

# TEXTILES: FROM WASTE TO RESOURCES IN DENMARK

An Interactive Qualifying Project Final Report

## Submitted to

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# Abstract

This project, organized by the Danish Waste Association (Dansk Affaldsforening), will discuss discarded textiles as a valuable resource for organizations in Denmark. We strived to reduce the environmental footprint of textiles by increasing the collection and subsequent reuse, and where not possible, recycling of used textiles through optimizing textile collection methods and cooperation between stakeholders of humanitarian organizations and municipalities. We will assess: 1) current reuse and recycling systems, 2) compare strategies among different organizations, and 3) facilitate cooperation through workshops.

# Executive Summary

Textiles are used in numerous common items such as clothing, shoes, furniture, cars, and more. The production of these textiles consumes large quantities of resources and generates a lot of pollutants. Furthermore, textile consumption has risen and thus, the environmental burden is increasing (Danish Government 2015). In order to minimize the environmental footprint of textiles, Denmark has been collecting textiles for reuse and recycling as well as launching initiatives on textile waste prevention and management. However, with over fifty percent of textiles still entering the waste stream, further research and solutions need to be developed in order to increase textile sustainability within Denmark.

In order to reduce the environmental burdens of textiles, the Danish waste sector is looking to increase textile collection for reuse and recycling. The goal of this project was to assist the Danish Waste Association's efforts to reduce the environmental footprint of textiles by increasing the collection and subsequent reuse, and where not possible, recycling of used textiles through optimizing textile collection methods and cooperation between stakeholders of humanitarian organizations and municipalities. We accomplished this goal via the following objectives:

1. Assess the current reuse and recycling systems in place
2. Identify similarities and differences in approaches to reuse and recycling of textiles among various organizations in Denmark
3. Facilitate stakeholder cooperation via a workshop

We accomplished the first two objectives by conducting site visits and interviews with representatives of stakeholders. By visiting the facilities and conducting interviews, we were able to identify areas of reuse and recycling that could be improved. To further understand the current systems, we did content analysis of previous studies. From the collected data, we constructed a cost benefit analysis and compiled a presentation which was used in a workshop in order to unify stakeholders and develop solutions to turn end of life textiles into resources.

The workshop brought together members from all aspects of the management system, providing a unique opportunity for cooperation. The responses to the discussion topics emphasized overlaps which made it possible to develop five different areas for analysis. The areas included the analysis of VAT-free status, the analysis of sharing benefits, the analysis of educating the consumer, the analysis of providing options to the consumer, and the analysis of convenience for the citizen.

After analyzing our findings we recommend the Danish Waste Association consider the following:

#### Convenience for the citizen

- Implement different strategies for rural and urban
- Provide door-to-door collection where appropriate
- Allow citizen to decide final destination of their used textiles

#### Consumer Behavior

- Survey on consumption and donating habits

#### Education

- Develop and provide educational pamphlets
- Develop and provide a comprehensive collection site map

#### Legislation

- Consider making changes to legislation
  - Incineration fees for humanitarian organizations
  - Protecting VAT-free status for humanitarian organizations

#### Cooperation

- Future workshops with the purpose of maintaining communication

These recommendations will prove useful for the Danish Waste Association.

# Authorship and Acknowledgements

Christine Carbone, Charles Hill, Caroline Meyer, and Leah Morales all contributed to the writing of this report in equal proportion. All sections were collaboratively written and revised in order to ensure accurate representation of data and clarity in writing.

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# Introduction

Increasing textile consumption is leading to rising environmental burdens. Between 1990 and 2004, the global demand for textiles increased by 20 million tons (Farrant, Olsen and Wangel 2010). The production of textiles to reach these demands has contributed to increasing CO<sub>2</sub> emissions, water usage, and toxic chemical use. To offset rising demands for textiles, alternative methods both in the production and in the provision of access to textiles for consumers must be considered in an effort to decrease the environmental impact of textiles.

Alternative strategies to reduce the damaging impact of textile production are being considered. Through efforts to optimize reuse and recycling of textiles, Denmark is currently collecting 46% of used textiles for reuse and recycling via the efforts of humanitarian organizations and private collectors. Although Denmark already collects a significant fraction of textiles, much of the textiles that are discarded in bulk and municipal waste are suitable for reuse and recycling (Watson et al 2015). Current estimates state that approximately 64% of textiles discarded as waste are suitable for reuse (Anders Damgaard, personal communication, March 31, 2016). Additionally, 11-21% of discarded textiles which cannot be reused are suitable for recycling (Anders Damgaard, personal communication, March 31, 2016). Thus, collection rates could be increased with increased cooperation among municipalities, humanitarian organizations, and private collectors.

There is currently little cooperation between municipalities and humanitarian organizations. While collection of textiles is organized well within organizations, collection is not well coordinated among the various organizations of the reuse and recycling industry. Since waste collection methods vary among municipalities, cooperation among all stakeholders is vital.

With increased cooperation among stakeholders leading to increased collection, more textiles can be salvaged for reuse and subsequent recycling. Reuse is preferred to recycling as this method provides a larger environmental benefit, even if the substitution factor—replacing a new textile with one that is reused—is low (Schmidt et al 2016). Since reuse of textiles is much more environmentally favorable than recycling, stakeholders should cooperate in order to collect the maximum amount of reusable textiles.

This project assisted the Danish Waste Association's efforts to reduce the environmental footprint of textiles by increasing the collection and subsequent reuse, and where not possible, recycling of used textiles through optimizing textile collection methods and cooperation between stakeholders of humanitarian organizations and municipalities. To accomplish this mission, we

assessed current textile reuse and recycling systems, identified similarities and differences in approaches to recycling and reusing textiles among various organizations within Denmark, and facilitated stakeholder cooperation via a workshop on methods to optimize the reuse and recycling of textiles.

# Background

Increased reuse and recycling of textiles are an integral part of Denmark's textile waste management goal. Although initiatives and proposals for increased reuse and recycling methods have come to fruition in recent years, there is still a large fraction of textiles that could and need to be collected. In this chapter, we investigate the various destinations in the life of textiles in Denmark.

Textiles are defined as any type of cloth or woven fabric. While textiles include a range of products from apparel to fabric in vehicles, this project deals only with clothing and light home textiles, which account for 65% of textiles in the Nordic region (2013a). Focus is placed on textiles constructed out of fabrics that are calculated to be the most common: cotton (57%), synthetics (34%), wool (4%), and other (4%) (Schmidt et al, 2016). After analyzing textile flow, we assess Danish collection, reuse, recycling, and incineration practices. We also display the issues the Danish system is currently facing in each of these areas. Finally, we discuss textile collection, reuse and recycling practices from other countries to demonstrate possibilities for the Danish textile economy.

## Hazardous Life Cycle of Textiles

Consumer demand continues to drive the steady production of textiles around the world, as shown by the global demand for textiles increasing by 20 million tons between 1990 and 2004 (Farrant, Olsen and Wangel 2010). The annual supply of clothes and home textiles in Denmark is 89,034 tons (2013a). As a point of comparison, greenhouse gas (GHG) emissions caused by the average yearly textile consumption of one person in Denmark is equivalent to pollution generated by traveling 2,143 km by car (Nielsen et al. 2014). Furthermore, textile consumption is equivalent to 55% of the average household's CO<sub>2</sub> emission from electricity use (Nielsen et al. 2014). Finally, water needed for textile production is 1.8 times higher than the annual consumption of the average household (Nielsen et al. 2014). As shown by these comparisons, efforts need to be made to address the environmental impact made by textiles.

All products have an environmental impact. Given the significant amount of textiles produced annually, it is imperative that ways to reuse, recycle, properly dispose of, or even reduce production need consideration. The life cycle of textiles includes production, transport, use, and end-of-life. Production has the largest environmental impact and covers all procedures from material extraction to assembly and design finishes (Nielsen et al. 2014). Transport covers all transportation in the lifecycle of the textile. Use includes washing of the textile; the product is

estimated to have a lifetime of four years and to be washed 20 times a year (Nielsen et al. 2014). A textile enters the end of life stage when it is discarded by its first user, although textiles can also become waste without ever having been worn. Figure 1 is a visualization of this journey. In order for a product to be considered eco-friendly, individuals must make, use, and dispose of products in an environmentally conscious manner (Muthu 2015).

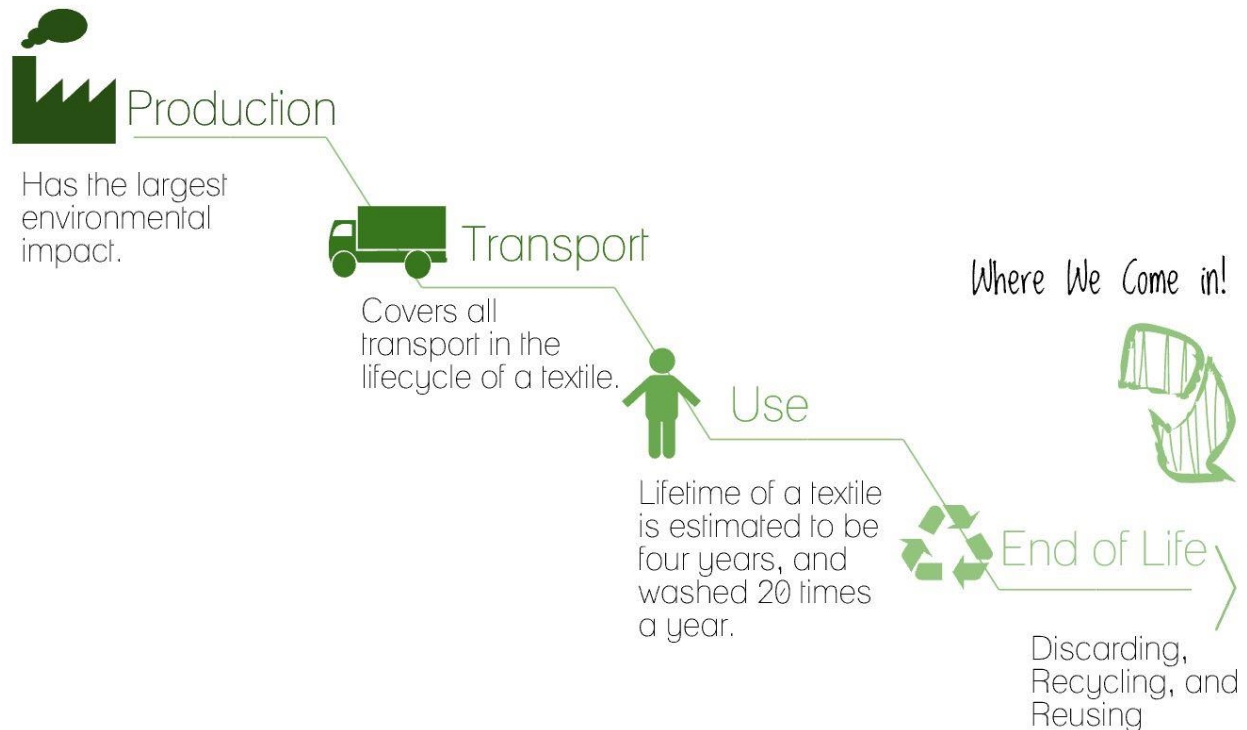


Figure 1: Visualization of textile life cycle, adapted from Nielson 2014.

## Production

In the life cycle of textiles, production uses the greatest amount of water and releases the most CO<sub>2</sub> gases (Nielsen et al. 2014). Campaigns to reduce environmental damage have determined that limiting the amount of textiles produced will have the greatest positive effect (Klepp and Paulander 2014). A hierarchy has been established in accordance to the appeal of waste management options. As shown by Figure 2 below, waste prevention is the most efficient option while landfilling is the least efficient with the highest environmental impact. Reducing textile production will not only limit the use of water, energy, and toxic chemicals, but will also reduce carbon emission related to transportation.



