

PARTNERSHIP FOR CIRCULAR TEXTILES - REYARN



Wolkat

Bacher
WORK WEAR SINCE 1897

RE>VALUATE
Facilitating change

PROJECT END REPORT

PROJECT INFORMATION

Project title:

Partnership for circular textiles - ReYarn

Project period:

May 2021 to April 2022

PROJECT ORGANISATION

Project lead and report making:

Kerli Kant Hvas & Nikola Kiørboe - Revaluate.

Tina Winberg - City of Copenhagen

PROJECT PARTNERS

Steen Trasborg & Ergün Arkin - Trasborg Denmark, Denmark

Jette Skov - Salvation Army ReDesign, Denmark

Kimberley van der Wal - Wolkat, Holland

Marie Budtz - Bacher Work Wear, Denmark

Lena Riechert Ewald - City of Copenhagen, Denmark

Kerli Kant Hvas & Nikola Kiørboe - Revaluate, Estonia/Denmark

Jonas Åbo Mortensen & Tina Winberg - City of Copenhagen, Denmark

DESIGN

Anders Juhl - DAY01

March 2023

TABLE OF CONTENTS

EXECUTIVE SUMMARY	4	Product 1: Home wear – tea towels	34
Local pre-sorting and reuse	5	Product 2: “Light workwear” overshirt	36
Product development and public procurement	5	Product 3: Home wear – mix of recycled and upcycled cushions	42
Public procurement	6	Update of procurement criteria	44
Circular value chain collaboration	6	Key lessons regarding product development and public procurement	44
<hr/>			
INTRODUCTION	8	PROJECT OUTREACH	46
Background	8	Citizen event and renew cards	46
Textile collection and sorting	8	LOOP conference	47
Textile recycling	9	<hr/>	
Public procurement	9	GENERAL LEARNINGS AND FUTURE IMPLICATIONS	48
Circular value chain collaboration	10	Future implications	50
The vision of ReYarn	10	<hr/>	
The ReYarn partner network	10	WORD LIST	52
The City of Copenhagen	10	<hr/>	
Reevaluate	11	APPENDIX A PROJECT DEVELOPMENT GOALS	54
Trasborg	11	<hr/>	
Salvation Army	11	APPENDIX B COLLECTION AND TRANSPORT	56
Wolkat	11	<hr/>	
Bacher	11	APPENDIX C DEVELOPMENT OF SORTING CRITERIA	58
Additional partners	11	<hr/>	
The ReYarn model explained	12	APPENDIX D RECEIVING, STORING, AND SORTING REYARN TEXTILES	62
<hr/>			
LOCAL PRE-SORTING AND REUSE	16	APPENDIX E RENEW CARDS	64
Sorting criteria	17	<hr/>	
Sorting pilots	18	APPENDIX F REYARN FABRIC AND PRODUCT REQUIREMENTS	65
Sorting pilot A and tests	18	<hr/>	
Sorting pilot B	21	APPENDIX G WASHING TEST RESULTS (TEA TOWEL)	66
ReYarn sorting experiences	22	<hr/>	
Sorting out waste	23	DESIGN PROPOSALS BY DESIGN SCHOOL KOLDING	67
Sorting for global reuse and recycling	24	<hr/>	
Key lessons regarding pre-sorting and local reuse	26		
ReYarn sorting model limitations	28		
<hr/>			
PRODUCT DEVELOPMENT AND PUBLIC PROCUREMENT	30		
Analyses of materials and products	32		
Product development and prototyping	33		

EXECUTIVE SUMMARY

The current waste management plan from the City of Copenhagen “Circular Copenhagen” has set up a range of initiatives, including a target for increased collection and better treatment of used textiles from households. The vision of the ReYarn project was therefore to develop and test circular solutions for the municipal post-consumer textiles, with the aim of gaining new insights and practical experience that could support the target of better treatment and, in more general, to capture the maximum value of the textile waste stream. The ReYarn project ran from May 2021 to April 2022.

In general, the Danish textile collection system is facing a range of challenges like low levels of local sorting capacity, low levels of local reuse, increasing volumes of low-quality textiles that end up being incinerated or exported, combined with difficulties in finding markets for the large, and ever-increasing, amounts of textile waste. Development of pre-sorting practices and capacity in Denmark, combined with better value chain management that enable full value capture of collected used textiles, is therefore key in transitioning towards a circular textile system.

