



Improving the Danish Textile Waste Management System

By:

Lyle Edwards
Emma Neumann
Domenico Straccia
Nick Tomasetti

Advised by:

Casper Schwartz Glottrup
Professor Robert Hersh
Professor Ingrid Shockey

Improving the Danish Textile Waste Management System

An Interactive Qualifying Project
Submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
degree of Bachelor of Science

By:
Lyle Edwards
Emma Neumann
Domenico Straccia
Nick Tomasetti

Date:
26 April 2024

Report Submitted to:

Casper Schwartz Glottrup, Kasper Dibbern Petersen, and Tanja Marie Nybo Kofoed
Amager Ressource Center

Professor Robert Hersh and Ingrid Shockey
Worcester Polytechnic Institute



This report represents work of WPI undergraduate students submitted to the faculty as evidence of a degree requirement. WPI routinely publishes these reports on its web site without editorial or peer review.



Abstract

In Denmark's newly implemented textile waste collection system, a significant portion of reusable and recyclable textiles end up as residual waste due to contamination from collection infrastructure and resident negligence. We worked with Amager Ressource Center (ARC) to improve the textile collection processes within ARC's administrative area and waste collection facilities. Our team analyzed data collected from residential surveys and interviews, observations from recycling and reuse centers across five municipalities, and key informant interviews with waste management professionals. Based on these findings, we provided recommendations to reduce contamination of the new textile waste stream, and to identify strategies to better inform residents of the new system.

Executive Summary

Background

The textile industry is a major contributor to global resource use and pollution. The European Union (EU) suggests that waste should be managed in the following order from most to least desirable: reuse, recycling, energy recovery, and then disposal via landfill (**Figure 1**). This waste hierarchy is also followed in Denmark and in other EU member states (European Commission, n.d.). Amager Ressource Center (ARC) is a waste management company in Denmark owned by five municipalities in the Copenhagen area. ARC's mission is to provide waste disposal with as little impact on the environment and climate as possible (ARC, 2024). The company is currently facing challenges with contamination and residential sorting of the new textile waste fraction (grouping). Textiles can either be collected directly via curbside pickup or can be brought to one of ARC's collection sites. If a piece of clothing can be reused, it is brought to UFF Humana (or other humanitarian organizations) for sorting and export. The textile waste stream collected from ARC's recycling centers is sent to Ragn-Sells, which pre-sorts textiles for recycling (ARC, 2024). Textiles that are soiled and can no longer be recycled or reused are placed into residual waste bins and are then incinerated for energy recovery. The waste management system in Denmark is complex, and there are many involved parties including ARC, the Danish EPA, UFF, Ragn-Sells, and the municipalities.



Figure 1. Diagram depicting the waste management hierarchy (European Commission, n.d.).

Approach

Our project goal was to improve the textile collection processes within ARC's administrative area and waste collection facilities. We accomplished this goal through our three objectives.

1. We evaluated textile collection practices at households and recycling centers. We observed the current textile collection system by visiting Ragn-Sells, UFF Humana, local recycling centers, and we participated in a "ride along" with a Frederiksberg textile collection truck.
2. We identified proper handling protocols and barriers for textile waste disposal and reuse. We conducted semi-structured expert interviews with officials from the Danish EPA, UFF Humana, Ragn-Sells, Circular, and Frederiksberg Collection. Insights from these discussions helped us develop questions for convenience interviews with residents at recycling centers. Finally, we used results from our interviews to create and distribute surveys in the form of QR codes at Amager Bakke and throughout recycling centers.
3. We recommended system improvements for community engagement, collection methods, and recycling centers. From our analysis of our interviews and survey, we identified feasible changes to the system and developed recommendations for ARC to improve the Danish textile waste collection system.

Findings

1. Textile Waste Information is Inadequate

We have found that the information distributed about the two-stream textile waste system is inadequate. Information is non-standardized, recycling center signage is lacking, and residents are struggling to understand the new system.

Key takeaways:

- Information on the textile waste stream is non-standardized across the municipalities.
- Residents are unaware of the two-stream system.
- Signage at recycling and reuse centers is sparse and existing signage is often hidden from view and lacks important information.

2. Collection Infrastructure and Resident Negligence Contaminate Textiles

We have found that collection infrastructure and community practices contribute to textile waste contamination. Textiles are a fragile waste fraction, soiled by water, food waste, and other contaminants. Visiting ARC's recycling and reuse centers, we found each are unique, though findings apply to most locations.

Key takeaways:

- Textile waste collection bins are not waterproof.
- Textile waste bins are not sheltered at recycling and reuse centers.
- Textile collection is infrequent and waste trucks are sometimes wet before collection.
- Textile waste bins are often left open, tampered with, and overfilled.
- Residents do not always bag textile waste.

3. Experts are Divided about the Prospects of the New Two-Stream System

Before speaking with experts about the newly implemented two-stream system for textile waste and reuse, we assumed that stakeholders in the waste industry were unified in their opinion of its effectiveness. However, during our expert interviews we realized a clear difference of opinion on the new two-stream system.

Key takeaways:

- Ragn-Sells and Circular have doubts about the future of the two-stream system.
- UFF Humana and the Danish EPA have hope for the success of the two-stream system.

Recommendations

Informed by our key findings, we have created a list of recommendations that address two overarching concerns that we identified in this study: insufficient information about the textile waste and reuse stream and widespread points of contamination.

Addressing Insufficient Information:

1. Develop a standardized media campaign that emphasizes the importance of the new textile waste stream.
2. Adjust existing signage on textile waste bins and at recycling and reuse centers.

Addressing Points of Contamination:

1. Adjust layout at recycling and reuse centers to provide shelter to textile waste bins.
2. Employ drying procedures for textile waste collection trucks.
3. Establish protocols for waste management workers to ensure textile waste bins are well-maintained.
4. Implement single-disposal bag dispensers at recycling and reuse centers in textile collection areas.



Acknowledgements

We would like to acknowledge Amager Ressource Center for their full support of our project. We would like to give a special thanks to Casper Schwartz Glottrup for his guidance and commitment to our project's success. We would also like to thank Kasper Dibbern Petersen and Tanja Marie Nybo Kofoed, along with the rest of the recycling department for their warm welcome in Denmark. Finally, we would like to thank UFF Humana, Ragn-Sells, the Danish EPA, and Circular for meeting with us and letting us tour their facilities.



Authorship

Section	Main Author(s)	Editor(s)
Abstract	L. Edwards	All
Executive Summary	L. Edwards, D. Straccia	All
Acknowledgements	N. Tomasetti	All
Chapter 1. Introduction	All	All
Chapter 2. Literature Review		All
Why recycle or reuse textiles?	N. Tomasetti	All
Contextualizing Danish waste management	D. Straccia	All
Key partners and municipalities	L. Edwards	All
Analysis of textile waste recovery method	N. Tomasetti	All
Preliminary challenges with the new textile collection system	D. Straccia	All
Relevant case studies in understanding and improving household textile waste management	L. Edwards, E. Neumann	All
Summary	D. Straccia	All
Chapter 3. Approach	All	All
Chapter 4. Results and Discussion		All
Finding 1: Textile Waste Information is Inadequate		
Information on the textile waste stream is non-standardized across the municipalities.	E. Neumann	All
Residents are unaware of the two-stream system.	E. Neumann, D. Straccia	All
Signage at recycling and reuse centers is sparse and existing signage is often hidden from view and lacks important information.	N. Tomasetti	All
Finding 2: Collection Infrastructure and Resident Negligence Contaminate Textiles		
Textile waste collection bins are not waterproof.	N. Tomasetti	All
Textile waste bins are not sheltered at recycling and reuse centers.	N. Tomasetti	All
Textile collection is infrequent and waste trucks are sometimes wet before collection.	D. Straccia	All
Textile waste bins are often left open, tampered with, and overfilled.	D. Straccia	All
Residents do not always bag textile waste.	E. Neumann	All
Finding 3: Experts are Divided about the Prospects of the New Two-Stream System		
Ragn-Sells and Circular have doubts about the future of the system.	L. Edwards	All
UFF Humana and the Danish EPA have hope for the success of the system.	L. Edwards	All
Discussion	All	All

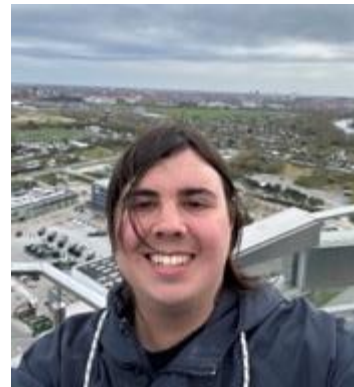
Chapter 5. Recommendations		All
Addressing Insufficient Information		All
Recommendation 1: Create a standardized media campaign that emphasizes the importance of the new textile waste stream.	D. Straccia	All
Recommendation 2: Adjust existing signage on textile waste bins and at recycling and reuse centers.	E. Neumann	All
Addressing Points of Contamination		All
Recommendation 1: Adjust layout at recycling and reuse centers to provide shelter to textile waste bins.	L. Edwards	All
Recommendation 2: Employ drying procedures for textile waste collection trucks.	N. Tomasetti	All
Recommendation 3: Establish protocols for waste management workers to ensure textile waste bins are well-maintained.	D. Straccia	All
Recommendation 4: Implement single-dispense bag dispensers at recycling and reuse centers in textile collection areas.	N. Tomasetti	All
Chapter 6. Conclusion	L. Edwards, N. Tomasetti	All

This work is original to the project authors and study participants and was not generated or assisted using ChatGPT or AI tools.

About the Authors

Lyle Edwards

Hello! My name is Lyle Edwards, and although I grew up around the world, I call Cape Cod Massachusetts home. I am currently majoring in Aerospace Engineering with a minor in Electrical and Computer Engineering at WPI. I am so grateful to have had the opportunity to learn and work with the people here in Copenhagen, Denmark. This project helped me understand the importance and complexities of waste management across multiple regions of a country.

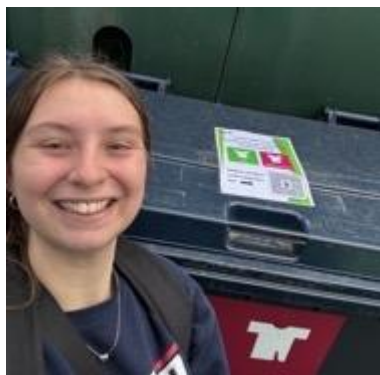


Nick Tomasetti

Hej! My name is Nick Tomasetti, and I am a chemical engineering student from Medway, Massachusetts. I have had an amazing time in Copenhagen, learning so much about Denmark's rich culture and meeting so many wonderful people! Working with Denmark's complex waste system has been an eye-opening experience, contributing to professional growth and lessons that I hope to bring back to the United States.