*Figure 2: Waste management hierarchy*

In addition to CO<sub>2</sub> emission and water consumption, toxic chemicals are used during textile production. For natural materials such as cotton, processing requires substantial amounts of chemical fertilizers and pesticides that pollute the soil (Challa 2014). Additionally, viscose is made from wood pulp, which is treated with hazardous chemicals including caustic soda and sulfuric acid (Challa 2014). Synthetic materials, such as nylon and polyester are made from petrochemicals and are non-biodegradable (Challa 2014). Each of these materials must also be bleached, dyed, and finished, which require large amounts of chemicals.

## End of life

Following production, textiles are transported, sold, and used. Eventually, textiles enter the end of life phase where they are either separately collected and reused or recycled, or discarded in mixed household waste. In the case of Denmark the primary treatment for mixed household waste is incineration with energy recovery. Reuse means that the textile product is used again for its original function while recycling entails recovery of the materials in the product for input to new production (of textiles or other products). Reuse can directly offset the production of new textiles, thereby reducing the impact from production. The caveat that reuse presents is the difficulty in quantifying the substitution factor. That is to say, there is only limited data on the extent to which the reuse of a product will prevent the purchase of a new product of the same kind. Farrant (2008) carried out a limited questionnaire survey of people purchasing second-hand items Estonia, Sweden and Denmark. By scaling up results to country demographics the study estimated displacement rates of 60% in Sweden/Denmark and 75% in Estonia.

Reuse is preferred to recycling as this method provides a larger environmental benefit even with low substitution factors (Schmidt et al 2016). A substitution factor is the replacement of a new textile with a reusable one instead. For example, a substitution factor of 1 means that

the purchase of a reusable textile replaced a new textile, while a factor of 0.2 means that the purchase of a reusable textile replaced 20% of a new textile. The impacts from different treatment routes can be seen in Figure 3; it is clearly demonstrated that reuse has significant environmental benefits compared to chemical recycling, even with a substitution factor lower than 0.33. The study estimates that the substitution factor could possibly be less than 0.1 before the reduced energy consumption is roughly equivalent for reuse and recycling (Schmidt, 2016). Thus optimal options for textiles are in line with the waste hierarchy; reuse before recycling, recycling before incineration with energy recovery.

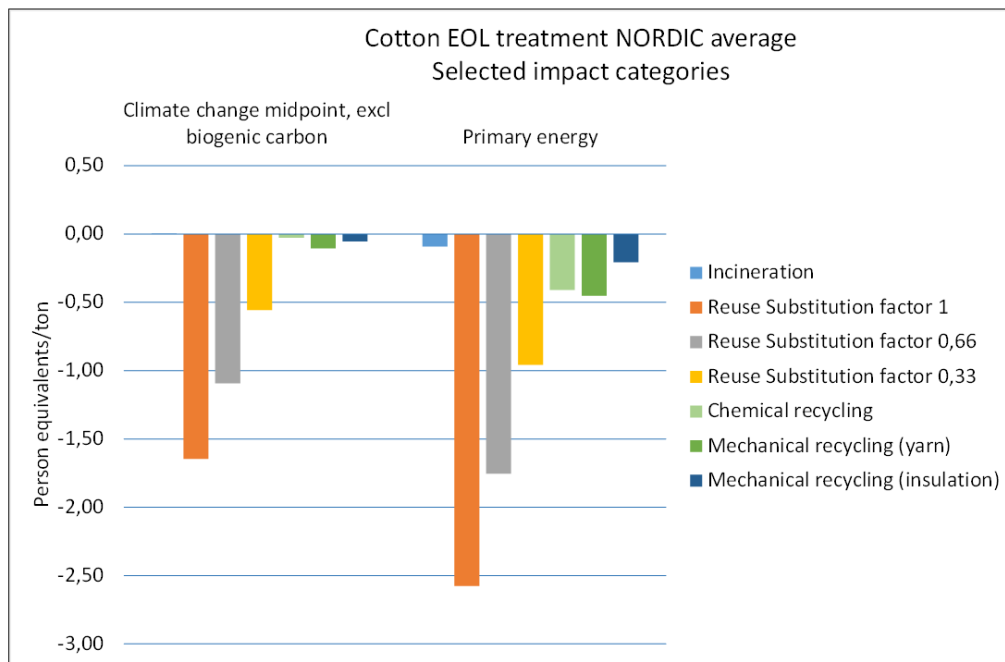


Figure 3: Impacts and benefits from different treatment routes for discarded average textile mix in the Nordic countries (Schmidt et al, 2016).

Moreover, far from all discarded textiles are suitable for reuse. A significant share has too much wear and tear to be reused. To optimize environmental benefits, textiles which are not suitable for reuse should be separately collected and recycled as far as possible. The overall goal of treatment of textiles is illustrated below in Figure 4; increase the active lifetime of textiles via passing through consecutive users, and when no longer fit for use, material recovery.

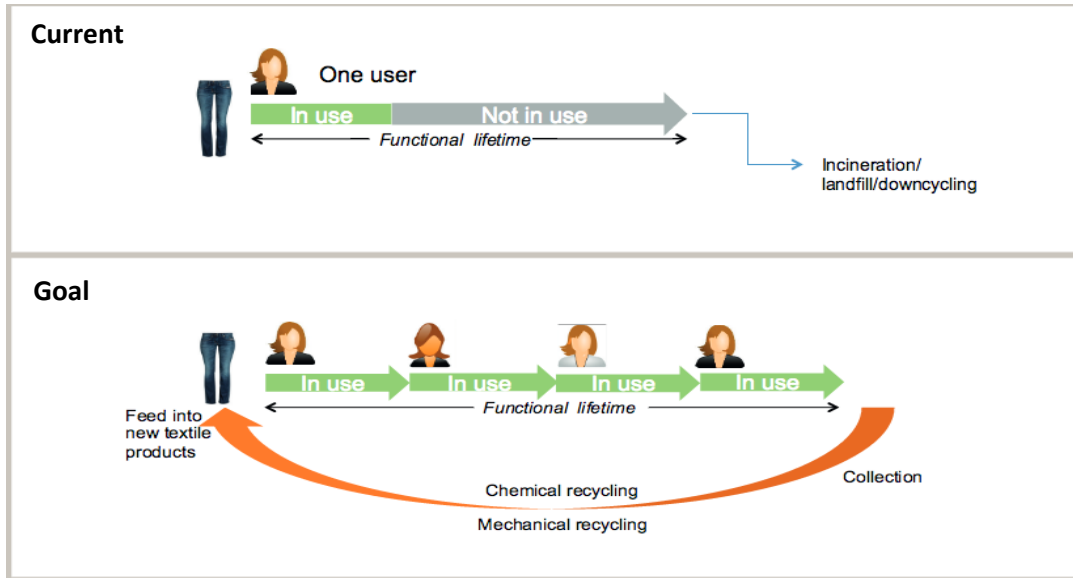


Figure 4: Overall goal for treatment of textiles to lower environmental burden (Watson, 2014).

In order to effectively increase textile sustainability, the current flow for the end-of-life stage of textiles must be assessed. In Denmark, there are currently five main destinations for textiles in this stage: domestic reuse, domestic recycling, exporting for reuse and recycling, landfilling (though almost non-existent in Denmark)(Tojo et al 2012), and incineration. Figure 4 below maps the flow of discarded textiles to these various destinations. Each of these outcomes will be discussed to fully understand this stage in the life of a textile.

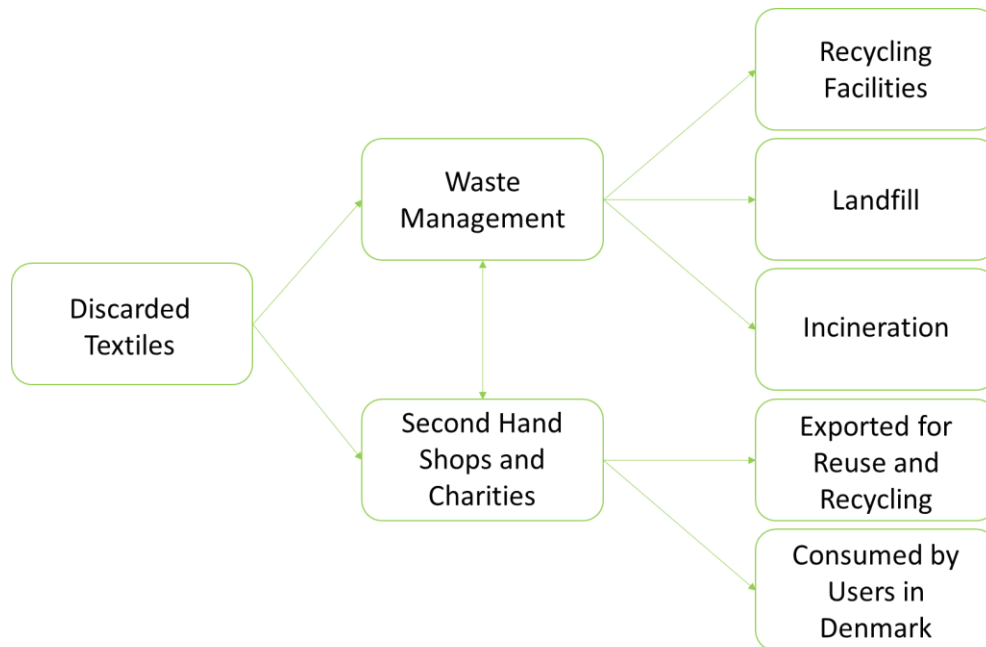


Figure 5: Textile flows in end-of-life stage in Denmark



When a textile is landfilled or incinerated, the material cannot be used again and the life of that textile is ended. To increase textile sustainability, a country must decrease consumption of new textiles by increasing the lifespan of textiles that are already in the cycle. As a preliminary step, the Nordic Council of Ministers commissioned a study to estimate the textile flow in Denmark in 2010. This study contains a flowchart that illustrates the flow of textiles; this chart includes estimates (in tons) of textiles being imported, exported, used, and at waste management facilities (see Figure 6) (Tojo et al. 2012). The flowchart draws attention to the major gap in Denmark's current system for textile sustainability— too many textiles are exiting the cycle and entering ordinary waste management.

This gap has a number of causes. Firstly, charities and other collectors have until very recently only accepted textiles that are directly suitable for reuse since there is currently little profit in the non-reusable fraction. This is exacerbated by the fact that consumers find it difficult to evaluate what is reusable. Secondly, some consumers aren't motivated enough to donate their textiles to charities and need to be activated in other ways via more convenient solutions.



Figure 6: Estimated Textile Flow (in tons) in Denmark, 2010, from Palm et al (2014b) using data from Tojo et al (2012) and Watson et al (2014)

Municipalities are responsible for the collection, sorting, reuse and recycling strategies of household waste. This can include textiles along with other recyclable items (Palm 2015). However, humanitarian organizations and private collectors are currently driving collection of textiles. As it stands, Salvation Army, Danish Red Cross, Danchurch Social, and Trasborg are the four main collectors of textiles in Denmark (Table 1, see page 12).

Although Denmark has taken steps to increase textile collection, improvement of textile sustainability could be further expanded as textile collection is primarily focused on materials that are discarded by individuals rather than larger corporations (Palm et al. 2014). Wholesalers and retailers generate textile waste in the form of unsold, unworn product, and damaged product (Palm et al. 2014). According to Palm, there is no data regarding the handling of waste generated by wholesalers and retailers, which suggests that textile reuse could possibly be improved by expanding the target audience for collection.

Thus, the major events that lead to textiles being removed from circulation in Denmark are exportation and incineration. When textiles are removed from circulation in a country, the only way to replenish them is to increase consumption. Therefore, textiles must be kept in circulation longer through reuse to make Denmark's textile economy more sustainable.

