use for a silver-treated garment. Reusing clothes instead of buying new ones would ease the chemical burden on the environment, since most remaining chemicals in reused clothes would already be washed away, while new clothes would bring new chemicals into the system. The use of reused clothes could also be directly beneficiary to the end user, who would not be dermally exposed to chemicals as frequently as a consumer who buys new garments rather than reused ones. This study estimates that the reuse of clothes at Emmaus Björkå replaced new clothes that would have consumed around 280 tonnes of chemicals during production. The only chemicals that for sure can be assumed to not be kept within production facilities but released into the environment, are the fertilizers and pesticides, which amounted to 21 tonnes and 740 kg, respectively. Reuse of clothes at Emmaus Björkå thus fulfills the environmental objective *A non-toxic environment*.

The estimated sold weights by Emmaus Björkå are very close to the weights that were delivered to the stores. This is reasonable since all clothes sent to stores are sorted thoroughly, those that does not measure up will not pass the sorting system. The fact that the calculation was so close to the amount delivered indicates that the assumptions are consistent with reality.

The proposed milestone target within the Swedish environmental objectives system states that 40 percent of the textiles put on the market should be reused by 2020. In 2013 the reuse was at 19 percent. There is still a long way to go before the proposed target is reached, but there is obvious potential for increased reuse. The figures from Table 6 reported that 16 percent of the Swedes revealed that they often or always dispose of usable clothes into the garbage, and a total of 62 percent has some time taken this course of action.

When formulating indicators of the reuse of clothes, it would not be sufficient to only study the revenue, due to the fact that second-hand clothes are rarely sold for the same price as brand new garments. However, one can detect trends by comparing sales figures. It appears that the sales at Emmaus Björkå increased at a higher rate than the sales of clothes in the whole of Sweden during the same period. The figures for the whole of Sweden included also shoes, while the data from Emmaus Björkå did not, but it is still assumed that the different sales rates can be compared to each other. An indicator of the reuse could be to compare the changes of consumption in the whole country with the change of sales from second-hand companies.

Improvements of this study could be achieved by assessing the rates at which cotton and polyester clothes are reused, since the durability might be different between the two materials. More detailed assessments of impacts from transport would also bring about increased accuracy of this study, as would a more in-depth assessment of the region dependence of energy consumption and polluting emissions from clothes production.

An interesting aspect that has not been investigated in the scope of this study is the possible amount of clothes that is neither donated, discarded or otherwise disposed of. There might be a growing stockpile of clothes in the Swedish households, and investigations of this would increase the understanding of consumption and could be a further driver for reuse.

5. Conclusions

From this study on the environmental benefits of second-hand shopping, the following conclusions have been drawn:

- The annual environmental savings from clothes sold at Emmaus Björkå saves:
  - 7 GWh energy
  - 1 500 tonnes of CO_2 emissions
  - 950 000 m^3 water
  - 9 tonnes of NO_x emissions
  - 8 tonnes of SO_2 emissions
  - 75 tonnes of fossil raw material
  - 21 tonnes of fertilizers
  - 740 kg of pesticides
  - 280 tonnes of chemicals
- Emmaus Björkå's business of selling used clothes mainly contribute to the environmental objectives of *Reduced climate impact*, *Natural Acidification Only*, *Zero Eutrophication* and *A non-toxic environment*.
- Reused clothes are more user friendly, due to the lack of potentially disturbing substances.
- An indicator of the reuse of clothes is given by comparing sales figures of second-hand clothes businesses to conventional clothing businesses.

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Appendix A: Literature search

Note that some articles often appeared in more than search, but they are only listed once, where they were first encountered.

Table A.1: Search phrases used in database *Web of Science*

Web of science			
Search words	**Number of hits**	**Included articles**	**Reference list lead to**
”second hand” AND environment*	424		
”second hand product” AND environment*	1		
”second hand” AND environment* NOT smoke	83	Farrant 2010	
”second hand” AND environment* AND textile NOT smoke	0		
”second hand” AND environment* AND textile AND benefi* NOT smoke	1		
”environmental benefit” AND ”second hand”	0		
”second hand” AND environment* AND sustainab* NOT smoke	7		
”second hand” AND environment* AND textile AND sustainab* NOT smoke	0		
resale OR resell* AND goods AND environment* AND sustainab* AND benefit AND reus*	775		
”used good*” AND ”environment* benefit*”	1		
reuse* AND textile* AND ”environment* benefit*”	3		
reuse* OR ”used goods” AND second-hand OR ”second hand”	55 090		
reuse* AND textile* AND sustainab*	27	Ekström 2014	Carlsson 2011, Gustafsson 2012, Roos 2010
Continued on next page			

Table A.1 – continued from previous page

Web of science			
Search words	**Number of hits**	**Included articles**	**Reference list lead to**
”environment* gain*” OR ”environment* benefit*” AND ”used good*” OR ”second hand” AND method NOT smoke	333		
LCA AND clothing	23		
LCA AND second-hand OR ”second hand” AND used OR reuse*	19		

Table A.2: Search phrases used in database *Scopus*

Scopus			
Search words	**Number of hits**	**Included articles**	**Reference list lead to**
”second hand” AND environment*	617		
”second hand product” AND environment*	3		
”second hand” AND environment* NOT smoke	180		
”second hand” AND environment* AND textile NOT smoke	8	Woolridge 2006	
”second hand” AND environment*AND textile AND benefi* NOT smoke	3		
”environmental benefit” AND ”second hand”	2		
”second hand” AND environment* AND sustainab* NOT smoke	17		
”second hand” AND environment* AND textile AND sustainab* NOT smoke	1		
resale OR resell* AND goods AND environment* AND sustainab* AND benefit AND reus*	0		
”used good*” AND ”environment* benefit*”	1		
reuse* AND textile* AND ”environment* benefit*”	6		
reuse* OR ”used goods” AND second-hand OR ”second hand”	60		
reuse* AND textile* AND sustainab*	48		
”environment* gain*” OR ”environment* benefit*” AND ”used good*” OR ”second hand” AND method NOT smoke	1		

Continued on next page

Scopus			
Search words	**Number of hits**	**Included articles**	**Reference list lead to**
LCA AND clothing	26		
LCA AND second-hand OR ”second hand” AND used OR reuse*	2		