Domenico Straccia

Hey! My name is Domenico Straccia. I am an aerospace engineering student from Walpole, Massachusetts. Growing up I have always loved biking, so to be able to do that every day in such an amazing city has been incredible. One thing I will greatly miss is my commute to work where I bike past Frederik's Church and go through Nyhavn. I am consistently awestruck by all the beautiful views lying in plain sight.




Emma Neumann

Hi! My name is Emma Neumann. I am a chemical engineering student from Merrimac, Massachusetts. I have enjoyed learning about the Danish waste system during my time on IQP. The care the Danes take in sorting their waste emphasizing the environmental importance of the waste hierarchy was a nice contrast to the way waste is sorted at home. I really enjoyed working with my teammates and our daily bike rides to work. By taking into consideration all opinions this project allowed me to grow as a professional.

Table of Contents:

Abstract	i
Executive Summary	ii
Acknowledgements.....	v
Authorship.....	vi
About the Authors.....	viii
Chapter 1. Introduction	1
Chapter 2. Literature Review	2
Why recycle or reuse textiles?	2
Contextualizing Danish waste management	3
Key partners and municipalities.....	3
Analysis of textile waste recovery methods.....	5
Preliminary challenges with the new textile collection system	6
Relevant case studies in understanding and improving household textile waste management ..	7
Summary	8
Chapter 3. Approach	9
Chapter 4. Results and Discussion.....	10
Finding 1: Textile Waste Information is Inadequate	10
Information on the textile waste stream is non-standardized across the municipalities.	10
Residents are unaware of the two-stream system.	11
Signage at recycling and reuse centers is sparse and existing signage is often hidden from view and lacks important information.	12
Finding 2: Collection Infrastructure and Resident Negligence Contaminate Textiles	13
Textile waste collection bins are not waterproof.	13
Textile waste bins are not sheltered at recycling and reuse centers.	14
Textile collection is infrequent and waste trucks are sometimes wet before collection.	15
Textile waste bins are often left open, tampered with, and overfilled.	15
Residents do not always bag textile waste.	16
Finding 3: Experts are Divided about the Prospects of the New Two-Stream System	17
Ragn-Sells and Circular have doubts about the future of the two-stream system.	17
UFF Humana and the Danish EPA have hope for the success of the two-stream system. ...	18
Discussion	18
Chapter 5. Recommendations	21
Addressing Insufficient Information.....	21
Recommendation 1: Develop a standardized media campaign that emphasizes the importance of the new textile waste stream.	21
Recommendation 2: Adjust existing signage on textile waste bins and at recycling and reuse centers.	22
Addressing Points of Contamination	25



Recommendation 1: Adjust layout at recycling and reuse centers to provide shelter to textile waste bins.....	25
Recommendation 2: Employ drying procedures for textile waste collection trucks.	27
Recommendation 3: Establish protocols for waste management workers to ensure textile waste bins are well-maintained.....	28
Recommendation 4: Implement single-dispense bag dispensers at recycling and reuse centers in textile collection areas.	28
Chapter 6. Conclusion.....	30
Bibliography.....	31
Appendices.....	34
Appendix A. General guide for expert interviews.....	34
Appendix B. Interview guide for bin collectors.....	34
Appendix C. Interview guide for community and residents.....	34
Appendix D. Survey questions.....	34
Appendix E. Additional Recycling Center Mockups.....	36
Appendix F. Translated Images of Sign.....	37

Table of Figures:

Figure 1. Diagram depicting the waste management hierarchy (European Commission, n.d.).....	2
Figure 2. ARC’s main operational facility and incineration plant, Amager Bakke (ARC, 2023).	4
Figure 3. Diagram depicting the flow of textiles in the two-stream system.	5
Figure 4. A flowchart detailing the methodology used to achieve our goal.	9
Table 1. The collection type and frequency of collection in each municipality (ARC)	10
Figure 5. Survey results for preferred methods of textile disposal.	11
Figure 6. Signage on sorting practices (a) and textile waste bin label (b). English translated signs can be found in Appendix F.....	12
Figure 7. Survey respondent rankings for importance of environmental impact of textile waste disposal.....	13
Figure 8. Common textile waste bins at recycling and reuse centers (most common on left to least common on right).	14
Figure 9. Textile waste bins stored outside while waterproof reuse bins sheltered from elements at the Sydhavn recycling center.	14
Figure 10. Overfilled textile waste bin at Bispeengen recycling center in Frederiksberg.	16
Figure 11. Unbagged textiles at Møllegade reuse center.	17
Figure 12. Shipping container setup for pilot mattress recycling trial.	19
Figure 13. Mock-up media post.	22
Figure 14. The redesigned textile waste sticker label emphasizes bagging of textiles.	23
Figure 15. A redesigned sign for recycling and reuse centers emphasizing the environmental impacts of reuse, textile waste, and residual waste.....	24
Figure 16. Mock-up of the implementation of a shipping container at Borgervænget recycling center.....	26
Figure 17. Birds-eye view of the implementation of a shipping container at Borgervænget recycling center.	26
Figure 18. United Nations Sustainable Development Goal 12.	30
Figure 19. Bispeengen recycling center birds-eye view.	36
Figure 20. Bispeengen recycling center front view.	36
Figure 21. A translated image of the sorting criteria signs at recycling centers.	37
Figure 22. A translated image of the redesigned sign for textiles at recycling centers.	38
Figure 23. A translated image of the bin labels at recycling centers for the textile waste fraction.	39
Figure 24. A translated image of the redesigned label for textile waste bins at recycling centers.	40



Chapter 1. Introduction

Denmark has become an international leader in climate change policy, pledging to cut emissions 70% by 2030 and to reach carbon neutrality by 2050 (United Nations Environmental Programme, n.d.). To reach this goal, Denmark continues to strengthen recycling and reuse initiatives, supporting a culture of waste-sorting, funding waste management research, and collecting new streams of waste. Until recently, textiles were not collected as one of Denmark's many waste fractions (separated groups of waste based on material); Textiles were either donated to Non-Government Organizations (NGO's) such as UFF Humana for reuse or thrown away with residual waste. The 2020 Danish Climate Plan mandated that by July 2023, textile waste must be collected as an additional waste stream at households and recycling centers (*Klimaplan for en Grøn*, 2020). This new fraction contains textiles that have become worn, stained, or broken and are sent for treatment to be recycled. In the Copenhagen area, the implementation of the textile waste stream is managed by Amager Ressource Center (ARC). ARC collects this new fraction in recycling centers and at the household for five municipalities: Dragør, Frederiksberg, Hvidovre, Copenhagen and Tårnby (Amager Ressource Center, n.d.-a).

After months of textile waste collection, ARC has found that some textiles collected for recycling are suitable for reuse and others are being soiled by weather conditions. This raises two questions: (1) whether the public is confused about the proper sorting in the two-stream system and (2) whether textiles are being contaminated at collection sites or in transit. ARC sees an opportunity to assess the user experience of the new textile collection system and to continue to improve the effectiveness of this system. The goal of this project was to improve the textile collection processes within ARC's administrative area and waste collection facilities. We had three objectives to support this goal: 1. Evaluate textile collection practices at households and recycling centers. 2. Identify proper handling protocols and barriers for textile waste disposal and reuse. 3. Recommend system improvements for community engagement, collection methods, and recycling centers. Textile waste, recycling, and reuse start with community disposal and collection; By pursuing these objectives, we offered a new perspective on the textile collection system to provide recommendations for improvement.

Chapter 2. Literature Review

In this section, we contextualize our project, and introduce research that shaped our approach. First, we discuss the motivation behind the project with respect to the proposed environmental benefits. We review legislation and recent changes to the Danish waste management system. We also describe the two-stream system for textiles in Denmark and its key stakeholders, followed by preliminary challenges with collection. Finally, we present case studies that detail household motivation for textile donation and potential improvements to collection systems.


Why recycle or reuse textiles?

The textile industry is a major contributor to global resource use and pollution. While exact measures of pollution are hard to determine due to manufacturing segmentation, some estimates attribute 8-10% of global annual CO₂ emissions, 20% of annual industrial waste pollution, 35% of ocean microplastic pollution, and the consumption of 79 trillion liters of water every year to the textile industry (Niinimäki et al., 2020). The environmental impact of the textile industry continues to grow, fueled by growing populations, economic development (Sandin & Peters, 2018), and textile overconsumption known as “fast fashion” (Niinimäki et al., 2020).

Industry growth has resulted in higher household and corporate textile waste (Niinimäki et al., 2020). The European Union (EU) suggests that waste should be managed in the following order from most to least desirable: reuse, recycling, energy recovery, and then disposal via landfill. This waste hierarchy (Figure 1) is also followed in Denmark and in other EU member states (European Commission, n.d.).



Figure 1. Diagram depicting the waste management hierarchy (European Commission, n.d.).



Each method of textile waste management has advantages and disadvantages, though recycling and reuse, when possible, have been widely accepted by sustainably motivated policymakers, businesses, and communities (Cuc et al., 2015).

Contextualizing Danish waste management

As a member of the European Union, Denmark abides by EU waste collection policy. The EU defines reuse as “Any operation by which products or components that are not waste are used again for the same purpose for which they were conceived” (European Commission Directorate-General Environment, 2012). They promote recycling as “any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes” (European Commission Directorate-General Environment, 2012). Furthermore, waste is viewed as “any substance or object which the holder discards or intends or is required to discard” (European Commission Directorate-General Environment, 2012).

In 2018, the European Parliament and the Council of the European Union made amendments to the Directive 2008/98/EC on waste to benefit the environment. This was done by improving the efficiency of waste use to achieve a circular economy (European Commission Directorate-General Environment, 2018). The EU defines circular economy as “a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible” (European Parliament, 2023). These amendments oblige member states to sort paper, metal, plastic, and glass waste separately, but only suggest the separate collection of textiles (European Commission Directorate-General Environment, 2018). Denmark implemented these new amendments and created their own climate plan consisting of ten waste fractions at the household, one of which is textiles (*Klimaplan for en Grøn*, 2020). This 10-fraction system is known colloquially as the “new” system.

Key partners and municipalities

ARC’s mission is to provide waste disposal with as little impact on the environment and climate as possible (ARC, 2024). They are most well known for their incineration plant, Amager Bakke, also called CopenHill (**Figure 2**). This facility accepts waste from five municipalities across Denmark, including Dragør, Frederiksberg, Hvidovre, Copenhagen and Tårnby. Waste is also imported from other European countries to be incinerated. ARC seeks to minimize the amount of waste, specifically textile waste, that is incinerated. Because ARC follows the waste management hierarchy, energy recovered from waste is not preferred if recycling or reuse is an option.



Figure 2. ARC’s main operational facility and incineration plant, Amager Bakke (ARC, 2023).