## Efforts being made to address the environmental impact of textiles

### *Solution 1: Altering production*

Consumers are becoming more conscious of the impact of textile production and are beginning to display a preference for eco-friendliness, forcing companies to produce eco-conscious products (Challa 2014). The Sustainable Apparel Coalition is a nonprofit organization that has pioneered the Higg Index—a groundbreaking self-assessment tool that is used to empower brands to measure their environmental, social, and labor impacts, and in-turn identifies areas for improvement. One of many brands that have applied the measurements outlined in the Higg Index is Adidas. This company's efforts include avoiding oil-based plastic to reduce carbon emissions, using thinner or lighter materials to reduce waste and embedded carbon, and dry-dying clothes to save water, chemicals, and energy. An advertisement part of the less waste campaign can be seen in Figure 7.



Figure 7: Adidas advertisement for less waste campaign (Adidas 2016).

### Solution 2: Textile Reuse

Textile reuse is a main component of increasing textile sustainability. As defined by Tojo et al, reuse includes “any operations by which products or components that are not waste are used again for the same purpose for which they were conceived” (2012, 15). By reusing instead of discarding, resources are saved as discarded clothes still contain approximately 70% of their life (Farrant et al. 2010). Furthermore, the energy consumed to reuse polyester and cotton only requires 1.8% and 2.6% of the respective production energies of those materials (Farrant et al. 2010). Thus, reusing textiles increases sustainability by conserving both resources and energy. As seen in Figure 6, much of the used textiles collected in Denmark end up in the separately collected sector. Of the 41,000 tons of textiles collected by charities and second hand shops in 2010, 23,000 tons were exported (Watson et al 2014). However, the export figure is much higher for the larger collectors; for the largest 13 collectors in Nordic countries 85% is exported for sorting, reuse and recycling in other countries (Watson et al. 2016).

The first destinations of textiles exported from Denmark are possible to track via contact with the collecting organizations. The top 13 Nordic collectors export directly to 35 different countries across the globe. Three quarters of exported textiles are exported in an unsorted state. These are mostly exported to Eastern European countries with large sorting facilities that act as interim destinations for the textiles (Watson et al, 2016). Once the textiles are sorted,

they either can stay in that country or can be exported. The destination of the textiles after they go through the sorting facilities is harder to track since most of the collectors do not have influence on their fate. Only 23% of the Nordic collectors have direct control over the eventual fate of the textiles (Watson et al, 2016). This lack of influence over the fate of the textiles is a major reason why tracking the flow of textiles is so difficult and why their eventual fate is difficult to follow. Export of second-hand textiles and its complexities will be further addressed later on.

Reuse of clothing in Denmark is not insignificant but could be increased. It was estimated that 12,500 tons were resold in Denmark in 2010 via charity second hand shops (Watson et al 2014). Private consumer to consumer reuse is much more difficult to estimate. This includes selling used textiles online, giving used textiles to family members, and repurposing textiles within the home (Tojo et al. 2012). Of these informal reuse options, only online sales can be tracked (Tojo et al. 2012). Online companies and flea markets have seen a recent rise in use (2013a). Popular Danish-based companies such as “Den Blå Avis” and Trendsales facilitate online clothing trades. Watson et al (2014) estimated online sales via these two companies and others to be at least 1,500 tons per year but could be higher. Additionally, luxury second-hand shops are also becoming more popular, especially in the larger cities (Tojo et al. 2012). While resale of used textiles is becoming increasingly popular, it is necessary to further expand this practice in order to increase textile sustainability.

Current collection of textiles for reuse is conducted primarily by charitable organizations (2013a). The six main collectors in Denmark include five humanitarian organizations, Røde Kors (Red Cross), Frelsens Hær (Salvation Army), Kirkens Korshær (Dan Church Social), UFF, and Folkekirkens Nødhjælp (Danish Church Aid), and a privately-owned actor Trasborg (Tojo et al. 2012). Textiles are primarily collected via public containers located at drop-off centers and shops; however, textiles are collected via door-to-door pickups in limited quantities (Palm et al 2014b). Each organization has a different procedure for dealing with textiles. Trasborg (as the only Nordic example) carries out detailed sorting in Denmark and then exports 100% of the reusable items for sale elsewhere. Frelsens Hær and Røde Kors take only quality items for resale in their own domestic shops and sends the remainder for sorting in other countries while UFF exports all the textiles they collect in unsorted state (‘original’) to their sorting facilities in Eastern Europe (Watson et al 2016).

As shown in Table 1 below, Trasborg has a higher incineration percentage than any of the humanitarian organizations. This is because Trasborg discards a greater quantity of textiles during the first sorting, thus causing humanitarian organizations to have higher reuse rates; this is primarily because sorting is carried out in Denmark where markets for recycled textiles are

small. Based on the estimated total values, approximately 15% of collected textiles were incinerated (Watson et al, 2014). In order to increase textile sustainability, Denmark must seek to extend the life of this 15% through alternative methods such as recycling.

*Table 1: Summary of estimation in tons of textile collection, reuse, exports, and incineration per actor in Denmark, adapted (Watson et al. 2014)*

	Antal butikker	Indsamling	Genbrug	Ekspor	Forbrænding
<b>Trasborg</b>	-	7.000	-	4.200	2.800
<b>Røde Kors</b>	<b>200</b>	6.000	600	4.800	600
<b>Frelsens Hær</b>	<b>20</b>	7.500	750	6.000	750
<b>UFF</b>	-	1.200	-	1.080	120
<b>Kirkens Korshær</b>	<b>240</b>	5.000	4.500	0	500
<b>Folkekirkens Nødhjælp</b>	<b>111</b>	500	250	220	30
<b>Andre*</b>	<b>600</b>	12.000	6.400	4.400	1.200
<b>Consumer to consumer</b>	-	-	1.500	-	-
<b>Total (afrundet)</b>	<b>1.170</b>	<b>39.000</b>	<b>14.000</b>	<b>21.000</b>	<b>6.000</b>

One main issue with textile reuse is individual responsibility. In the waste prevention strategy, Denmark without Waste II, it was found that between 2003 and 2010 consumption of clothes and other textiles by households went up by 36% (2015). However, consumers were estimated to have discarded half of the textile products they obtained to be incinerated, rather than reused or recycled. While it may seem that the increased consumption and startlingly high rate of disposal demonstrates a lack of consumer awareness regarding the environmental cost of textile consumption and the potential of textile reuse and recycling, there are other factors that could be influencing these increases. For example, the frequency of buying, pleasure, and the price are the main factors for increased textile consumption (Farrant et al. 2010). The complexities this issue presents warrant further investigation.

### *Solution 3: Recycling*

Certain fractions of textiles are often not suitable for reuse but can still be recycled. In the years leading up to 2011, 6,000 tons of industrial wipes were generated in Nordic countries by recycling textiles (Tojo et al. 2012). This process provided jobs and saved on incineration costs; however, this practice has been discontinued.

Currently, textile recycling in Denmark is minimal (Palm et al. 2014b). Recycling textiles is the reprocessing of textile waste into new products, which can be done as 99% of used textiles are able to be recycled (Gadkari and Burji 2015). The environmental benefits of

recycling textiles include reduction in petroleum usage, reduction of greenhouse gases, and conservation of energy (Gadkari and Burji 2015). Of the 59,300 tons of textiles discarded by users and collected in Denmark in 2010, around 140-180 tons of those textiles were recycled in Denmark (Tojo et al. 2012). The major recycling processes in Denmark include cutting textiles into pieces to sell them as industrial wipes and making textiles into cloths to be re-sold (Tojo et al. 2012). Previously, the municipality of Haderslev collected used textiles at the local recycling depot to be sent to the recycling facility, where the textiles were cut into industrial wipes as a social project (Palm et al. 2014). The practice has been suspended as they were operating out of their jurisdiction; municipalities are not authorized to carry out processes that are carried out by privatized companies. This is one example of political complexities that arise while investigating this subject.

The remainder of the textile recycling comes from the trade organization for laundry and textile cleaning called Brancheforeningen for vask og tekstiludlejning (BVT). BVT estimates that around 80-100 tons of used textiles a year are re-sold as cloths consisting of mainly cotton or cotton/polyester textiles (Tojo et al. 2012). Dantextil (a Danish Organization) exports additional textiles with recycling potential to other European countries to be recycled (Palm et al. 2014). Dantextil receives around 5-6,000 tons of used textiles from collection organizations in Denmark a year (Palm et al. 2014). These used textiles are not wanted by other organizations for selling purposes; therefore, these textiles are exported (Palm et al. 2014). To decrease the amount of textiles incinerated, recycling must be used as a subsequent step to reuse in Denmark and other countries in cooperation with Denmark in order to decrease environmental burden of textiles.

#### *Solution 4: Exporting*

Currently, Denmark exports approximately 75% of its reusable textiles due to a lack of demand for second-hand clothes (SHC) and economic challenges with respect to operating sorting facilities within Denmark (Table 1), although there is one sorting facility run by Trarborg that carries out detailed sorting. Nordic used textiles are exported to 115 different countries, with about 82% exported to 10 primary countries (Watson et al 2016). Of the 10 countries that make up the majority of direct exports, only one is outside of the EU (Watson et al 2016). About 60% of the collected textiles from the four biggest collectors in Denmark are exported in their original state (Watson et al 2016), the rest are exported in a presorted state. The Danish collectors receive around 6 DKK/kg for unsorted ('original') textiles (Watson et al, 2016). These unsorted textiles are almost exclusively exported to EU countries for sorting. Once these textiles are

sorted, the non-reusable textiles either remain in the sorting country for down-cycling, or are shipped to eastern Asia for mechanical recycling (Watson et al, 2016). Very little sorting is done outside of these countries but sorted textiles that are reusable are exported all over the world.

The final destination of Nordic textiles mostly comprise other European countries, but a large portion have a final destination outside of the EU. India, Pakistan, and African nations make up about 30% of the final destinations for SHC as there is a large demand there (Watson, 2016). However, experts have differing opinions as to whether or not exporting to these countries is an effective means of handling SHC. An INDEX article argues that this practice is detrimental to the African countries as it places huge environmental and economical burdens on the countries (2013b). On the other hand the import of used textiles creates thousands of jobs. In Nairobi alone the used textile market is estimated to provide 65 000 jobs (Crowe 2014). Moreover, since only sorted wearable quality textiles are exported to Africa from the Nordic countries, waste generation and environmental impact is probably low. Nevertheless, some African countries inhibit imports of used textiles via bans, restrictions, and prohibitively high taxes as a political stance to protect their new textile industries (Watson et al, 2016). Per contra, Dr. Simone Fields argues that the commercialized SHC trade in Sub-Saharan Africa is beneficial as there has been a rise in poverty which makes inexpensive clothing options necessary (Fields 2003). However, Dr. Field study does not address any of the environmental ramifications of the SHC trade. Watson et al, 2016 are currently carrying out field studies in receiving countries to determine how impacts can be reduced and benefits increased via closer control of the fate of textiles exported to Sub-Saharan Africa at these volumes reaching close to 12,000 tons a year (Watson, 2016). While the SHC may be largely reused initially, once the clothing is no longer wanted, it is landfilled since there are no reuse systems in place (2013b). In her study "Environmental Benefits of Reusing Clothes," Farrant reaches a similar conclusion as the INDEX article (Farrant, Olsen and Wangel 2008). As described, this current system is not sustainable; collectors in Denmark are simply exporting the problem.