The ReYarn partnership project addressed these challenges by developing and piloting a circular textile value chain model that followed circular economy principles and that focused on key elements in the post-consumer textile value chain: pre-sorting, local reuse, recycling, and uptake of recycled materials. The partnership team consisted of six partners, which covered each step of this value chain.

THE PROJECT WAS ARRANGED AROUND THE FOLLOWING FOUR KEY GOALS:

- 1** Development of manual pre-sorting practices and capacity in Denmark with focus on increasing local reuse and minimization of waste
- 2** Development of cooperation between local sorting and a recycling company to enable full exploitation of the value of used textiles and transparency throughout the value chain
- 3** Gaining knowledge and practical experience in developing circular textile products for use in the public sector
- 4** Providing insights that support the development of future procurement criteria within textiles in a municipal context

LOCAL PRE-SORTING AND REUSE

By firstly defining and then piloting a model for local pre-sorting it was demonstrated that it is possible to construct a model where local reuse is prioritized, where the share of waste to incineration is minimised, and where the two are integrated with global reuse and recycling into one single model. In this model, the destination of the collected textiles was defined from the collective perspective of the actors that represented the various steps in the post-consumer value chain, resulting in a new set of sorting criteria which the project partners then applied in two different sorting pilots. This exercise indicated that when cross value chain collaboration is built, priority needs to be given to ensuring that value is defined and understood in the same way by all partners.

The learnings from the two sorting pilots further showed that direct experience with the local reuse market is necessary if local reuse rates should increase. It also showed that manual pre-sorting for recycling over waste is an iterative process that needs to happen in close collaboration between the sorter and recycler in order to identify the maximum amounts of textiles with recycling value in the waste fraction. Piloting such a new sorting set-up was a valuable learning experience for the involved partners where existing sorting processes and definitions of waste was reevaluated, and which also emphasized that adapting existing sorting practices to new ones is resource demanding for sorters both in terms of internal capacity building and adjustments of current operations. Finally, the pilots highlighted the need for more standardized data collection methods and tools that can help harmonize data flows and facilitate operators in the value chain to collect and use data that supports overall circular value chain development.

PRODUCT DEVELOPMENT AND PUBLIC PROCUREMENT

Another cornerstone of the ReYarn project was to create uptake of recycled fibres by use of public procurement. This link would on one hand create an opportunity for the municipality to get concrete experience with products made from

recycled fibres and on the other hand create an important signal to the recycler that there is an outlet for the recycled material, affecting the entire business case of the value chain partners and thus also the system as a whole.

In the ReYarn project, the collected textiles that did not have reuse value locally or globally were sorted and processed by the project mechanical recycling partner. Based on the output from their processes, three different scalable fiber-to-fiber mechanical recycling product cases were piloted:

- tea-towels for municipal use (e.g., in public canteens and kindergartens)
- an overshirt for selected municipal staff
- a cushion intended for use in households (a consumer good product that have use outside the municipality)

The main lesson from developing the tea-towel was, that even with a rather simple product, the price premium proved to be the main barrier to large scale procurement, indicating that public procurement needs to include a stronger focus on innovation and reflect political will to invest in new solutions and to support emerging markets.

From working with the overshirt, which was a more comprehensive and complicated process, it was further shown that a holistic integrated product development strategy needs to be implemented to ensure that recycled products with a high level of innovation, succeed in the market. This means e.g., to work more actively with customers, producers, and end-users to define product requirements but also to ensure close dialogue and collaboration between textile professionals and designers and the recycler, creating necessary feedback and dialogue on the recycled materials.

In general, the project partners reported to have benefitted from the learning-by-doing environment and emphasized that it felt important for capacity building internally in their organizations.

PUBLIC PROCUREMENT

Several lessons were drawn from working with market uptake of post-consumer recycled fibres in a public procurement setting:

- Mechanically recycled fibres have their advantage as they can be processed based on relatively complex feedstocks and produced in large volumes. In this value chain, the recycled fabrics proved to primarily be relevant for home wear and light work wear (as opposed to e.g., heavy work wear).
- Public tenders can play a significant role in creating a market for recycled textile fibres but needs to be designed so they support innovation and a market which is still not in full scale and function.
- There is a need for discussing whether current textile standards and requirements could be adjusted to better include the properties of materials from recycled fibers while still living up to the purposes they should serve.
- This also means that pricing should consider the full life cycle of the product – e.g., though a life cycle assessment. This would mean that the procurer does not choose the lowest initial purchase price but instead the lowest full lifetime cost, which includes issues such as the material content of the product, product lifetime, repairability and possible end-of-life strategies. This, however, requires intensive use of product data which is in current times out of the scope for many municipalities.
- Further, it should be considered whether tenders with fewer product categories to a greater extent could meet circular material requirements.
- Although the issues with logos have been discussed in several projects and fora prior to this, it proved to (still) be a hindering barrier for further processing in the reuse value chain. More conscious design and/or use of logos is thus needed.