To put the preferred waste management hierarchy into practice, considering how residents interact with the system of textile waste, recycling, and reuse is critical. Residents directly influence where textiles start their journey, which impacts the chances of them being incinerated. ARC has a dedicated team that works with the collection and recycling centers in the municipalities to ensure waste is upcycled through either reuse or recycling wherever possible. The company is currently facing challenges with the new textile waste fraction. To better understand where improvements can be made to this system, it is essential to have a good understanding of the current system in place. In collaboration with ARC, we have interpreted the current system of the flow of textiles in the participating municipalities of Denmark. **Figure 3** indicates where textiles end up, as well as the contents of each stream.

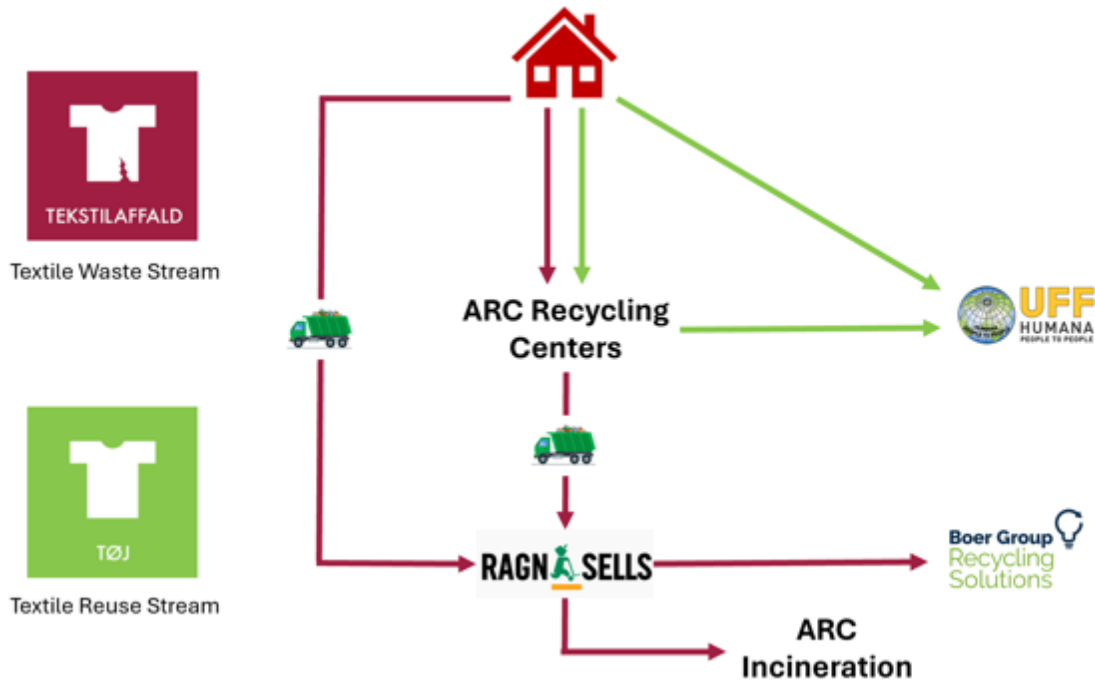



Figure 3. Diagram depicting the flow of textiles in the two-stream system.

Guidelines for waste disposal are created by the Danish EPA and are implemented by the municipalities. Textiles can either be collected directly via curbside pickup or can be brought to one of ARC’s collection sites. If a textile can be reused, it is brought to UFF Humana (or other humanitarian organizations) for sorting. There are dedicated UFF bins in the urban environment and at recycling centers. The textile waste stream collected from ARC’s recycling centers is sent to an organization called Ragn-Sells, which pre-sorts textiles to either be sent for incineration at Amager Bakke, or to Boer Group in Germany for further sorting (ARC, 2024). Textiles that are soiled and can no longer be recycled or reused should go into residual waste bins starting at the household level. These textile waste bins at the household along with the textile waste and reuse bins at recycling centers are identified with the green and red pictograms seen in **Figure 3**. These pictograms are made by Circular and are distributed to municipalities for use. While our project is centered around the textile waste streams from household to one of these drop-off locations, it is important to understand the full system as context to inform decision making in any singular step of the process.

Analysis of textile waste recovery methods

To better contextualize each method of waste management, it is important to look at both the benefits and drawbacks of each disposal method.

Residual waste is often disposed of in landfills or by incineration (Cuc et al., 2015). Discarding waste in landfills is often the last resort as neither material nor energy is recovered (Cuc et al., 2015). Unlike landfills, incineration recovers energy from waste that is used to power and heat homes (Bodin, 2016). Despite meaningful energy recovery, incineration produces additional emissions and contaminants (Bodin, 2016). These emissions are small compared to



manufacturing emissions, making incineration a viable waste management option especially when clothing is not fit for recycling or reuse (Niinimäki et al., 2020).

Textile recycling methods have developed substantially over the past two decades, fueled by increasing research in the field (Sandin & Peters, 2018). Generally, textile recycling involves breaking down textile fibers and reusing them in new products. Fibers are commonly broken down by mechanical and chemical processes (Niinimäki et al., 2020). The final product of these recycling processes varies, producing similar clothing (primary recycling), a new product (secondary recycling), or basic chemicals (tertiary recycling) (Cuc et al., 2015; Niinimäki et al., 2020). The effectiveness of textile recycling is significantly inhibited by sorting requirements. To recover useful fibers, textiles must be sorted by color, material, and size (Cuc et al., 2015). Historically, most of this sorting has been done by hand. Recently however, new technologies have employed automated infrared sorting systems with sorting accuracies around 90% (Niinimäki et al., 2020). Despite sorting drawbacks, further advancement in the industry is promising and continues to be a popular method for sustainable textile waste management.


Textile waste can also be reused through donations, borrowing, renting, and thrifting (Sandin & Peters, 2018). Textile reuse eases the demand for newly manufactured textiles, consequently reducing pollution and emissions (Niinimäki et al., 2020). While reuse is seemingly the best way to extend product lifetime, it still has limitations. Given that donated textiles must be transported to be redistributed, emissions are produced. If the lifetime of secondhand clothing is limited, the reuse process may not be worthwhile, contributing greater emissions per wear time than new clothing (Sandin & Peters, 2018). Like other waste management methods reuse has limitations and impacts, keeping these ideas in mind helps to shape improvements towards the system.

Textile waste management is nuanced – incineration, recycling, and reuse all have their own advantages and disadvantages. To claim one system is better than any other would be misinformed; Each system is necessary to completely deal with the wide variety of clothing that is disposed of every year. ARC’s goal is to ensure that textile waste serves its highest sustainable purpose.

Preliminary challenges with the new textile collection system

The updated 2024 waste prevention plan points out challenges that the country is facing with this new collection of textiles (Circular Copenhagen, 2019). Households resent the number of separate bins needed outside to properly sort their waste since it takes up a lot of space. As a result, the introduction of a textile bin is unwanted and inconvenient. The report suggests the use of other methods for the collection of textiles instead of an additional bin, such as including textiles in bulky waste or placing a textile bag on top of the cardboard waste bin (Circular Copenhagen, 2019). The collection method is dependent on the municipality with each having its own jurisdiction on the way these waste streams are run (Schwartz Glottrup & Nybo Koefod, 2024). This convolution of the system presents glaring issues with standardization and mass amounts of information given to the public. The lack of standardized information and waste collection creates confusion to the public who are seeing conflicting methods in use throughout Denmark.

Textile waste management is not an issue that will disappear on its own. Individuals, companies, and governmental bodies are each working towards feasible yet unique solutions to



this issue. With so many different systems in place, the proper disposal of textiles becomes confusing. This further promotes misuse and poor disposal practices.

Relevant case studies in understanding and improving household textile waste management

The following case studies help to (1) contextualize what factors determine how consumers decide to discard their textile waste and (2) demonstrate technology that has proven to help make waste collection more efficient.


Case 1. Canada:

A study conducted out of Ontario Canada sought to understand how a person's fashion affected how they managed their unwanted textiles. Each respondent was assigned a fashion index and then were split into two groups: fashion consumers and non-fashion consumers. They found that fashion consumers were more aware of, and had participated in more alternate forms of, managing textile waste: swap events, take-back, resell, and donation. The survey also noted that respondents reported that 50% of their unwanted textiles were targeted for donation. However, this is only their intention and not the end destination of the textile, which ultimately will be determined by convenience and accessibility to donation stations and bins. They also found that non-fashion consumers send 50% of their unwanted textiles for waste and fashion consumers only send 38% for residual waste (Weber et al, 2017). The influence of fashion in textiles is important in understanding consumer motivation for unwanted textiles to better solve the issue of textiles ending up in waste streams such as landfills and incineration.

The consumer's motives for waste management are important as they choose the act of donation, reselling, or residual waste. It was found to be important for the consumer to understand the journey of the textile after the act, so they felt a moral obligation to dispose of unwanted textiles using donation or resale instead of waste (Sonnenberg et al, 2022). Textiles are a unique waste stream where citizens hold personal attachment to the items they are discarding, so emotions may be a root cause of improper use. Danish residents share this mentality and also care where their textiles end up, making the textile waste stream more nuanced than it appears (Schwartz Glottrup & Nybo Koefod, 2024).

Case 2. Finland:

In addition to wanting to reduce the number of textiles in the residual waste stream because of consumer error, ARC also seeks to reduce the number of textiles soiled by weather conditions resulting in additional waste. A study was conducted in June 2023 which investigated the optimization of the curbside pickup process for textile waste. The study looked at improving bin collection by implementing a dynamic route optimization for pickup. Tests were conducted by modifying textile bins with basic sensors, which would alert trucks when to empty specific bins. The data was then compared to the standard, unmodified system currently in place. This study also included a cost-benefit analysis of how financially sustainable such an approach would be (Martikkala, 2023).



It was found that there was a 7.33% reduction in time it takes to collect textiles, as well as a decrease in “bin overflow” of 78%. (Martikkala, 2023) This means that textiles were spending less time in bins and were less likely to be contaminated. Furthermore, a cost analysis was performed on the operation of their implemented system. In sum, “with smart bins and route-optimization the cost of collected textile waste per kg is reduced by 7.4%.” (Martikkala, 2023). The implementation of low-cost technologies in the curbside pickup textile stream suggests long term financial sustainability with a complex system is achievable. This was beneficial to our project where one of our objectives focused on minimizing the number of textiles that end up as waste due to exposure to the elements or other waste products.

These case studies help to frame and understand the range of challenges surrounding the management of unwanted textiles. Studying the influences of fashion sheds light on the motivation and intent to donate. In addition, studying new technologies for waste management highlight potential improvements to existing systems. Our team used these lessons to test recommendations on how to better their current textile collection system and improve the quality of textiles donated and recycled.