## Textile sustainability initiatives occurring outside Denmark

### *Initiatives in Europe (UK)*

The United Kingdom is also seeking to increase textile sustainability. In 2010, the UK presented a revised action plan for increasing textile sustainability (2011). The action plan focuses on the following areas (2010, 9):

1. Improving Environmental Performance across the Supply Chain

- Sustainable Design
  - Fibres and Fabrics
  - Maximising Reuse, Recycling and end of life management
  - Clothes Cleaning
2. Consumption trends and behavior
  3. Awareness, media, education and networks
  4. Creating market drivers for sustainable clothing
  5. Instruments for improving traceability along the supply chain (ethics, trade and environment).

While this UK action plan bears similarities to the action plan proposed by the Nordic Council of Ministers, there are some differences in focus and approach (Palm et al. 2014). Therefore, both regions could benefit from communicating and sharing ideas for increasing textile sustainability.

The UK is currently behind Denmark in efforts to improve textile sustainability. According to a study conducted by Woolridge et. al, 4-5% of the current municipal waste stream in the UK is textiles; of this fraction, approximately 25% is recycled or reused by companies such as Salvation Army (Woolridge et al. 2006). The remaining 75% is either landfilled or incinerated (Woolridge et al. 2006). When compared with previously mentioned statistics, the UK is incinerating/landfilling approximately 55% more textiles than Denmark.

Although the UK is behind Denmark in textile sustainability, their current reuse system is quite similar to that of Denmark. Humanitarian organizations, such as the Salvation Army, SCOPE, BHF, and Oxfam, are the proprietors of approximately 85% of the textile collection banks (Woolridge et al. 2006). However, the UK has also implemented curbside collection of textiles for approximately 1 million homes. In a study conducted by Karousakis and Birol, residents reported that they desired curbside collection for textiles and would be willing to pay for curbside collection; the author concludes that a cost-benefit analysis should be conducted to see if increased curbside collection would be beneficial (Karousakis and Birol 2008). Based on these findings, Denmark should also consider using curbside collection in order to increase textile sustainability.

### *Recycling Initiatives in Other Countries*

In order to optimize recycling within Denmark, it is necessary to move towards advancing large-scale textile recycling processes, as is seen in other countries. The Nordic council has researched current recycling advances that can be broken down into improvements



in sorting, mechanical recycling, and chemical recycling (Palm 2015). There is a current project taking place called T4T INDENTITEX, which aims to sort textiles on an industrial scale (Palm 2015). This technology could be useful for sorting textiles into fibers for recycling, while at the same time, using little manpower and lowering the cost for textile recycling (Palm 2015). This technology could be utilized in order to reduce worker costs in Danish textile recycling plants.

In France, the company Le Relais has taken great strides in performing different types of mechanical recycling like shredding, tearing, and cutting for insulation or wipers (Palm 2015). Le Relais operates with 90,000 textile containers, which is a large-scale recycling process that can be used as a model for recycling facilities in Denmark (Palm 2015). Au Dela Du Fil (France) produces yarn from industrial textile waste and post-consumer textiles to be used for the production of other textiles (Palm 2015). The yarn produced is of a lower quality (also known as down-cycling) than manufactured textile fibers; processes to improve quality are still under investigation. The Japan Environmental Planning Co Ltd has a target of recycling all clothes sold and worn in Japan (2012, just-style management briefing: Textile and clothing recycling worldwide). They helped retailers like Uniqlo collect clothes for the UN High Commissioner for Refugees and other aid organizations to turn used clothes into heat insulation fabrics, gloves, and fuel (2012, just-style management briefing: Textile and clothing recycling worldwide). In 2010 alone, 2.6 million clothes were recycled through their efforts (2012, just-style management briefing: Textile and clothing recycling worldwide).

The last form of large scale recycling, chemical recycling, is still not fully developed; however, there is one company in Japan, called TEIJIN, that is leading the way. The current process developed by TEIJIN is the recycling of polyester clothing with polyethylene terephthalate (PET) to produce a material similar to polyester (Palm 2015). The cost to do this is two to three times higher than producing polyester so further technology and innovations are needed to make this a feasible recycling method (Palm 2015). Clearly, Denmark should further investigate large scale recycling in order to minimize further production of textiles.

## Steps Denmark is Taking to Increase Textile Sustainability

The Danes have progressed toward a more sustainable society but have not yet reached their full potential. Denmark has launched a “Denmark without Waste II” initiative to diminish the environmental impact of textiles and other wastes through prevention. Unfortunately, as good as “zero waste” sounds, the incentive to produce less waste is lacking. The municipalities in Denmark generally have their own incinerators to produce energy for the

town. When less waste is incinerated, the incinerator is not working at full capacity; therefore, there is an incentive to create more waste in order to create more energy by incinerating waste (Zero Waste Europe 2014). There is clearly a gap between the direction Denmark wishes to take and the level of understanding the residents and companies possess.

The Nordic region has also launched multiple initiatives to develop other solutions for textile sustainability. For example, “The Nordic Working Papers” published a proposal by Nielsen & Schmidt (2014) to change “consumer behavior towards increased prevention of textile waste” (Nielsen et al. 2014). The proposal argues that a reduction in consumption of new textiles, demand for durable textiles, eco-efficiency, and cleaning cloth correctly and less often are targets to change the negative effects of textile waste (Nielsen et al. 2014). Unfortunately, similar to the zero waste campaign, consumers and stakeholders are not well informed of the negative effects of textile waste and therefore campaigns and proposals are not fully effective.

The Danish Waste Association (Dansk Affaldsforening) is working toward connecting the community to fill in the gaps between legislation and the municipalities and stakeholders. One of the objectives of the association is the “promotion of cooperation, knowledge-sharing, and dissemination of knowledge among members together with related organizations, associations, and other stakeholders.” (About Danish Waste Association). As shown in Figure 1, textiles have a long and complicated supply chain. It is for this reason that humanitarian organizations, second-hand retailers, municipalities and any other stakeholders must cooperate in order to further each other’s efforts in reducing the environmental burden posed by textiles. As it currently stands, Denmark lacks a clearly defined flow for textile reuse and recycling. In a policy brief on Nordic textile reuse and recycling commitment, David Palm of the Swedish Environmental Research Institute states that clarification of ownership of used textiles and textile waste is needed (2013a). He suggests that both reusable and recyclable textiles be collected in a single, unseparated fraction as consumers are not capable of separating textiles into the appropriate fractions or categories (Palm 2015). Some charities such as Red Cross have recently begun accepting all kinds of used textiles in their containers and not only textiles suitable for reuse.

However, Tojo states that “different municipalities differ in terms of how forthcoming and supportive they are towards charity collectors,” therefore, “the role of municipalities [should] be made clearer and that municipalities should be encouraged to collaborate with these collectors” (2012, 58). This collaboration would allow the municipalities and humanitarian organizations to share the financial burden of collecting used textiles. It is clear that municipalities and stakeholders (i.e. humanitarian organizations and private collectors) should collaborate;

however, the manner and extent of collaboration requires further investigation. By encouraging cooperation between members of the Danish Waste Association, they are more likely to be unified, and initiatives are more likely to be successful. The DWA also intends to find problem areas and relay possible solutions to their members and stakeholders. Efficient communication between municipalities, the association members, and legislation is a key factor in successful implementation of effective waste practices.

Our goal is to assist the Danish Waste Association in their efforts to reduce the environmental impact of textiles by filling in gaps in the textile life cycle. There are many places in the life cycle where textiles could be relocated but instead are getting incinerated or exported, amongst other methods. We believe that, with more communication between each stages of the life cycle, Denmark can work toward a more sustainable consumption of textiles.

# Methods

This project assisted the Danish Waste Association's efforts to reduce the environmental footprint of textiles by increasing reuse and recycling through optimizing textile collection methods and cooperation between stakeholders of humanitarian organizations and municipalities. The team developed and carried out the following objectives in order to accomplish this mission:

1. Assess current textile reuse and recycling systems
2. Identify similarities and differences in approaches to reusing and recycling textiles among different organizations in Denmark
3. Facilitate stakeholder cooperation via a workshop on methods to optimize the reuse and recycling of textiles

## Objective 1: Assess current textile reuse and recycling systems in Denmark

Denmark's current reuse system is facilitated primarily by humanitarian organizations and a few privately owned companies. In order to better understand how each company operates—collecting, sorting, and assigning product destination— we interviewed several of the most prominent stakeholders involved in the textile reuse and recycling industry as follows: Red Cross, Danish Church Aid, Ulandshjælp Fra Folk Til Folk (UFF), and Tråsborg. Through semi-structured interviews, we gathered information regarding:

- Each organization's current practices regarding collection, sorting, and assigning product destinations
- Each organization's statistics for product destination and where these statistics can be found (public vs. private)
- What areas of operations each organization thinks it does well
- What areas of operations each organization thinks need improvement
- What each organization hopes to gain from this project

Through this line of inquiry, we learned about each of the stakeholders' views on textile reuse and recycling. After the interviews, we constructed a quantitative code in order to quantitatively evaluate the interviewees' responses. The specific questions that we used in these interviews can be found in Appendix 1. All members securely stored information obtained during interviews on password protected devices.

In addition to interviews with stakeholders, we engaged with the following waste companies owned by Danish municipalities in order to document their current textile waste infrastructure: Vestforbraending, Amager Resource Center, Dansk Affald, Arwos, and Renosyd. Through semi-structured interviews with representatives from each company, we gained information about:

- How the textiles are currently being collected separately in these municipalities
- How are the textiles being sorted
- Current flow of textiles in these municipalities
- What limitations are present that prevent recycling of textiles in these municipalities
- What can the Danish government do to persuade municipalities to recycle more textiles

Through these questions we learned more about the limitations that are preventing municipalities from co-operating with humanitarian organizations and optimizing the reuse and recycling of textiles. After the interviews, we constructed a quantitative code in order to evaluate the interviewees' responses. The specific questions that we used for these interviews can be found in Appendix 2. All members securely stored information obtained during interviews on password protected devices.

Similarly, we interviewed consultants to assess the overall picture of the textile industry. Our primary contact was with David Watson, a consultant from PlanMiljø. His extensive work with textiles made him a valuable resource when considering all aspects of the lifecycle of textiles. We also spoke with the senior researcher of the joint UFF-DTU research project on reuse and recycling of textiles to investigate the most recent statistics and get a more technical perspective. We conducted discussions with a consultant from Isobro and the EPA in order to further investigate the legal responsibilities as outlined by these lobbyists and their guidelines.

## **Objective 2: Identify Similarities and Differences in Approaches to Reusing and Recycling Textiles Among Different Organizations in Denmark**

Through our efforts in objective one, we were able to compare and contrast the systems of each organization. In order to effectively quantify these similarities and differences we developed a cost-benefit analysis. We used the analysis to highlight the need for increased textile collection through demonstrating significant environmental and financial benefits. From this data, we produced projections based on increased collection of textiles. The criteria we

used to monetize and evaluate each cost and benefit are displayed in Table 2. In addition to the monetized values in the table, we included the effects of environmental impacts. This was necessary due to the high significance in our project, and to provide an accurate comparison of the benefits.

*Table 2: Criteria for performing a cost benefit analysis.*

<b>Cost or benefit</b>	<b>How we monetized and evaluated them</b>
Cost to separately collect textiles that are currently being placed in bulky waste	<ul style="list-style-type: none"> <li>- Additional collection bins set up for humanitarian organizations</li> <li>- Collection bags given to households</li> </ul>
Cost to sort collected textiles from different waste streams	<ul style="list-style-type: none"> <li>- Labor to sort textiles from recycled streams</li> </ul>
Profit from selling collected textiles	<ul style="list-style-type: none"> <li>- Amount of collected textiles that are: reusable, recyclable, or energy recoverable</li> <li>- Selling price of collected textiles per ton</li> <li>- Price municipalities charge humanitarian organizations per ton of textiles</li> </ul>
Environmental Benefits from increased collection of textiles	<ul style="list-style-type: none"> <li>- Percent of collected textiles that are: reusable, recyclable, or energy recoverable</li> <li>- CO2 savings per ton of textiles separately collected</li> <li>- Water savings per ton of textiles separately collected</li> </ul>

We determined the cost and profits for increased separate collection of textiles by basing the cost-benefit analysis off of the collection models being tested at the Amager Resource Center (ARC) and Dansk Affald. The humanitarian organization UFF has a contract with the ARC that allows them to have 50 collection bins at the ARC recycling centers. In return UFF pays ARC a set amount for each ton of textiles that is collected. During interviews with representatives for both parties, we obtained the costs for each step of this process as well as the expected benefits, and after which, generated a model of this collection strategy in order to show aggregate profit for both partners over a five-year period. We determined the profits for the ARC using equation 1 below and determined the profits for UFF using equation 2.

$$ARC = Aprice * w * t - 50 * b \tag{1}$$

Aprice = Price (DKK/ton) ARC sells the collected textiles to UFF

w = predicted collected textiles from new bins (tons/year)

t = time (years)

b = price of a bin (DKK)

$$UFF = (Uprice - Aprice) * w * t \quad (2)$$

Uprice = price UFF expects to sell collected textiles from ARC (DKK/ton)

Dansk Affald is currently testing a new collection method for textiles involving curbside collection in their DuoFlex™ bin sorting system. They currently have the DuoFlex™ bins at all of the households in the municipalities that they service; therefore, the only added costs would result from providing plastic bags for these households to package used textiles and the labor hours needed to separate the bags out of the paper and cardboard streams at the waste management facility. Dansk Affald has collected data for the first 3 months of 2016 and will maintain the trial for the duration of the year. Based on the data collected in the trial so far, we used equation 3 to determine the amount of profit a municipality could gain from curbside collection with a similar system.

$$DAprofit = w * p - b * bprice - h * lprice \quad (3)$$

DAprofit = Dansk Affald profit from curbside collection of textiles (DKK/year)

w = projected textiles collected a year curbside (tons/year)

p = price that the collected textiles can be sold for (DKK)

b = number of bags given to households a year

bprice = price of each bag (DKK)

h = extra hours to sort out the textiles collected (hr)

lprice = price of sorting labor (DKK/hr)

We also used the cost benefit analysis to show the impact of increased collection on the environment, municipalities, and collectors on a national level. We estimated that money could be made by municipalities with separate collection as opposed to incineration. We used equation 4 to determine how much profit could be generated by increasing the percentage of textiles collected and thus, decrease the percentage incinerated. This equation is based on the assumption that the municipalities do not cooperate with other collectors and only sell the collected textiles to sorting facilities abroad.

$$M = P * i * mprice \quad (4)$$

M = money (DKK) made for municipalities

P = potential collectible textiles in Denmark (in tons)

i = percent increase in collected textiles

mprice = price municipalities sell to textile handlers (DKK/ton)

We also considered the possibility of municipalities working with collection organizations via contracts that allow them to buy the collected textiles, as modeled by the UFF-ARC contract. Using equations 5 and 6, the team calculated the potential profits for both collection organizations and municipalities that are abiding by this model.

$$M1 = P * i * mprice \quad (5)$$

M1 = money (DKK) made for municipalities

P = potential collectible textiles (in tons)

i = percent increase in collected textiles

mprice = price municipalities sell to textile handlers (DKK/ton)

$$M2 = P * i * (price - mprice) \quad (6)$$

M2 = money (DKK) made for collection organizations

P = potential collectible textiles (in tons)

i = percent increase in collected textiles

mprice = price municipalities sell to collection organizations (DKK/ton)

price = price collection organizations sell textiles for (DKK/ton)

The last aspect of the cost benefit analysis was to determine the environmental impact from increased collection. Although we could not monetize these points, we included this data with the cost benefit analysis due to its central nature, as the overarching goal of this project is to reduce the environmental footprint of textiles. We calculated water savings from increased collection using equation 7 assuming an optimistic 1:1 substitution factor. Another assumption was that 80% of collected textiles would be reused, 15% would be recycled, and 5% would be incinerated. To determine the possible decrease in carbon dioxide emissions, we used equation 8 with the same assumptions used to determine the decrease in water usage.

$$WS = P * i * (pR * wR + pRe * wRe + pI * wI) \quad (7)$$

WS = total water savings (in tons)

P = potential collectible textiles (in tons)

i = percent increase in collected textiles

pR = percent of reusable textiles in collected textiles

wR = water saved from reusable textiles collected (tons of water / ton of textiles)

pRe = percent of recyclable textiles in collected textiles



wRe = water saved from recyclable textiles collected (tons of water / ton of textiles)

pl = percent of incinerated textiles in collected textiles

wI = water saved from incinerated textiles collected (tons of water / ton of textiles)

$$CS = P * i * (pR * cR + pRe * cRe + pI * cI) \quad (8)$$

CS = total water savings (in tons)

P = potential collectible textiles (in tons)

i = percent increase in collected textiles

pR = percent of reusable textiles in collected textiles

cR = CO<sub>2</sub> emissions saved from reusable textiles collected (tons of CO<sub>2</sub> / ton of textiles)

pRe = percent of recyclable textiles in collected textiles

cRe = CO<sub>2</sub> emissions saved from recyclable textiles collected (tons of CO<sub>2</sub> / ton of textiles)

pI = percent of incinerated textiles in collected textiles

cI = CO<sub>2</sub> emissions saved from incinerated textiles collected (tons of CO<sub>2</sub> / ton of textiles)

### Objective 3: Facilitate Stakeholder Cooperation via a Workshop on Methods to Optimize the Reuse and Recycling of Textiles

From site visits and interviews, we compiled conclusive information to be used in the development of a persuasive presentation for a stakeholder workshop. The presentation contained the current life cycle of a textile and specifically highlighted the importance of prolonging the end of life portion and the importance of increasing collection. These highlighted items were supported with a cost benefit analysis, interview data analysis, and content analysis. We also presented the stakeholders with a preliminary collection bin map and an informative pamphlet to be used to help educate individuals and increase collection. At the end of the presentation, we identified the gaps in the system that were discovered through background research and interviews. We presented these gaps in conjunctions with questions in order to facilitate discussion about developing and implementing strategies. The questions are as follows:

How can...

- Convenience increase for consumers, and correspondingly increase the volume of collected textiles?
- Contamination be minimized?
- Benefits be shared?
- The humanitarian organizations be included?
- Waste be defined, and who has ownership?
- Value Added Tax (VAT)-free status be maintained?
- The impact of exportation on the consumer be reduced?

We left the questions for consideration until the end of the day, after other members gave their own presentations. The workshop concluded with participants gathering together to discuss the proposed questions and develop solutions in a cooperative fashion. We each sat at different tables in order to facilitate discussion and record their suggestions.

# Results and Analysis

In this chapter presents the data acquired through the interviews and site visits conducted throughout the project, as described in the Methods chapter.

## Interviews with Stakeholders

From our interviews with stakeholders, Objectives 1 and 2 which focused on an assessment of current reuse and recycling systems and a comparison of various strategies among companies within Denmark, were accomplished. The stakeholders seen in Table 3 were interviewed in order to understand the current reuse and recycling systems for textiles and to gain insight into potential areas for improvement. Through conversing with these individuals it was possible to more clearly see the potential in textiles as a resource.

*Table 3: Table of interviewed representatives*

<b>Organization</b>	<b>Type</b>	<b>Contact</b>	<b>Position</b>	<b>Date</b>
PlanMiljo	Consultant Firm	David Watson	Senior Consultant	March 15, 2016
Vestforbraending	Waste Management Facility	Morten Strandlod	Head of Marketing	March 16, 2016
Dansk Affald	Waste Management Facility	Jesper Vange Heinzl	Sales and Marketing Manager	March 29, 2016
Arwos	Waste Management Facility	Halfdan Neumann	Teamleader	March 29, 2016
Danish Church Aid	Humanitarian Organization	Morten Ebbesen	Head of Center	March 30, 2016
Renosyd	Waste Management Facility	Jeppe Vestergaard	Project coordinator	March 30, 2016

Amager Resource Center	Waste Management Facility	Linda Rebien	Development Consultant	April 4, 2016
UFF	Humanitarian Organization	Kaj Pihl	Director	April 7, 2016
Isobro	Lobbyist Organization	Vibeke Anderson	Independent Consultant	April 7, 2016
Trasborg	Private Collector	Steen Trasborg	Owner	April 13, 2016
EPA	Government Agency	Anne-Mette Lysemose Bendsen	Consultant	April 14, 2016
Red Cross	Humanitarian Organization	Tina Donnerberg	Head of Commercial Activities	April 20, 2016

All of the interviews of individuals in Table 3 were informal and semi-structured. A quantitative code was constructed based off of the questions in Appendices 1 and 2. The code was designed to be categories that were exclusively disjunctive (Table 4). A dash was used for categories with missing data. The positive responses for each category were tallied and converted to percentages. As can be seen from the data in Table 4, the stakeholders operate similarly. The most notable piece of data was that all but one interviewed stakeholders viewed inter-stakeholder cooperation positively.

Table 4: Results from thematically coding our interviews

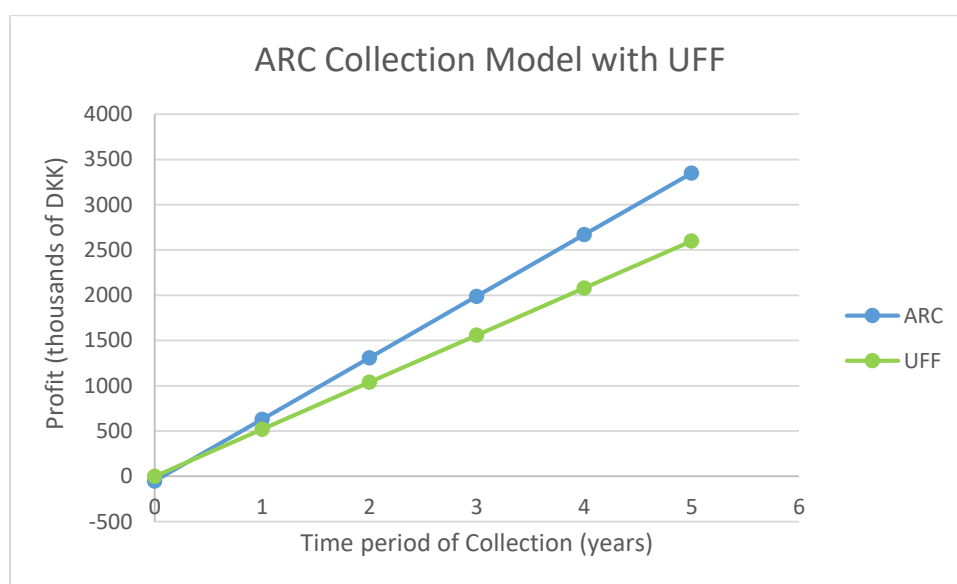
Organization	Collection Strategies		Target Audience		Sorting Strategy			Unsorted Destination		Attitude-Coop		Salvage Criteria		Recycling Practices		Direct Export		Waste Capacity		Want from Project	
	Bin	Curbside	None	Target	None	Minimal	Fine	Ship Out	Incinerate	Pos	Neg	Has	Doesn't	Incinerate	Sends for Recycling	EU	Asia/Africa	Can take More	Maxed	Perpective	Data
Vestforbrænding	Yes	No	Yes	No	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	-	-	Yes	Yes
Danish Waste	Yes	Yes	No	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	No	-	-	Yes	Yes
UFF	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Renosyd	Yes	No	Yes	No	No	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes
Arwos	Yes	No	Yes	No	No	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes
Danish Church Aid	Yes	No	Yes	No	No	Yes	No	Yes	No	Yes	No	No	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes
ARC	Yes	No	Yes	No	Yes	No	No	Yes	No	Yes	No	No	Yes	No	Yes	No	No	Yes	No	Yes	-
Red Cross	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Trasborg	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	-	-
<b>Percent Yes</b>	<b>100</b>	<b>11</b>	<b>89</b>	<b>11</b>	<b>33</b>	<b>44</b>	<b>33</b>	<b>89</b>	<b>67</b>	<b>89</b>	<b>11</b>	<b>44</b>	<b>56</b>	<b>78</b>	<b>89</b>	<b>56</b>	<b>33</b>	<b>67</b>	<b>11</b>	<b>89</b>	<b>78</b>

## Cost Benefit Analysis

To present our findings to the stakeholders, a cost benefit analysis was prepared to show the possible profit and environmental benefits of increased collection. Although environmental benefits are not monetized in the cost benefit analysis, they are imperative in this project and have a significant impact on the textile market. The cost and profits for increased separate collection of textiles based on the Amager Resource Center (ARC)-UFF trial over a five-year period are depicted in Table 5 below. As can be seen in Figure 8, both ARC and UFF are projected to experience increased profits over the five-year interval.