Summary

Motivated by environmental benefits and inefficiencies in the new textile management system, our project is well supported by ARC, the Danish EPA, UFF, Ragn-Sells, the municipalities, and taxpayers. We found that it is important to consider both the advantages and disadvantages of common waste and reuse methods, influencing how we choose to interpret the textile collection system (Objective 1). Our first case study suggests that personal motivation for reuse and recycling is essential to understanding proper community involvement in textile sorting. We tested theories proposed by our case studies and learned more about personal motivation in Denmark (Objective 2). Our second case study along with other information gathered informed system recommendations (Objective 3).

Chapter 3. Approach

Our project goal was to improve the textile collection processes within ARC's administrative area and waste collection facilities. We accomplished this goal through our three objectives.

- 1) We evaluated textile collection practices at households and recycling centers. We observed the current textile collection system by visiting Ragn-Sells, UFF Humana, local recycling centers, and participated in a "ride along" with a Frederiksberg textile collection truck. At these locations, we noted process conditions, and documented equipment failures, household errors, and the condition of textile waste. We documented our findings through photography and field notes.
- 2) We identified proper handling protocols and barriers for textile waste disposal and reuse. We conducted semi-structured expert interviews with officials from the Danish EPA, UFF, Ragn-Sells, Circular (Appendix A), and Frederiksberg Collection (Appendix B). In these interviews we focused on the handling of textiles, opinions on the new two-stream system, and actions taken to improve collection. Insights from these discussions helped us construct questions for informal convenience interviews with residents at recycling centers (Appendix C). Finally, we used results from our interviews to create and distribute surveys in the form of QR codes at Amager Bakke and throughout recycling centers (Appendix D).
- 3) We recommended system improvements for community engagement, collection methods, and recycling centers. From our analysis of our interviews and survey, we identified feasible changes to the system and developed recommendations for different stakeholders to improve the Danish textile waste collection system. An outline of our methodology is illustrated in **Figure 4**.

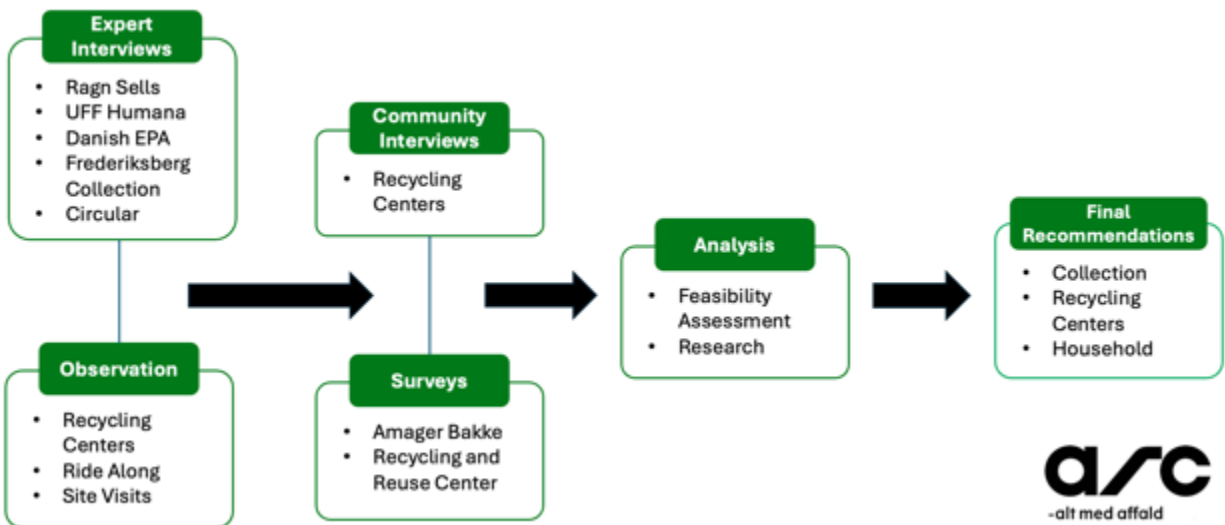


Figure 4. A flowchart detailing the methodology used to achieve our goal.

Chapter 4. Results and Discussion

Our team observed textile collection through visits to Ragn-Sells, UFF Humana, local recycling centers, and participating in a “ride-along” with a Frederiksberg collection truck. Our semi-structured expert interviews with UFF Humana, Ragn-Sells, the Danish EPA and Circular, as well as community interviews with residents at recycling centers, helped identify proper handling protocols and barriers for textile waste disposal and reuse. We also evaluated collection practices at households and recycling centers. This chapter highlights and discusses key findings from our study.

Finding 1: Textile Waste Information is Inadequate

We have found that information distributed around the two-stream textile waste system is inadequate. Information is non-standardized, recycling center signage is lacking, and residents are struggling to understand the new system.

Information on the textile waste stream is non-standardized across the municipalities.

While EU and Danish law mandates the collection of textile waste at households, municipalities have the discretion to decide how this waste is collected. As illustrated in **Table 1**, there are different methods of collection in place for municipalities in ARC’s administrative area.

Table 1. The collection type and frequency of collection in each municipality (ARC)

Municipality	Residential type	Collection method	Collection interval
Dragør	Single and Multi	Curbside	-
Frederiksberg	Single-family	In cardboard container	Once a month
Frederiksberg	Multi-family	In specific container	Once a month
Hvidovre	Single-family	Curbside	4 times a year
Hvidovre	Multi-family	Call for pick-up	No interval
Tårnby	Single and Multi	Curbside	-
Recycling centers	-	In specific container	2 times a week

Municipalities are also responsible for distributing information on waste fractions to residents. Our interviews with experts from the Danish EPA found that proper handling protocols exist and are clearly prescribed using the EU’s waste hierarchy to construct guidelines for Denmark (EPA Interview 1, March 15, 2024). While the EPA provides this information, each municipality has control over the information distributed. Municipalities may choose to distribute the EPA’s graphics and information or create their own - often, choosing the latter. An interview with a spokesperson from UFF Humana noted that “When every municipality in Denmark has a slightly different system and guidelines for textile waste and reuse, it causes confusion” (UFF Interview 1, March 13, 2024).

Residents are unaware of the two-stream system.

To better understand the perspective of residents in the five municipalities, we conducted 20 interviews using a sample of convenience across multiple recycling centers operated by ARC. When asked if they understood the new textile waste system, many respondents were confused, not having heard of the textile waste fraction. We found that 50% of individuals we interviewed did not know that there was a textile waste stream outside of the reuse stream. Of those that were aware of the new fraction, many failed to accurately describe sorting criteria, suggesting a lack of awareness of critical components of the system.

What do you do with your textiles that are not as nice [compared to reuse]?

I throw [them] out.

Have you heard about the new textile [waste] system?

No, no. What is it?

- Resident 4, Borgervænget

To further understand resident perspectives, we distributed a survey to ARC employees and posted flyers at recycling centers. Combining results from both pools of participants to analyze the data, we collected 27 responses – 17 from ARC employees and 10 from residents in the participating municipalities. Respondents were asked to rank the top three ways in which they dispose of their textiles (**Figure 5**). Based on these results, we found few respondents disposed of textile waste at the household, shown by the red portion. This suggests that participants may not be aware of the new household textile waste collection system.

Methods of Textile Disposal

First to Last Choice of Disposal
Outer to Inner Circle

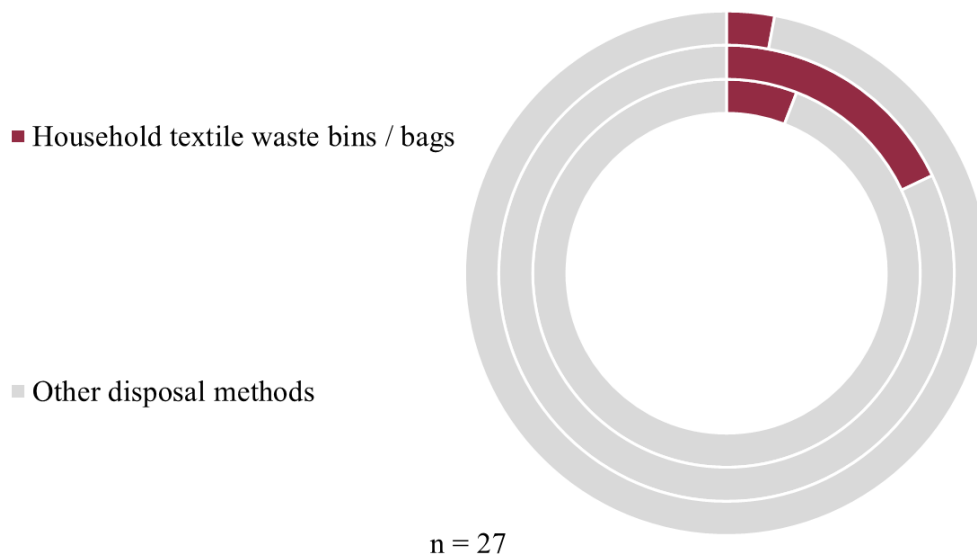


Figure 5. Survey results for preferred methods of textile disposal.

Signage at recycling and reuse centers is sparse and existing signage is often hidden from view and lacks important information.

All centers have standardized pictograms and bin labels, though some also contain additional textile disposal information. The additional signage highlights criteria for textile waste sorting and reminds residents to knot their textile bag before disposal (**Figure 6a**). While this signage is helpful, a limited number of centers currently have this sign displayed.

Of the centers that display this information, signage is often hidden and out of sight for residents. On standardized bin labels, information about sorting criteria is listed at the bottom of the bin, limiting readability for citizens (**Figure 6b**).



Figure 6. Signage on sorting practices (a) and textile waste bin label (b). English translated signs can be found in Appendix F.

Additionally, other information is omitted from existing signage altogether. Our survey asked respondents to rank the importance of the environmental impact of textile disposal. Our results suggest that respondents value the environmental impact of textile disposal, with 74% ranking it as important or very important (**Figure 7**). Important information like the environmental impact is valued by residents, but it is absent from existing signage.

How important is the environmental impact of textile disposal to you?

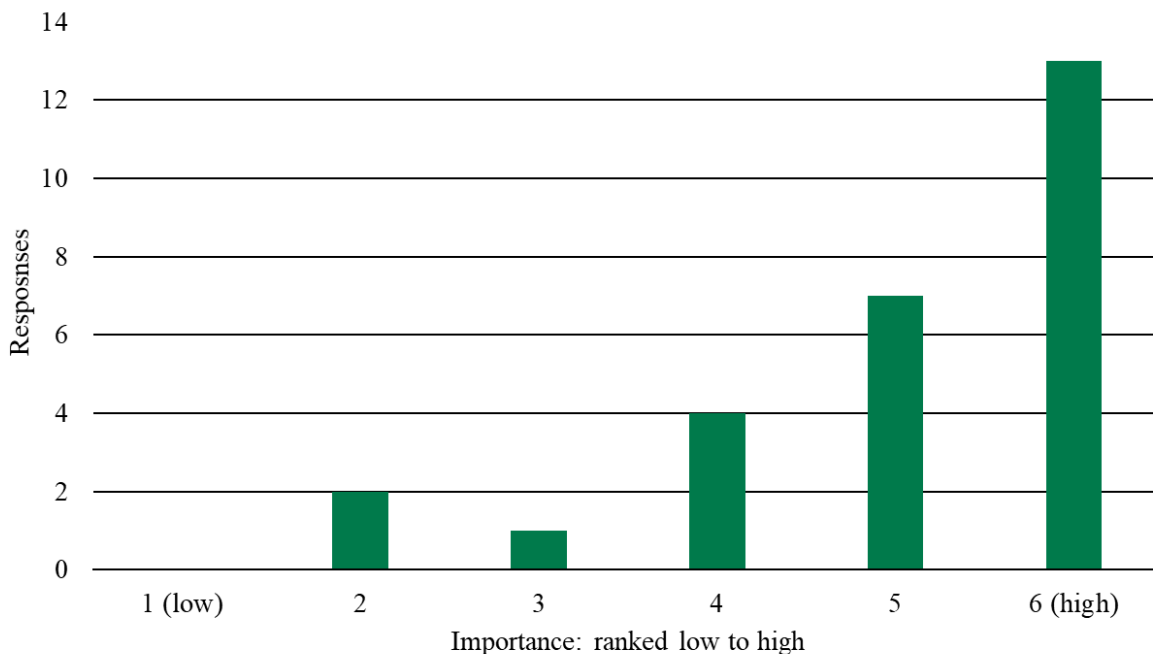


Figure 7. Survey respondent rankings for importance of environmental impact of textile waste disposal.

Furthermore, conversations with Ragn-Sells suggest hybrid textiles (textiles that have non-recyclable elements) are frequently disposed of in textile waste bins (Ragn-Sells Interview 1, March 14, 2024). Information at recycling centers does not inform residents of nuances like this in the textile waste fraction.

Finding 2: Collection Infrastructure and Resident Negligence Contaminate Textiles

We have found that collection infrastructure and community practices contribute to textile waste contamination. Textiles are a fragile waste fraction, that can be soiled by water, food waste, and other contaminants. Visiting ARC’s recycling and reuse centers, we found that each center is unique, though the findings apply to most locations.

Textile waste collection bins are not waterproof.

Across the centers we visited, we observed three main bin designs for textile waste (**Figure 8**). Each bin has different capacities and mechanism for opening. None of the designs were waterproof. In **Figure 8a**, the bin opens upwards to the back, allowing water to hit clothes and to leak behind the lid. The bin shown in **Figure 8b** opens outwards to the sides, allowing water to hit clothes and seep through the central crack when the lid is closed. The bin shown in **Figure 8c** opens towards residents, allowing water to enter the bin when open.



Figure 8. Common textile waste bins at recycling and reuse centers (most common on left to least common on right).

Textile waste bins are not sheltered at recycling and reuse centers.

In the centers we visited, only a few textile waste bins were located under an external covering. In some centers, external coverings or shelters were used to house fractions that are not contaminated by exposure to water. Other centers protected waterproof textile reuse containers, leaving vulnerable textile waste containers uncovered (**Figure 9**).



Figure 9. Textile waste bins stored outside while waterproof reuse bins sheltered from elements at the Sydhavn recycling center.



Textile collection is infrequent and waste trucks are sometimes wet before collection.

On our “ride along” conducted with the Frederiksberg textile collection truck we observed bins with varying amounts of textiles. Some bins were completely empty, and others were overflowing with waste. Our driver mentioned that collection workers are supposed to report overfilled bins in a company app, alerting maintenance workers to add bins to collection locations. Even with additional capacity, household textile waste bins still overflow, and with workers collecting the same bin once a month, contamination occurs frequently.

In addition to collection frequency and maintenance, we learned about the waste collection trucks. Textile waste is collected by a truck specifically for textiles to prevent cross contamination between fractions. Despite this practice, when other trucks break down, the textile waste truck is sometimes used to collect other waste fractions. The inside of the truck is always washed afterwards to minimize contamination. Trucks are equipped with a drainage system to remove most of the water from the inside of the truck, though there is no drying protocol in place to remove any additional water after washing or in between pickups.

After textiles are picked up in ARC’s administrative area, waste trucks bring the textile waste to UFF Humana (from Copenhagen) or Ragn-Sells (from Dragør, Frederiksberg, Hvidovre, and Tårnby). From our trip to Ragn-Sells we observed rust-coated bags of textiles. When talking with a representative from Ragn-Sells it was explained how water in the metal collection trucks may produce rust that contaminates the textiles.

Textile waste bins are often left open, tampered with, and overfilled.

An interview conducted with a Frederiksberg textile collection worker revealed that people rip open bags and sift through household textile waste bins, often leading to bin lids being left open and clothes strewn about. Conversations with workers at recycling centers revealed similar behavior where they have seen residents going through the bins.

At recycling centers, we also found that textile waste bins are consistently full, exposing textiles to the elements (**Figure 10**). An interview with a recycling center worker pointed to the lack of locking mechanism on the textile waste bins as a contributor to overfilling. Reuse bins at recycling centers automatically lock once they are full. The worker stated once the reuse bins are full, people then dump all their textiles into the waste bins.



Figure 10. Overfilled textile waste bin at Bispeengen recycling center in Frederiksberg.

Residents do not always bag textile waste.

Employees in ARC's recycling department told us that bagging textiles is the best practice for both the textile reuse and textile waste stream as it protects textiles from contamination. We observed unbagged textiles in the textile waste bins at recycling centers as seen in **Figure 11**. At one center visit, we saw a resident dump clothing out of a water-tight bag into the textile waste bin. We then observed the result of these unbagged textiles at Ragn-Sells where the quality of textile waste (contamination) and bagging practices were visibly better for some municipalities compared to others.



Figure 11. Unbagged textiles at Møllegade reuse center.

Finding 3: Experts are Divided about the Prospects of the New Two-Stream System

Before speaking with experts about the newly implemented two-stream system for textile waste and reuse, we assumed that stakeholders in the waste industry were unified in their opinion of its effectiveness. However, during our expert interviews we realized a clear difference of opinion on the new two-stream system.

Ragn-Sells and Circular have doubts about the future of the two-stream system.

Ragn-Sells has the opinion that “the two-stream system [for textiles] will die.” It cited how the EU eventually wants to create a uniform system for waste disposal. It believes that the residents’ confusion stemming from the two-stream system, as well as the lack of export traceability from NGO’s, will cause Denmark to combine the system into one stream (Ragn-Sells Interview 1, March 14, 2024). Ragn-Sells provided insight into how the ever-changing market for reusable and recyclable textiles shifts what can be upcycled into a new product that companies and consumers will buy. Recycling

“The two-stream system [for textiles] will die.”

- Ragn-Sells representative

textiles is becoming less profitable because the virgin material used in the production of new textiles cannot be as easily recycled (Ragn-Sells Interview 1, March 14, 2024).

Ragn-Sells also believed the average resident cannot keep up with the complex market to properly sort what is considered recyclable or reusable. Textile waste is sorted by hand. Sorting workers are trained to identify what is recyclable from what belongs in residual waste. Waste is sorted without gloves so that the worker can determine if clothes are wet. Other considerations like smell and stains also help determine whether textiles can be recycled or not. Only expert sorting companies, such as the one Ragn-Sells contracts with, are truly capable of making the decision of whether a textile can be reused, recycled, or if it belongs in the residual waste stream (Ragn-Sells Interview 1, March 14, 2024). Interview 1, March 14, 2024). Circular also holds this opinion. Representatives from the company noted that “citizens are not aware of [which] textiles are reusable or should be recycled” (Circular Interview 1, April 5, 2024). The ineffectiveness of the two-stream system is supported by Ragn-Sells’ data and our own observations, such as entire batches of textiles being wet, smelling, or contaminated with organic waste.

UFF Humana and the Danish EPA have hope for the success of the two-stream system.

UFF Humana is aware of the problems with the two-stream system but remains hopeful. According to UFF, 78% of textiles collected from their humanitarian bins are suitable for reuse (UFF Interview 1, March 13, 2024). UFF cites time as the biggest barrier for proper textile waste disposal. “We have had 50 years to perfect the [textile reuse] system. The same time and dedication need to be put into this new [two-stream textile waste] system” (UFF Interview 1, March 13, 2024). A representative from UFF noted that “Implementing a one-stream system for textiles will deprive people the right to know what is and isn’t reusable” (UFF Interview 1, March 13, 2024). The Danish EPA shares this opinion, working to support and build the system since its implementation (Danish EPA Interview 1, March 15, 2024).

“Implementing a one-stream system for textiles will deprive people the right to know what is and isn’t reusable.”

- UFF representative

Discussion

Observations and conversations with residents, collection workers, and waste experts reveal flaws with the two-stream textile collection system. A discussion of failures of the new system can help guide system improvements going forward.


The textile waste fraction is new and confusing. Many residents are either unaware of the fraction or its sorting criteria due to the lack of standardized information distributed by the municipalities. Further, residents may ignore information that is published by municipalities. While recycling centers try to combat this with signs explaining the sorting criteria of the fraction, it is often overlooked or inaccessible. Our meeting with UFF brought to light a case study done in Norway, Sweden, Germany, and Denmark that determined how the structure and information at recycling centers affect the quality of textiles disposed. It was found that Sweden’s textile collection process was the best because of the quality and quantity of information for instructions

to properly sort textiles. The information also promoted the importance of the system, and where the clothes end up after the residents dispose of them (Nørup et al., 2018). The amount of information given to residents at different recycling centers strongly correlates to proper practices of waste disposal. The lack of information provided to Danish residents contributes to improper disposal, leading to contamination and the downgrading of textiles. Informed by our interviews and surveys, information must be distributed to residents so that they are informed of the system, the criteria for each stream, and the overall environmental impact.

Collection infrastructure and intentional resident misuse also contribute to textile waste contamination. Collection infrastructure, including bins and trucks, are not well designed to house textile waste. The new textile waste bins were rolled out quickly, potentially contributing to overlooked design elements. Despite its current state, infrastructure (bins and shelters) exists to protect textiles from water contamination. Containers have been designed for water-sensitive waste fractions, including outfitted shipping containers that are being used for a pilot mattress recycling trial (Figure 12). Trucks, while equipped with drainage systems, likely never dry completely, further contaminating textiles in transit.



Figure 12. Shipping container setup for pilot mattress recycling trial.