*Table 5: Cost and Profits of increased separate collection of textiles based on ARC-UFF trial.*

ARC model for collection						
Time (years)	0	1	2	3	4	5
ARC profit (thousands of DKK)	-50	630	1310	1990	2670	3350
UFF profit (thousands of DKK)	0	520	1040	1560	2080	2600



*Figure 8: Graph representing aggregated profits for 5 years with increased separate collection of textiles based on ARC-UFF trial*

As shown through the projections for the ARC-UFF cooperation, partnerships between municipalities and separate collectors are mutually beneficial. Data from this relationship suggests that future partnerships are a plausible option to increase collection and profit.

The results from the cost benefit analysis include the profit a municipality could gain from curbside collection with a similar system to Dansk Affald's Duoflex™ sorting bin. Table 6 shows the resources required and the overall profit based on tons of textiles collected. Figure 9 further demonstrates the positive, direct correlation between profits and collection.

Table 6: Resources required and profits based on tons of textiles collected.

Curbside collection model											
Projected collected textiles (tons)	0	5	10	15	20	25	30	35	40	45	50
Bags to collect textiles	0	4540	9080	13620	18160	22700	27240	31780	36320	40860	45400
Hours added	0	1.261111	2.522222	3.783333	5.044444	6.305556	7.566667	8.827778	10.08889	11.35	12.61111
Profit (thousands of DKK)	0	12.13728	24.27456	36.41183	48.54911	60.68639	72.82367	84.96094	97.09822	109.2355	121.3728

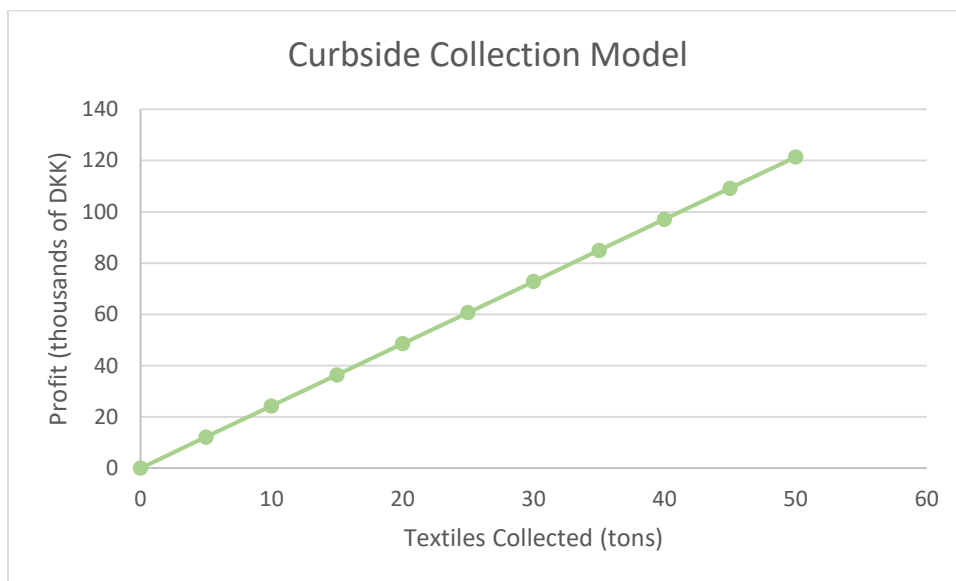


Figure 9: Graph representing profits based on tons of textiles collected with curbside collection

Data from the Duoflex™ system advocates for curbside collection. The profits along with the added convenience for residents make curbside collection another possibility for municipalities to increase collection of reusable or recyclable textiles.

With cooperation between municipalities and collectors, profits are available for each organization. Figure 10 below displays the money available through increased collection; just a 10% increase in collection could present a profit near 15 million Danish krone between municipalities and collectors.

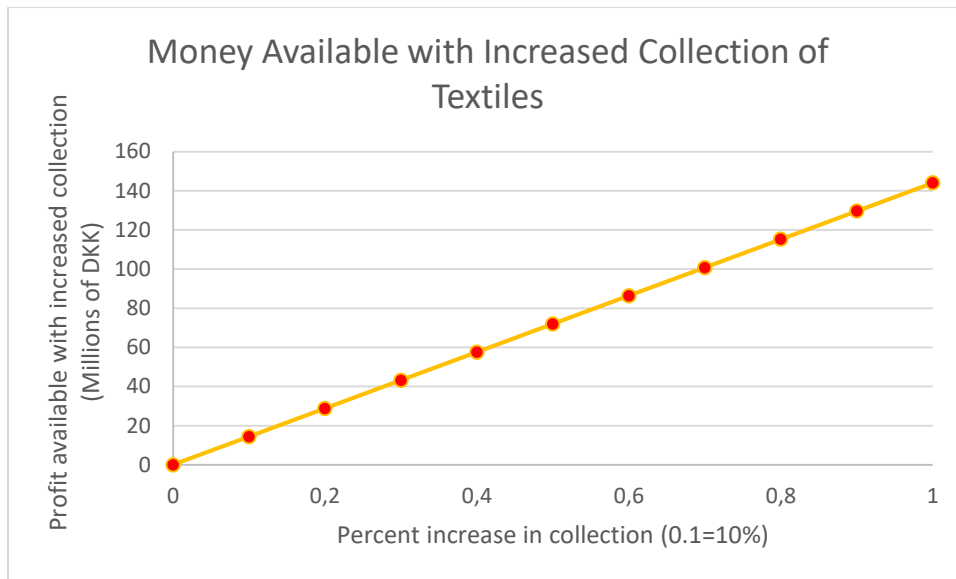


Figure 10: Graph of the money available with increased collection

To show the profit for municipalities, humanitarian organizations, and private collectors, calculations using equations 5 and 6 were carried out. The results of these equations can be found in Table 7 and are displayed in Figure 11.

Table 7: Money available to municipalities and humanitarian organizations and private collectors if they were to work separately

Percent increase in collection of textiles not being separately collected											
Percent increase in textiles collected	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Profit available for municipalities (millions of DKK)	0	8.16	16.32	24.48	32.64	40.8	48.96	57.12	65.28	73.44	81.6
Profit available for collectors (millions of DKK)	0	6.24	12.48	18.72	24.96	31.2	37.44	43.68	49.92	56.16	62.4

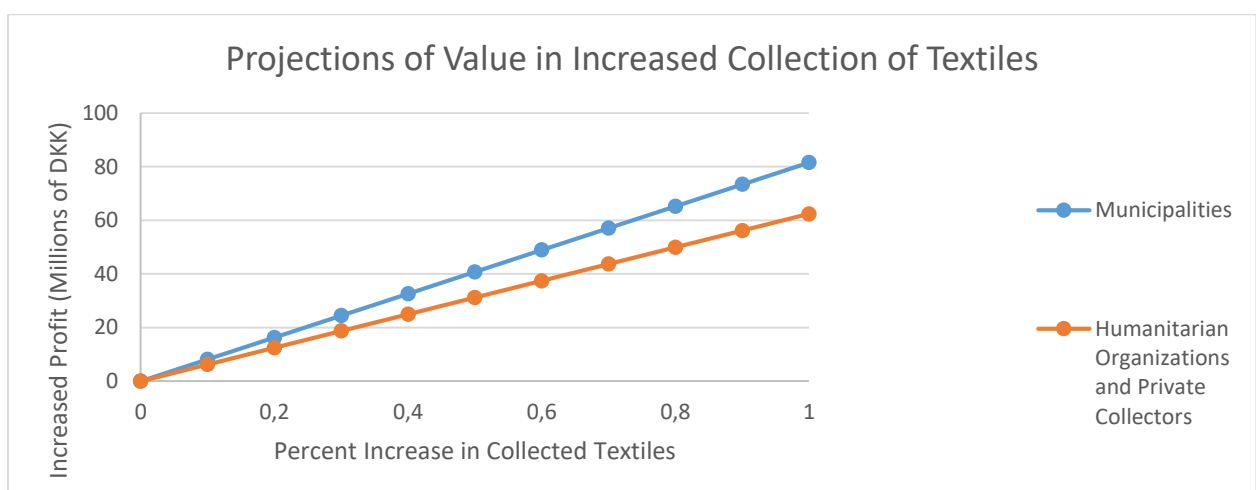


Figure 11: Graph displaying profit for municipalities, humanitarian organizations, and private collectors



The increase in profit for both municipalities and collectors exhibits that an increase in collection can benefit everyone, not just one kind of collector. With cooperation, every actor in textile reuse can reap benefits.

Apart from profit, increased collection poses global environmental benefits. Table 8 and Figures 12 & 13 display the decreases in the annual carbon dioxide emissions and water usage by Denmark when textile collection is increased.

*Table 8: Environmental benefits of increased collection of textiles*

Environmental Effect of Increased Collection in Textiles											
Percent increase in textiles collected	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Reusable textiles (tons)	28000	31840	35680	39520	43360	47200	51040	54880	58720	62560	66400
Water used through reuse (tons)	-1.3E+08	-1.4E+08	-1.62E+08	-1.8E+08	-2E+08	-2.1E+08	-2.3E+08	-2.48E+08	-2.66E+08	-2.83E+08	-3.01E+08
CO2 emissions through reuse (tons)	-588000	-668640	-749280	-829920	-910560	-991200	-1071840	-1152480	-1233120	-1313760	-1394400
Recyclable textiles (tons)	7000	7720	8440	9160	9880	10600	11320	12040	12760	13480	14200
Water used through recycling (tons)	-373605	-412033	-450461.4	-488889	-527317	-565745	-604173	-642601.3	-681029.3	-719457.3	-757885.2
CO2 emissions through recycling (tons)	-9100	-10036	-10972	-11908	-12844	-13780	-14716	-15652	-16588	-17524	-18460
Incineration grade textiles (tons)	55000	49440	44880	40320	35760	31200	26640	22080	17520	12960	8400
Water used through incineration (tons)	253148.5	227557.5	206569.2	185580.9	164592.6	143604.2	122615.9	101627.62	80639.3	59650.992	38662.68
CO2 emissions through incineration (tons)	-55000	-49440	-44880	-40320	-35760	-31200	-26640	-22080	-17520	-12960	-8400
Total water used from textiles in Denmark (millions of tons)	276.0265	258.5788	241.1357	223.6927	206.2496	188.8065	171.3634	153.92027	136.4772	119.03407	101.591
Total CO2 emissions from textiles in Denmark (hundred thousand tons)	12.169	11.40884	10.63868	9.86852	9.09836	8.3282	7.55804	6.78788	6.01772	5.24756	4.4774