Resident negligence contributes to textile contamination because infrastructure fails to protect textiles unless they are properly disposed of. As residents dig through textile waste bins, leave lids open, or overfill containers, textile waste becomes contaminated. These actions are intentional and while they can be deterred, they cannot be entirely prevented. What is within ARC’s control is system infrastructure – something that can be changed to mitigate contamination caused by residents, and to reduce direct collection contamination.

Experts with differing opinions may be preventing collaboration to take actionable steps towards improving the current system. Disagreements on the prospects of the new two-stream system can also lead to inconsistencies in how the system is run. For example, workers at recycling centers disagreed on the viability of the two-stream system. At one recycling center, workers tried creating a “one-stream system” by making the textile waste bins inaccessible. Workers noticed residents placed all their textiles in textile waste bins if they were next to or in front of the reuse bins. Putting the reuse bins front and center also made the textile waste bins overflow less often. At a different recycling center, a worker was very enthusiastic about the two-stream system, and even suggested ideas to introduce more opportunities for donating reusable textiles.

The complexity of the new system and lack of agreement among experts in the field is itself a barrier for proper textile waste disposal and reuse. Circular and Ragn-Sells’ pragmatic and slightly pessimistic point of view stands in contrast to UFF and the Danish EPA’s optimistic outlook for the future of the more complex two-stream system. According to the Danish EPA, the two-stream system was developed to protect humanitarian organizations such as UFF Humana (EPA Interview 1, March 15, 2024). The two-stream system protects UFF by giving it a steady and reliable source of reusable textiles. All of ARC’s recycling and reuse centers have textile reuse bins, and it contracts with UFF to collect textiles from these bins. ARC contracts with UFF because it fulfills the company’s internal requirements regarding traceability of exported reusable textiles. Without the two-stream system in place, the textile reuse and waste fractions would combine into one fraction. This allows for companies who may be more capable of handling large amounts of textile waste to bid on collection from ARC’s recycling and reuse centers. The two-stream system allows many communities around the world to receive much needed reusable textiles. However, problems arise from protecting the current system in place. Because UFF does not export waste, it is not regulated by the government of Denmark like Ragn Sells. Despite UFF creating a transparency report every year detailing the export of reusable textiles, there is worry that some of what is being sent overseas could be considered waste (Ragn-Sells Interview 1, March 14, 2024). A two-stream system may promote greater amounts of textiles being reused because it keeps separate a stream of uncontaminated reusable textiles. However, keeping this system would require more administrative work for the NGO’s in regard to documentation and traceability.

Amid expert disagreement, the Danish EPA has pushed for the two-stream system, sending media campaigns promoting it to the municipalities. UFF has evidence that its textile reuse stream is performing exceptionally well. However, it recognizes that in terms of barriers for textile waste disposal and reuse, the major problems come from the newly implemented waste stream. Despite both sides seeing the two-stream system differently, there is still agreement that systemic changes must be made, creating opportunities for improvement.

Chapter 5. Recommendations

Informed by our key findings, we have created a list of recommendations that address two overarching concerns that we identified in this study: insufficient information about the textile waste and reuse stream and widespread points of contamination.

Addressing Insufficient Information

Recommendation 1: Develop a standardized media campaign that emphasizes the importance of the new textile waste stream.

Why:

We recommend that ARC's municipalities initiate a joint social media campaign on textile waste disposal. From our interview with UFF, we found that a lack of cohesion among past media campaigns confuses residents and further perpetuates improper disposal. Our community interviews corroborate this claim as we found most interviewees were confused about the new two-stream textile waste system. Standardization of this campaign is therefore crucial. We also determined that a large portion of interviewees either received their information from some form of social media, public outreach, or through word-of-mouth. Posting on each municipality's socials will address a large number of residents.

How:

A media campaign would be a collaboration between ARC, its five municipalities, and the Danish EPA. The priority of this media campaign will be to alert residents that there is a new waste stream, since we found that residents lack this essential information. A campaign rather than a one-off post reduces the risk of the information being overlooked.

Specifically, the focus of the media campaign would be to highlight proper textile waste disposal and to specify what can and cannot be in each stream. A great way to accomplish this would be through comedy and eye-catching imagery, which audiences respond better to than copious amounts of information. There is an opportunity to educate residents about the environmental impact of recycling textiles, teaching the waste hierarchy, and to clarify what happens to textiles once they are disposed of.

An example of a mock-up media post can be seen in **Figure 13**, where a trashcan character is being used to draw in audience members. The post is not information-heavy and instead gives a bite-sized piece of information that is crucial to improving the textile waste system. The goal is to give the audience something to remember, which can be accomplished through a fun character like this personified trashcan.



Figure 13. Mock-up media post.

When:

To optimize engagement and outreach, we recommend that this campaign be carried out for a week, with media postings daily, or for an entire month, posting on the same days each week. This scheduled frequency enables topics posted to stay relevant for the viewer. Supporting activities and outreach can also occur at the recycling centers to build awareness during the campaign.

Recommendation 2: Adjust existing signage on textile waste bins and at recycling and reuse centers.

Why:

We recommend moving existing information and generating new signage to encourage proper disposal methods and sorting of textiles. Existing information at centers that describe differences between textile waste, textile reuse, and residual waste are helpful, but are often overlooked by residents. We believe the placement of this information has been partially to blame. Signage must not be obstructed and should be placed in a location that does not hinder waste collection. If shelter for textile waste areas is implemented, signage can be built into design plans. Additionally, information at the bottom of textile waste bin labels should be emphasized, moving information to a more eye-catching location.

Our survey results indicated that new information is needed on the signage. We found that respondents in the five municipalities suggest that the environmental impact of recycling is important to them. At the same time, we found that residents clearly lack the knowledge needed to properly dispose of their textile waste. We suggest educational signage be placed at recycling centers to inform residents about where textile waste and reuse ends up. We also suggest that stickers be placed on textile waste bins at both recycling centers and at household collection points to remind residents to bag their textile waste.

How:

For household collection points, a pictogram of a bag reminding residents to place their textiles in a clear bag like the one used for reuse at recycling centers can be added to the textile waste bins. The more comprehensive sticker signage at recycling centers can continue to have information about what goes into the stream: i.e. clothes with holes, stains, etc. (**Figure 14**).



Figure 14. The redesigned textile waste sticker label emphasizes bagging of textiles.

We recommend conducting site assessments at recycling and reuse centers to determine the ideal location for educational signs based on previously stated criteria. Once the signs are redesigned to include environmental impact they can be installed at these centers (**Figure 15**).



Figure 15. A redesigned sign for recycling and reuse centers emphasizing the environmental impacts of reuse, textile waste, and residual waste.

When:

The bins can be updated with new stickers when the weather conditions are ideal. The addition of a sticker on textile waste bins reminding residents to bag their textiles can be implemented at households by collection workers during their route and recycling center staff at recycling and reuse centers.

Adding and improving existing informational signs at recycling and reuse centers requires minimal rearrangement based on visibility, as the signs do not take up significant space. This allows for implementation to begin once the design is finalized.

Addressing Points of Contamination

Recommendation 1: Adjust layout at recycling and reuse centers to provide shelter to textile waste bins.

Why:

We recommend that textile waste bins be placed under existing shelter, or that shelter be installed in textile waste collection areas. From our site assessments, most recycling center collection areas for textiles do not adequately prevent contamination from the elements. For larger facilities, we recommend shipping containers be placed at recycling centers in areas where textile waste is collected. Waste bins can then be placed inside the shipping container, protecting textiles from the weather. A semi-permanent tent can be substituted if space constraints prevent a container from being installed.

At the smaller reuse centers where shipping containers are not practical, we recommend placing textile bins in available space under permanent structures or sheds. From our observations of reuse centers, there was often underutilized space under such weatherproof coverings.

Finally, we recommend restructuring the layout of textile waste and reuse bins at larger recycling centers. We determined that the location of textile reuse and textile waste bins may influence the frequency of bin use. Specifically, textile reuse and waste bins need to be equally accessible and prioritized. A re-ordering of bin layout could simultaneously reduce the overfilling of specific bins, while facilitating and prioritizing the core initiative of the two-stream system.

How:

Implementation of our recommendations could follow the procedure below:

1. Conduct a site assessment of each recycling center to determine if there is space to fit a shipping container to house the textile waste bins. Similar audits for reuse centers should be done to assess if there is available existing infrastructure to shelter the textile waste bins.
2. Identify locations where a shipping container should be used, a tent should be used, or if existing infrastructure should be used to cover the textile waste bins.
3. For each category, draft a sample of how the layout of textile bins at recycling centers should look based on the recommendations above. An example of this can be found in **Figure 16** and **Figure 17**, as well as in Appendix E.
4. Obtain approval from municipalities, and any permits required to place a shipping container or semi-permanent tent.
5. Once structures are in place, move textile bins according to draft layout.

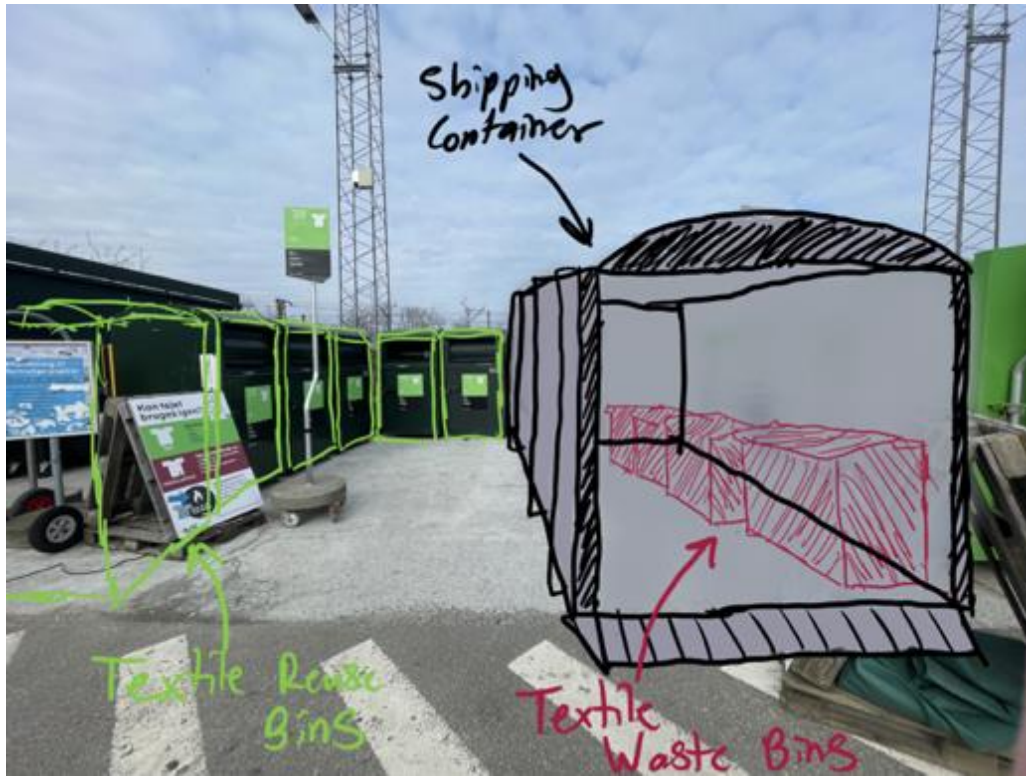


Figure 16. Mock-up of the implementation of a shipping container at Borgervænget recycling center.

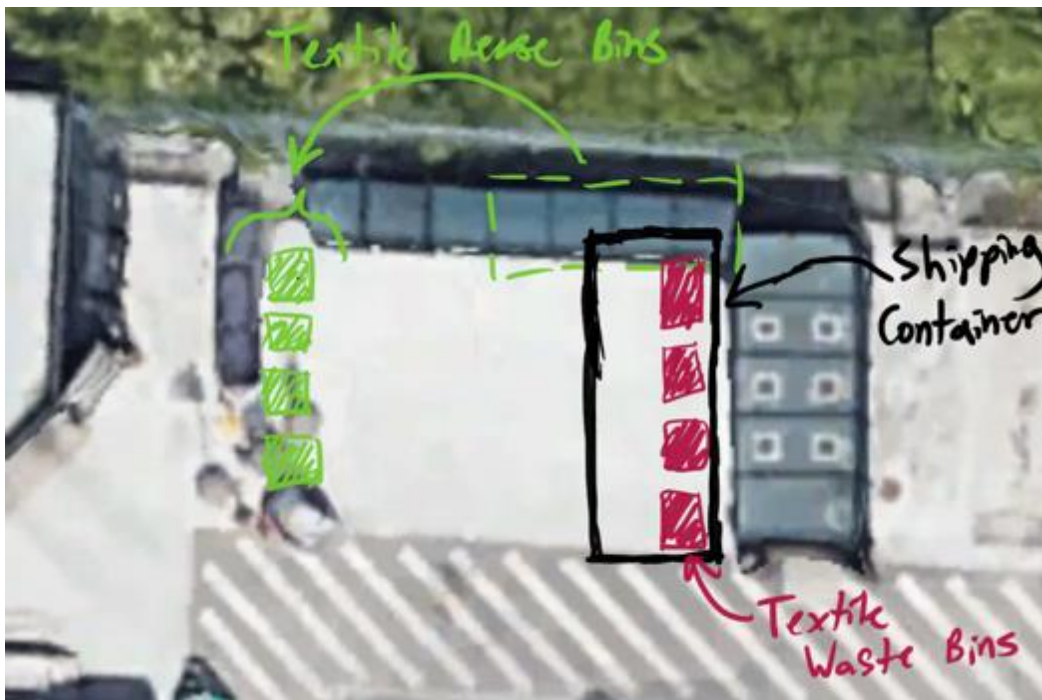


Figure 17. Birds-eye view of the implementation of a shipping container at Borgervænget recycling center.

When:

Implementing shipping containers and tents could take some time. It will depend on how quickly site assessments can be performed, how difficult it is to obtain permission/permits, and how quickly shipping containers and tents can be acquired. Because this process would be a large undertaking, we recommend conducting pilot testing at a sample of recycling centers. This could follow a similar pattern as the trial run for utilizing shipping containers to house mattresses, a similarly water-sensitive fraction.

The moving of bins within existing facilities does not require an investment in new equipment and is a low-cost solution. Implementation of this recommendation can begin immediately.

Recommendation 2: Employ drying procedures for textile waste collection trucks.**Why:**

We recommend that textile waste collection trucks be dried after washing and at the end of each pickup run. We learned that trucks are cleaned after collecting non-textile waste but are not dried, leading to possible contamination from water and rust. Further, given the significant percentage of textiles that are wet after being collected, normal collection dampens the inside of the trucks, potentially contaminating subsequent pickups.

Based on industrial practices for drying metal surfaces, we suggest the following methods be tested to dry trucks, in order of increasing cost:

1. Manual drying
2. Industrial drying fan
3. Industrial heat lamp

The responsibility for the collection of textiles is on the different contracting companies. As such, each company must consider the drying effectiveness, cost, and time required for each drying method.

How:

To implement this recommendation, we suggest that one municipality test drying efficiency and share results with other municipalities in ARC's administrative area. Together, municipalities could locate resources internally before purchasing equipment. Using sourced equipment, municipalities should test drying procedures, using a dry truck humidity reading as a benchmark. These tests should take place between pickups and after washing to simulate collection conditions. The capital cost and time to dry should both be considered when determining the best drying solution. After sharing results, equipment can be bought, and drying protocols can be standardized across textile pickup trucks.

When:

After sourcing drying equipment, a municipality should run the trial immediately and should share results promptly to prevent additional contamination. Based on results, other municipalities should invest in equipment and draft protocols for use.



Recommendation 3: Establish protocols for waste management workers to ensure textile waste bins are well-maintained.

Why:

We recommend that waste management workers who collect other waste fractions help surveil and maintain the textile waste fraction at the household level. Textile waste bins have longer periods between pickups and are often found open with textiles strewn about. If the textile waste bins are checked by waste management workers picking up other fractions, they can ensure that the textiles have a shorter period of exposure from the elements. This recommendation does not significantly delay the workers' day and would not require any modification of their pickup routes.

How:

Our recommendation would require that workers who collect other waste fractions check on the textile waste bins during their regularly scheduled routes. If a textile waste bin lid is open, then they would close it. If textiles are outside their assigned bin, then they would put them back in. By enlisting a larger number of workers to maintain these bins, each worker would only have to occasionally service the textile waste bin on their route. This recommendation would require waste management workers to be informed on the best practices of textile waste disposal.

To test the validity of this recommendation, we suggest a survey or interviews with waste management workers to identify if this would be a burden. We also suggest collecting data from Ragn-Sells in municipalities where this is implemented to identify if there is a visible decrease in soiled textiles.

When:

This recommendation can start on a trial basis to determine validity defined by criteria stated previously. Based on the success of this trial the other municipalities should follow accordingly.

Recommendation 4: Implement single-dispense bag dispensers at recycling and reuse centers in textile collection areas.

Why:

We recommend setting up secure single-dispense bag dispensers at recycling centers. From our observations, a significant portion of textiles are disposed without being bagged, exposing items to contamination. Currently, bags are not provided at textile collection areas unless an employee is asked to provide them.

In our interviews with ARC employees and recycling/reuse center workers, we learned that there is a risk of residents taking advantage of free items at centers. This may include taking rolls of bags lying around. As such, the proposed bag dispenser must be anchored to a fixed structure and must be in a location where workers can monitor for misuse. Bags should be single-dispense to prevent residents from taking more bags than needed and should be accompanied by a sign noting proper use and consequences for improper use.

**How:**

To implement this recommendation, we suggest that pilot tests be completed in a single recycling center. A single bag dispenser can be purchased, and appropriate signage can be drafted. Workers at the proposed recycling center should observe and document the quality of textile waste before the trial has begun. The trial should take place over a few weeks. Before truck collection, recycling center workers should document textile pickups, noting changes in bagging practices. Workers should monitor the bag dispenser and refill the dispenser when empty. If observations show a significant difference in bagging practices, dispensers and signage should be implemented in other ARC recycling and reuse centers.

When:

The trial should be run for approximately a month to conclusively determine effectiveness. Based on analysis of pilot results, additional trials can be run at other centers, or rollout of dispensers across all centers can be coordinated.

Chapter 6. Conclusion

Denmark is among the first EU countries to implement a two-stream system for textile waste collection. Our study revealed points of concern in the organization of household collection and recycling centers during the rollout of this new initiative. Our recommendations included steps to improve the textile collection processes within ARC’s administrative area and waste collection facilities. We hope that this project will benefit ARC and its immediate goals. We also appreciate the opportunity to contribute to the greater cause of UN Sustainable Development Goal 12, as we move toward more responsible future planning for cities around the world (**Figure 18**).

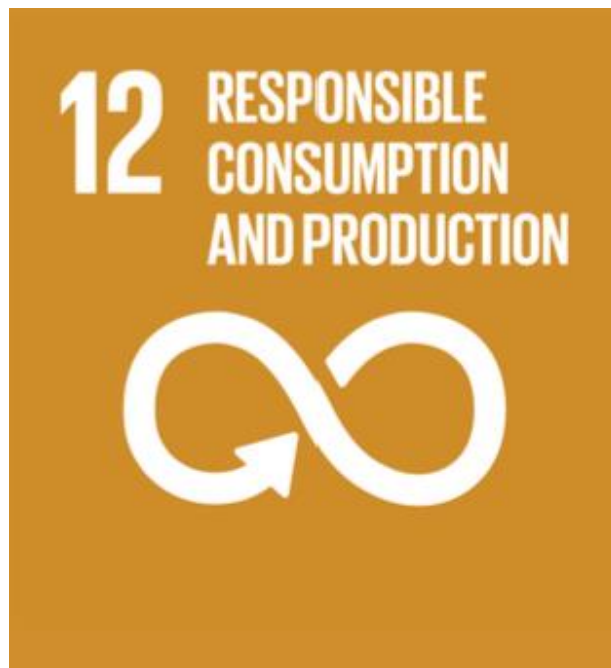


Figure 18. United Nations Sustainable Development Goal 12.

We feel confident that simple changes will help to strengthen the two-stream system, improving resident awareness and reducing textile waste contamination. The two-stream system for textiles is new, and it is apparent that all involved parties have not yet fully bought into recent changes. With Danish legislation supporting the two-stream system, drastic changes cannot be made without political support. Whether the two-stream or one-stream system is the best option for Denmark moving forward is yet to be determined. While discussions continue, it is important to strengthen the system in place – an action that our recommendations support and that ARC has direct control over.