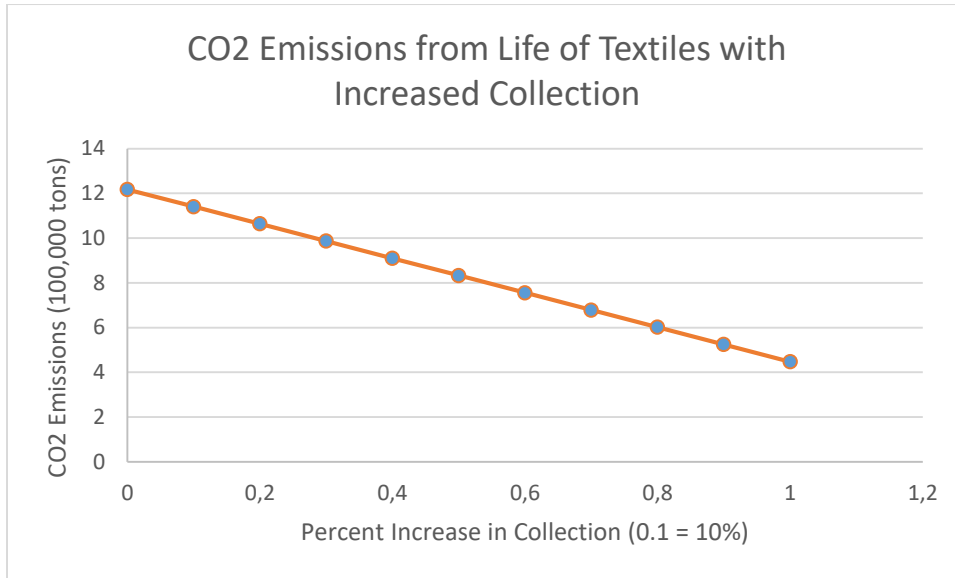


Figure 12: Graph displaying CO2 emissions prevented through increased collection.

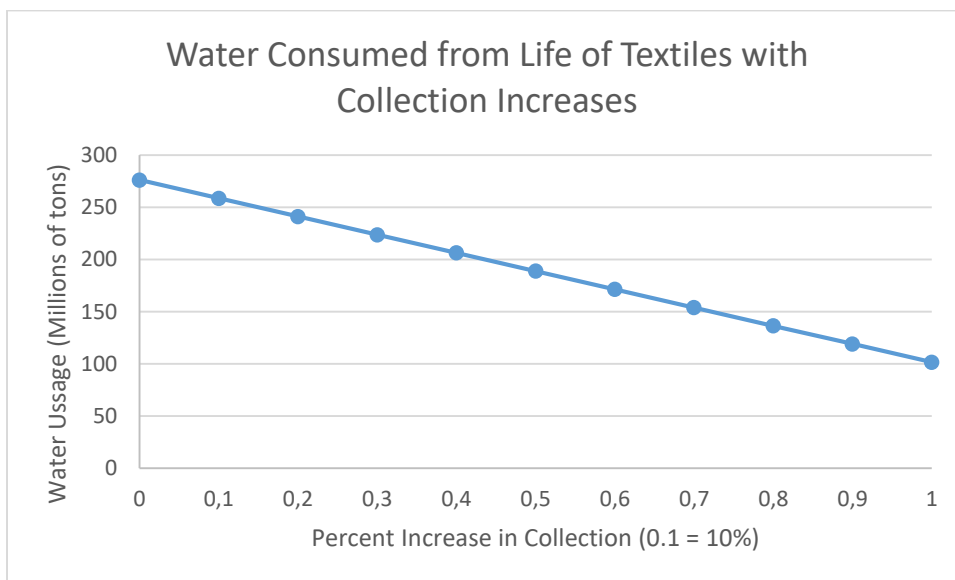


Figure 13: Graph of water consumption prevented through increased collection.

There are clear environmental advantages to increased textile reuse. With just a 10% increase in collection and subsequent reuse, near 30 million tons of water is saved and there is a decrease of near 100,000 tons of carbon dioxide emissions. The environmental benefits as well as the potential profit available to all operators in textile collection and reuse provide sufficient incentive for increased collection through cooperation.

## Workshop

A workshop was held on April 27<sup>th</sup>, 2016 where members of the Danish Waste Association, humanitarian organizations, and waste management organizations could work together to find solutions to problems present in the textile management system. This event brought members from all aspects of the management system together, providing a unique opportunity for cooperation. Responses to the discussion topics are shown in Figure 14 below. This figure emphasized overlaps in responses and made it possible to develop five different areas for analysis.

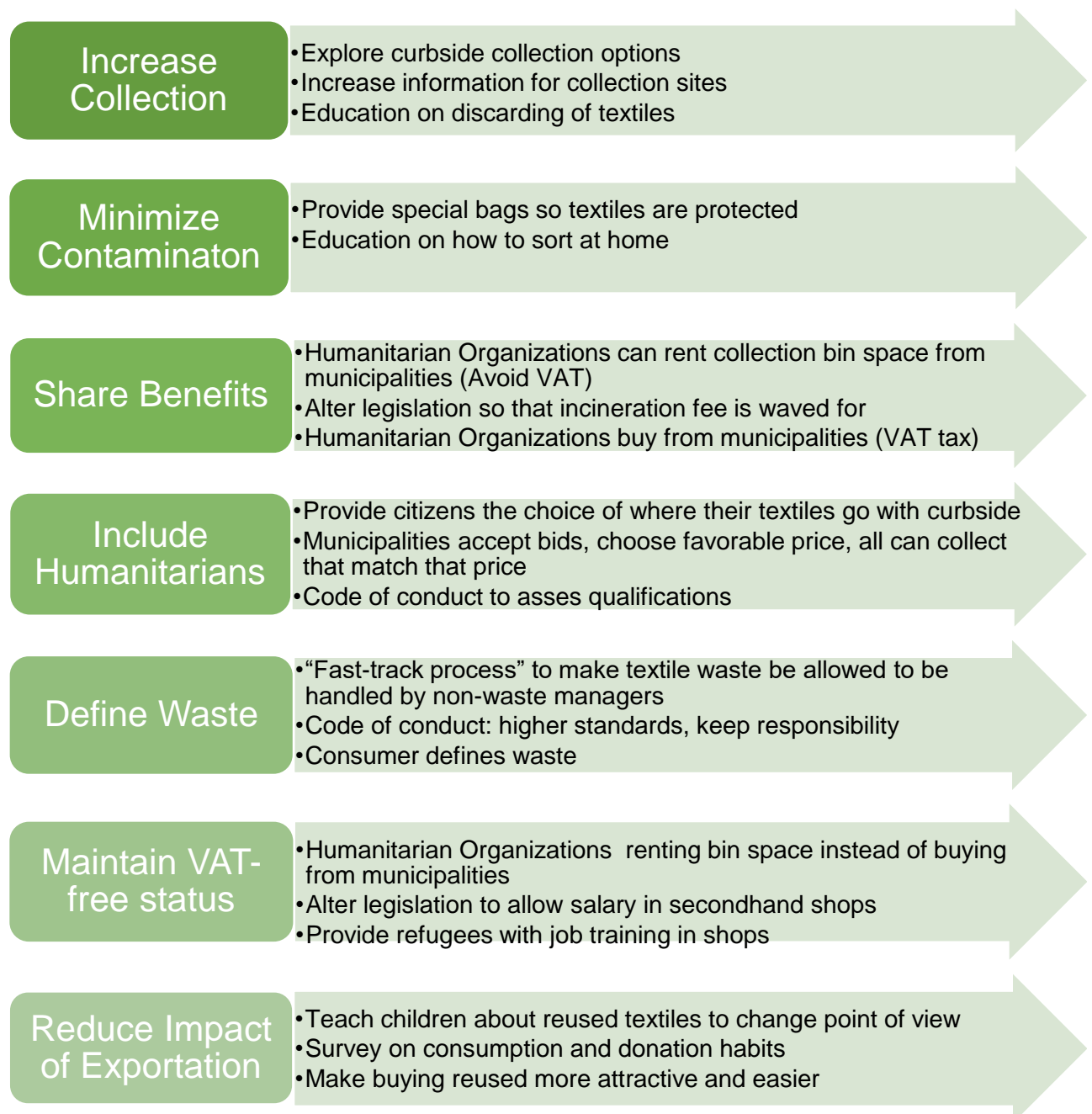


Figure 14: Results from workshop discussion topics

## Analysis of VAT-Free Status

In order to encourage cooperation between humanitarian organizations and municipalities, humanitarian organizations must be able to maintain their VAT-free status. Current humanitarian-municipality cooperation models include municipalities collecting textiles in their recycling center bins and then selling the textiles on a per kilogram basis to humanitarian organizations. The primary issue with this form of cooperation is that humanitarian organizations have to export these textiles immediately after purchasing them in order to qualify for VAT-free status. The exportation of these textiles decreases the amount available to be sold in shops and eliminates that fraction of textiles for reuse within Denmark. During the workshop, a participant suggested allowing humanitarian organizations to purchase space for collection bins instead of paying for the textiles per kilo from the municipalities. This solution would allow the humanitarian organizations to remain VAT-free while selling collected textiles within Denmark. This form of cooperation would be beneficial for both stakeholders and thus, a trial for this should be considered for future implementation.

Another point of concern stems from the employment options available to humanitarian organizations. In order to maintain their VAT-free status, humanitarian organizations can only have volunteers operating their second hand shops. Meanwhile, municipality owned waste companies have recently begun opening second hand stores which are operated by paid employees, and thus, can be open for longer periods of time. These flexible hours of operation give the municipality shops a competitive edge over the humanitarian organizations who are limited by volunteer availability. One solution would be for the humanitarian organizations to take in refugees for job training at their shops. This option would allow the organizations to maintain their VAT-free status as well as provide them with a steadier work force to operate their shops on a constant basis. Members participating in the workshop also suggested developing legislation that would permit humanitarian organizations to have salaried employees in their second hand shops while maintaining their VAT-free status. This legislation change would make the competition even between both types of stakeholders' second hand shops.

## Analysis of Sharing Benefits

In order to better facilitate stakeholder cooperation between municipalities and humanitarian organizations, the benefits of the industry must be appropriately shared. Current benefit sharing models between municipalities and humanitarian organizations were discussed during the workshop. These models included both Danish Church Aid's cooperation with Arwos and Renosyd as well as UFF's cooperation with ARC. Arwos sells

the textiles that they are unable to sell in their second hand shop to Danish Church Aid who then exports them for a profit. Similarly, Danish Church Aid allows Renosyd to use one of their collection bins for their second hand shop, and in return, Renosyd sells the textiles that they are unable to sell in their shop back to Danish Church Aid to be exported. Currently, UFF buys textiles from ARC and then exports the textiles for a profit. During the workshop, some municipalities were in favor of these methods; however, some were not in favor of these methods as these relations included a bidding process in which the municipalities would select a single humanitarian organization to partner with each year. Several of the stakeholders believed this method to first, be unfair for other collectors and second, eliminate the citizens' option for determining the destination of their textiles. A possible solution would be to allow the citizens to vote on with whom their local municipality works. Another solution would be for the municipalities to cooperate with multiple humanitarian organizations; the municipality could select the most favorable bid provided by the humanitarian organizations and allow any organization that is willing to match the bid to collect textiles from them. An additional solution could be for municipalities to use the proposed code of conduct for humanitarian organizations when selecting a partner organization.

Another issue that is present with cooperation between humanitarian organizations and municipalities is the incineration fees that humanitarian organizations are charged. Currently, humanitarian organizations are the primary collectors and sorters of textiles, but with the collection of textiles comes unwanted waste in the bins as well. The humanitarian organizations are then required to sort out the waste and bring it to the municipalities to be incinerated. This process results in the humanitarian organizations paying an incineration fee even though their purpose was not to collect waste. After lengthy discussion during the workshop, it seemed unlikely that a legislation change to wave this fee would be successful. One potential solution would be to change the legislature to have textiles classified as waste that any organization could handle; this modification would allow humanitarian organizations to collect all textiles, and perhaps would be influential in changing the current Minister's opinion on waving the fee as humanitarian organizations would now be collecting all textile fractions. While these presented solutions were not positively received by every stakeholder, these solutions focus on each organization's different strengths in order to bring about cooperation between stakeholders.