Bibliography

- Amager Ressource Center. (n.d.) *About ARC*. Retrieved January 25, 2024, from <https://a-r-c.dk/english/visit-arc/>
- Amager Ressource Center. (n.d.) *From Waste to Energy – The technology Inside Amager Bakke*. Retrieved January 25, 2024, from <https://a-r-c.dk/english/from-waste-to-energy/>
- Berg, B. (2001). *Qualitative Research Methods for The Social Sciences (Fourth Edition)*. Allyn and Bacon. ISBN 0-205-31847-9
- Bodin, R. (2016). *To Reuse or to Incinerate?: A case study of the environmental impacts of two alternative waste management strategies for household textile waste in nine municipalities in northern Stockholm, Sweden (Dissertation)*. Retrieved from <https://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-192876>.
- Circular Copenhagen. (2019). *Resource and Waste Management Plan 2024*. København Kommune. https://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detalje&id=1991
- Circle Economy. (2023). *The Circularity Gap Report - Denmark*. [https://assets-global.website-files.com/5e185aa4d27bcf348400ed82/6554e0ccaa7fbc587fe6fc73_Web%20version%20-%2020231106%20-%20CGR%20Denmark%20-%20Report%20-%2020210x297mm%20\(1\).pdf](https://assets-global.website-files.com/5e185aa4d27bcf348400ed82/6554e0ccaa7fbc587fe6fc73_Web%20version%20-%2020231106%20-%20CGR%20Denmark%20-%20Report%20-%2020210x297mm%20(1).pdf)
- Cuc, S., Iordanescu, M., Gîrneata, A., & Irinel, M. (2015). Environmental and socioeconomic sustainability through textile recycling/Sustenabilitatea de mediu si socioeconomica prin reciclarea textilelor. *Industria Textila*, 66(3), 156-163.
- European Commission. (n.d.). *Waste framework directive*. Environment. https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en
- European Commission Directorate-General Environment. (2012). *Guidance on the interpretation of key provisions of directive 2008/98/ec on waste*. European Commission. <https://ec.europa.eu/eurostat/documents/342366/351811/WEEE-2+Guidance+of+interpretation+Directive+2008-09-EC+on+waste.pdf/cb1c4f5e-d534-470a-cd71-3dc8b7d53bf7?t=1621959857496>
- European Commission Directorate-General Environment. (2018). *Directive (eu) 2018/851 of the european parliament and of the council of 30 may 2018 amending directive 2008/98/ec*. Official Journal of the European Union. <https://eur-lex.europa.eu/eli/dir/2018/851/oj#d1e723-109-1>
- European Environment Agency. (2021). *Overview of national waste prevention programmes in Europe*. European Union. <https://www.eea.europa.eu/themes/waste/waste->

[prevention/countries/2021-waste-prevention-country-profiles/denmark-waste-prevention-country-profile-2021](https://www.eurostat.ec.europa.eu/press-room/articles/2021-waste-prevention-country-profiles/denmark-waste-prevention-country-profile-2021)

European Parliament. (2023). Circular economy: definition, importance and benefits. European Union.

https://www.europarl.europa.eu/pdfs/news/expert/2023/5/story/20151201STO05603/20151201STO05603_en.pdf

Gustav Sandin, Greg M. Peters, Environmental impact of textile reuse and recycling – A review, *Journal of Cleaner Production*, Volume 184, 2018, Pages 353-365, ISSN 0959-6526, <https://doi.org/10.1016/j.jclepro.2018.02.266>.

Jacoby, J., Berning, C. K., & Dietvorst, T. F. (1977). What about Disposition? *Journal of Marketing*, 41(2), 22-28. <https://doi.org/10.1177/002224297704100212>

Kjær, B. (2013). Municipal Waste Management in Denmark. European Environment Agency. <https://www.eea.europa.eu/publications/managing-municipal-solid-waste/denmark-municipal-waste-management>

Klimaplan for en Grøn Affaldssektor og Cirkulær økonomi. Regeringen. (2020, June 16). <https://www.regeringen.dk/media/9591/aftaletekst.pdf>

Martikkala, A., Mayanti, B., Helo, P., Lobov, A., & Ituarte, I. F. (2023). Smart textile waste collection system–Dynamic route optimization with IoT. *Journal of Environmental Management*, 335, 117548. <https://doi.org/10.1016/j.jenvman.2023.117548>

Niinimäki, K., Peters, G., Dahlbo, H. et al. (2020). The environmental price of fast fashion. *Nat Rev Earth Environ* 1, 189–200 (2020). <https://doi-org.ezpv7-web-p-u01.wpi.edu/10.1038/s43017-020-0039-9>.

Nørup, N., Pihl, K., Damgaard, A., & Scheutz, C. (2018). Development and testing of a sorting and quality assessment method for textile waste. *Waste management*, 79, 8-21 <https://doi.org/10.1016/j.wasman.2018.07.008>

Schwartz Glottrup, Casper. Nybo Kofoed, Tanja Marie. (2024). *Background information for textile project*, Amager Ressource Center

Sonnenberg, N. C., Stols, M. J., Taljaard-Swart, H., & Marx-Pienaar, N. J. M. M. (2022). Apparel disposal in the South African emerging market context: Exploring female consumers' motivation and intent to donate post-consumer textile waste. *Resources, Conservation and Recycling*, 182, 106311. <https://doi.org/10.1016/j.resconrec.2022.106311>

Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy. (2023, June 19). United States Environmental Protection Agency.



<https://www.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy>

United Nations Environmental Programme. (n.d.). *Denmark*. Climate & Clean Air Coalition. Retrieved January 26, 2024, from <https://www.ccacoalition.org/partners/denmark>

United Nations. *Goal 12: Ensure sustainable consumption and production patterns*. Retrieved February 23, 2024, from <https://www.un.org/sustainabledevelopment/sustainable-consumption-production/>

Ward, K. (2020). *Researching The City: A Guide For Students (Second Edition)*. Sage. ISBN 978-1-5297-0095-4

Weber, S., Lynes, J., & Young, S. B. (2017). Fashion interest as a driver for consumer textile waste management: reuse, recycle or disposal. *International Journal of Consumer Studies*, 41(2), 207-215. <https://doi.org/10.1111/ijcs.12328>

Appendices

Appendix A. General guide for expert interviews

1. What barriers do you see with the textile collection system?
2. What solutions have been tested to improve the system in place?
3. What do you think it will take to improve the residential textile management practices?
4. What pitfalls do you see with the current media campaign for textile collection?

Appendix B. Interview guide for bin collectors


1. What are the common issues you see with textile waste collection?
2. Do you feel that people generally dispose of their waste correctly?
3. Do you feel that people THINK they dispose of their waste correctly?
4. Are people content with the number of bins and the sorting they must do?
5. Is the system too complicated?
6. Do you find that the new system brought improvements or setbacks to waste separation?
7. What would it take to make the process perfect?

Appendix C. Interview guide for community and residents

1. What are your current thoughts on the new textile waste collection?
2. In your opinion, how do you define textile waste?
3. How does textile waste differ from reuse?
4. What would it take to make recycling textiles properly easier for you?

Appendix D. Survey questions

1. How do you get rid of your used textiles? (Rank top three in terms of frequency)
 - Household textile waste bins / bags
 - Humanitarian Organization bins
 - Humanitarian Organization stores
 - Reuse Shops/Flea Markets
 - Residual Waste
 - Recycling Centers
 - Other (Please specify)
2. How do you receive your information from your municipality on waste disposal?
 - Social media
 - Radio
 - Television
 - In-mail flyers or Digital Post
 - Public bulletin board
 - Municipality Website

- 
- Other
 - I do not
3. What is the best way for you to receive information on waste disposal?
 - Social media
 - Radio
 - Television
 - In-mail flyers or Digital Post
 - Public bulletin board
 - Municipality Website
 - Other
 4. How often do you find the textile bins full when you try and get rid of your textiles?
 - (not at all) 1-6 (very often) Recycling Centers
 - (not at all) 1-6 (very often) Household
 5. Do you bag your used textiles before placing them in textile waste bins?
 - Yes
 - No
 - N/A (do not use bins)
 6. Is your textile waste location sheltered from weather conditions (rainfall, snow, etc.)?
 - Yes
 - No
 7. How important is it to you to know what happens to your textiles after being disposed?
 - (not at all) 1-6 (very)
 8. How important is the environmental impact of textile disposal to you?
 - (not at all) 1-6 (very)
 9. How important is the convenience of textile disposal to you?
 - (not at all) 1-6 (very)
 10. What would it take to make getting rid of your used textiles properly easier for you?
 - (open ended)
 11. Any feedback about survey or topic?
 - (open ended)
 12. What municipality do you live in?
 - Dragør
 - Tårnby
 - Frederiksberg
 - Hvidovre
 - Copenhagen
 - Other (Please specify)
 13. If you would like to be contacted for an interview, please provide your email below.

Appendix E. Additional Recycling Center Mockups



Figure 19. Bispeengen recycling center birds-eye view.

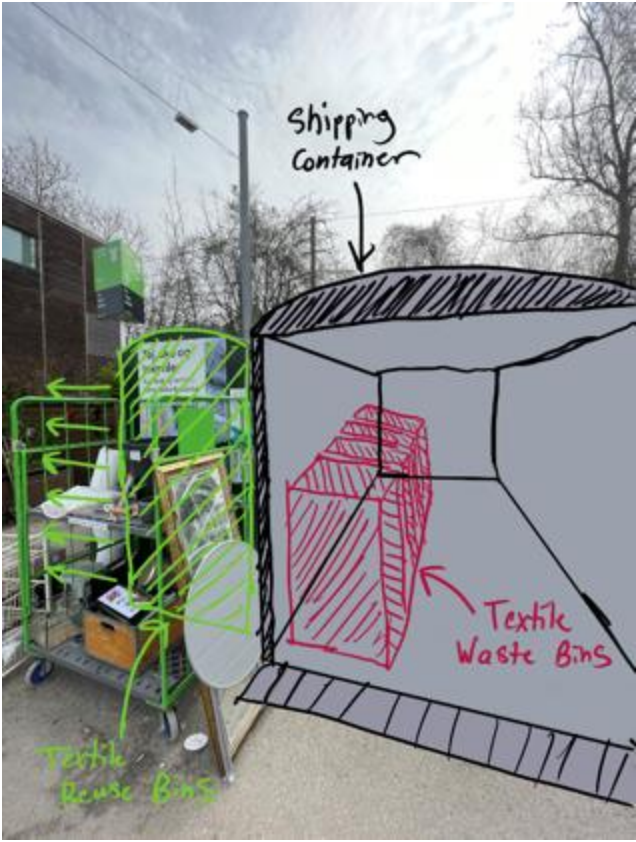


Figure 20. Bispeengen recycling center front view.

Appendix F. Translated Images of Sign



Figure 21. A translated image of the sorting criteria signs at recycling centers.

Can the clothes
used again?

Clothes for Recycling:

- Tøj
- Shoe
- Belts
- Bags

Remember
to tie a knot
on the bag

Clothes and textiles for recycling:

- . Holes, torn or stained
- . Pillows, duvets
- . Towels, curtains
- . Fabric residues

TEXTILE WASTE

Clothing and textiles for energy:

- Soiled with mould, urine or stains from paint/oil
- Cushions, mats
- Bath curtains
- Used shoes

Wad and earth
beat leak styles

REMAINDER
AFTER SORTING

a/c

Ask a recycling supervisor if you are in doubt

Figure 22. A translated image of the redesigned sign for textiles at recycling centers.



Figure 23. A translated image of the bin labels at recycling centers for the textile waste fraction.



Figure 24. A translated image of the redesigned label for textile waste bins at recycling centers.