## Analysis of Educating the Consumer

Educating the consumer was a reoccurring topic when formulating solutions to the posed questions. Citizens play a vital role in successfully reducing the environmental footprint of textiles as they decide whether or not a discarded textile is considered waste. As such, they should be provided with the means to make an informed decision.

Providing a clear outline of what is acceptable to be donated is vital to successfully increase collection as well as reduce contamination. Some organizations would like to collect everything, so that consumer will not shy away from sorting certain textiles, by addressing the issue this may not be mandatory. It is possible to increase collection by informing the consumer that more than just wearable clothes can be donated. Not only to say that what one person may consider unwearable is not necessarily true for another, but also to imply donating household textiles. Advocating “don’t throw them away” is good because it will increase collection, but it is also necessary to clearly outline what cannot be donated in order to reduce contamination. Wet clothes, clothes covered in oily substances, and clothes with distinct odors should not be donated.

A comprehensive collection bin map has far-reaching implications. By compiling all the locations of each organization’s collection centers onto one map, the consumer will be able to locate the most convenient donation center or collection bin. Additionally, this map would present citizens with all their options and enable them to make a knowledgeable decision on where they would like their clothes to go.

Finally, the citizen should be educated on consuming in addition to donating. While donating textiles is important, the act of donating should not lead to increased consumption, because this will offset the environmental benefits.

## Analysis of Providing Options to the Consumer

Providing options for the consumer is imperative. By having collection points provided by humanitarian organizations, municipalities, and stores such as H&M, a larger audience is captured for collection. For example, a person may not care to donate for charity reasons, so if that is his/her only option he/she will not donate at all; on the other hand, he/she may like to shop and be willing to donate if it is offered in conjunction with incentives by a clothing store. Thus, having various organizations involved in collection could increase donations as well as convenience.

## Analysis of Convenience for the Citizen

Convenience was agreed to be an important factor in citizens’ discarding habits. Thus, multiple options to increase convenience and subsequently increase collection were discussed. While curbside collection would be convenient for residents, it poses problems for collectors. Cost, equality, and theft were all concerns that arose during this discussion. Curbside collection was mentioned to be a better option for rural areas, while urban areas would need to explore other possibilities as providing door to door collection for urban residents would be costly and impractical as many apartments do not currently use curbside waste collection. Collecting curbside would also detract from the amount given to

humanitarian organizations, unless there was an agreement between the organizations and the municipalities collecting. A suggested solution was to allow residents the choice of where their collected textiles go; this option may be a way to resolve the aforementioned issue. Lastly, the possibility of theft increases when discussing curbside collection. Therefore, ways to protect bins from theft would need to be explored in order to mitigate this issue.

# Conclusion

The rise in textile consumption and waste production increases water and chemical usage, as well as CO<sub>2</sub> emissions, which amplifies Denmark's environmental footprint. From background research we concluded that reuse and recycling of textiles would mitigate the effects of production and consumption. The need to further explore the systems prompted us to interviews which made it possible to identify the gaps within the reuse and recycling infrastructures. This information was used to design an overall cost benefit analysis and furthermore, compiled into an informative presentation. This presentation, which outlined gaps noticed in the system, was given at a workshop attended by members of the Danish Waste Association, humanitarian organizations, and municipalities with the goal of facilitating cooperative discussion and formulating solutions.

We concluded that it is necessary for participants that handle textiles during the end of life stage to be well informed of all problems in the system so that the issues can be addressed effectively. We concluded that there needs to be cooperation between humanitarian organizations and municipalities in order to increase collection and alleviate legal issues regarding the collection of textile waste. Additionally, we concluded that there needs to be education for the public in order to widen the scope of textiles that are eligible for donation, reduce contamination, and encourage purchase of second hand textiles. Finally, there needs to be options for the consumer in order to increase convenience and expand the target audience. When addressing these factors it is necessary to draw upon the strengths of each organization to increase efficacy in the system.



# Future Recommendations

During the workshop, multiple issues were elucidated which led to our formulation of future considerations for the Danish textile management system.

## Convenience Solutions

There could be two strategies implemented, one for rural and one for urban settings. On a rural scale curbside collection is more feasible because it already occurs for other waste fractions due to the low population density. For urban residents, providing door-to-door collection is impractical and costly because these waste collection methods are not currently in place. Therefore, it is necessary to formulate two separate strategies that are appropriate for different systems. To incorporate different collection agencies within this curbside collection scheme citizens could be provided with the option to select the final destination of their used textiles.

## Behavioral Solutions

We recommend conducting surveys on consumption and donation habits as it is the first step in addressing the behavioral issues. This will provide a better understanding of the problem and make it possible to develop effective solutions.

## Educational Solutions

In order to increase collection and reduce contamination it is necessary to educate the consumer. We suggest the use of educational pamphlets as well as a comprehensive collection site map, which will allow the consumer to identify the most convenient and appropriate donating option. An example can be viewed below.

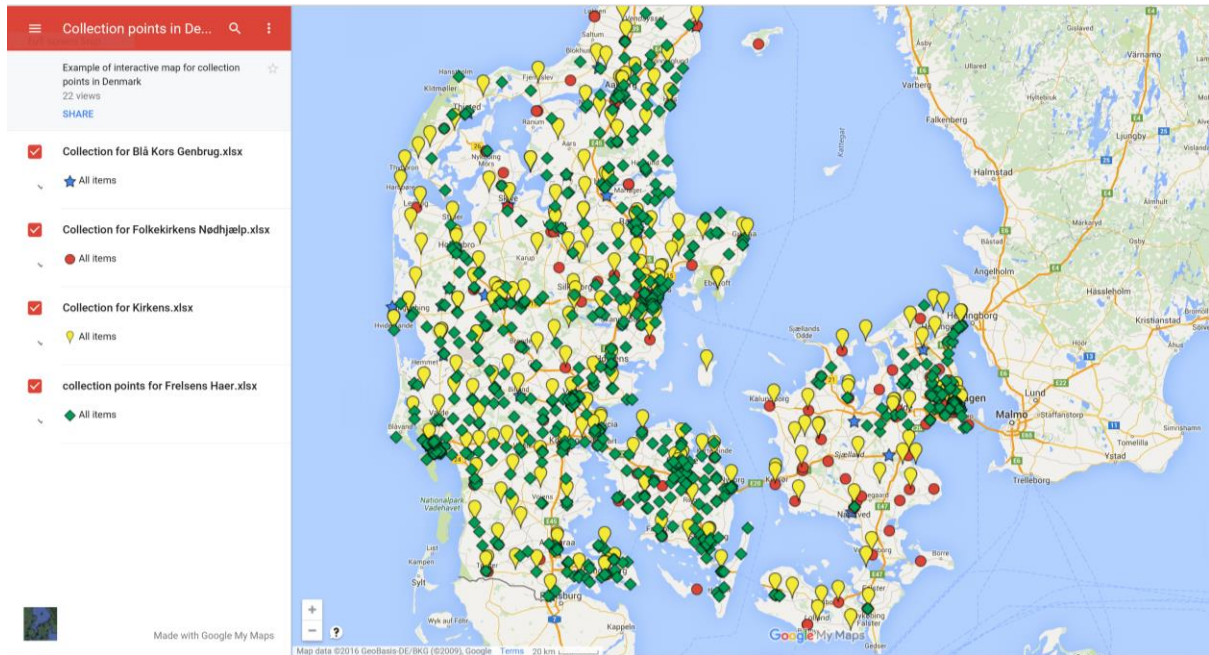


Figure 15: Collection Site Map

## Legislation Changes

Changes in legislation are necessary in the future in order to remove many of the complexities surrounding this issue. Two examples of these complexities include issues with humanitarian organizations maintaining their VAT-free status as well as having to pay incineration fees. We would recommend that changes be considered as is outlined in our analysis.

## Cooperation Solutions

In order for cooperation to be successful all actors involved in the textile management industry must be included. We suggest future workshops to maintain communication and continue to develop fair and impartial solutions. These workshops could provide a platform for these actors to share their progress and data regarding this waste fraction.

# Appendix 1

The following prompt was used at the beginning of the interview.

## **Verbal Consent:**

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting an interview of humanitarian organizations to learn more about textile reuse in Denmark. We strongly believe this kind of research will ultimately enhance the sustainability of textiles in Denmark.

Your participation in this interview is completely voluntary and you may withdraw at any time. This interview will take approximately one hour. If consent is given, this interview will be recorded for backup purposes. Please remember that your answers will remain confidential. No names or identifying information will appear on the questionnaires or in any of the project reports or publications unless consent is given.

This is a cooperative project between the Danish Waste Association and WPI, and your participation is greatly appreciated. If interested, a copy of our results can be provided at the conclusion of the study.

## Proposed Questions:

1. What are your current collection strategies?
2. Who is your target audience for collection?
3. What are your current sorting strategies?
4. What are your criteria for determining whether or not a textile can be salvaged?
5. Do you send textiles to be recycled? If not, would you consider diverting textiles from the waste stream and sending them to be recycled?
6. Do you export second-hand clothes? If so, to what locations and in what quantities?
7. What are your current product destination statistics? Do you share these statistics?
  - a. If so, with whom?
  - b. If not, would you consider sharing these statistics
8. After discussing your collecting, sorting, and assigning strategies, what areas do you think your organization excels in?

9. After discussing your collecting, sorting, and assigning strategies, what areas do you think your organization can improve in?
10. What does your organization hope to gain from the findings of this team's project?
11. Are there any other areas you would like to discuss?
12. Do you have any questions for the team?

**Closing Remark:** Thank you for helping us with this project!

# Appendix 2

## **Verbal Consent:**

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting an interview of municipalities to learn more about textile waste management in Denmark. We strongly believe this kind of research will ultimately enhance the sustainability of textiles in Denmark.

Your participation in this interview is completely voluntary and you may withdraw at any time. This interview will take approximately one hour. If consent is given, then this interview will be recorded for backup purposes. Please remember that your answers will remain confidential. No names or identifying information will appear on the questionnaires or in any of the project reports or publications unless consent is given.

This is a cooperative project between the Danish Waste Association and WPI, and your participation is greatly appreciated. If interested, a copy of our results can be provided at the conclusion of the study.

## Proposed questions for municipalities in Denmark:

### Questions for the municipalities

1. How do you collect textile waste in the municipality?
2. How much does it cost to collect the textile waste separately?
3. What are the current textile sorting and recycling methods in your facility?
4. How much man hours a year are put towards sorting textile waste?
5. What is the average salary for employees?
6. How much does it cost for sorting equipment?
7. How much does it cost to run the textile recycling operation?
8. How much textiles were recycled in 2015 (in tons)?
9. What is the demand for your recycled textile products?
10. Do you get sales from your recycled products? If so how much?
11. What is your relationship with stores and humanitarian organizations in Denmark?
12. What limitations are there in your facility that are preventing more textiles from being recycled?
13. What actions or incentives could the Danish government give to municipalities to increase the amount of textiles that are recycled?

14. Do you think these actions or incentives would motivate other municipalities to optimize reuse and recycling of textiles?
15. What actions or incentives could the Danish government give to municipalities to increase the amount of textiles that are recycled?
16. Do you think these actions or incentives would motivate other municipalities to optimize reuse and recycling of textiles?

**Closing Remark:** Thank you for helping us with this project!

All information obtained during an interview will be stored securely on password protected devices.

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