CIRCULAR VALUE CHAIN COLLABORATION

On a wider and more general level, the partner consortia obtained a series of valuable experiences with working with other value chain actors which will be important to address when conducting similar pilots. For example, close value chain collaboration is vital to capture the maximum value of the used garments. This required the collaboration partners to often work in a different way and disrupting their current business model and ways of doing things. As the surrounding markets are still functioning on a linear foundation, it is not possible for the actors to go full circular at once and alone which means that often in these collaborative innovation projects actors must work in two parallel tracks to learn, experiment, and prove circular practices, which therefore becomes time- and resource demanding.

The ReYarn experience also showed that physical and regular meetings are important for building trust between partners and that this trust is essential for creating a pre-competitive collaboration environment, experimenting with new processes, and exploring circular business opportunities. The partners emphasized that it was valuable that all partners met regularly, even at times when not everyone were directly involved in the agenda to capture all inputs and experiences for the processes. Further the partners also highlighted, that it was necessary to prioritize agreeing on a common terminology and goals to be able to work towards a shared goal. Therefore, there was also need for setting aside time and be open to clarify common goals, defining words, and understanding the details of challenges and barriers, that each of the partners faced. This process was also perceived as an important part of the wider trust-building and showed that circular economy needs sufficient time, priority, and willingness from all partners in order to truly succeed.

Finally, it is the intention that the insights and experiences from ReYarn regarding new local pre-sorting practices in Denmark, closer collaboration between the municipality, local reuse organizations and a recycling company, applying recycled materials in a public procurement context and collaborating across the textile value chain will provide knowledge, inspiration and ideas for other actors who are also searching to pursue (more) circular strategies and collaborations across the textile value chain.



INTRODUCTION

Reducing the environmental impacts of textile production and consumption and minimizing textile waste has gained an important focus in the agendas of governments, municipalities, non-profit sector, and private industry. In 2019, the City of Copenhagen presented its current Resource and Waste Management plan 2024 "Circular Copenhagen" which among other initiatives sets up a target for increased collection and better treatment of used textiles from households. The aim is to collect 2000 tonnes of textile waste for recycling, by 2024 at the latest. In parallel, the EU has introduced mandatory separate collection of textiles by 2025. Both initiatives require new solutions for collecting and handling of post-consumer textile waste which has led the City of Copenhagen to seek new circular practices and solutions within the textile value chain. The ReYarn partnership was created to provide new insights and learnings as a step on this journey. The following text describes the context in which it was made.

BACKGROUND

Over the recent years, several strategies, initiatives, and legislation have emerged which backs up the need for developing and experimenting new solutions and collaborations for a more circular textile sector. One of the highlights is the EU Strategy for Sustainable and Circular Textiles which was presented in March 2022 and which, amongst many things, presents a vision for textiles in 2030. This vision seeks to make the circular textiles ecosystem thriving by making re-use and repair services widely available and to reduce incineration and landfilling of textiles

to a minimum. It also aims for ensuring that textile products placed on the EU market to a great extent are made of recycled fibres that are economically profitable, driven by sufficient capacities for innovative fibre-to-fibre recycling. Further, the strategy emphasizes the role of public procurement, and in the coming years the EU Commission is expected to introduce mandatory green public procurement criteria for textile products.

TEXTILE COLLECTION AND SORTING

As in many other countries, the Danish textile collection system is facing a problem of increasing numbers of low-quality textiles that have no reuse value and therefore end up being incinerated or exported, with the risk of ultimately ending up in landfills around the world. It is difficult to find markets for the large, and ever-increasing amounts of textile waste and one of many needs for changing this situation, and to capture more value from the textile stream, is to improve the pre-sorting infrastructure and practices. This is true in general, and particularly in Denmark.

The Danish textile sorting (incl. pre-sorting) capacity is limited to a few sorting operators which primarily serve the local reuse markets (mainly nonprofit collectors with charity stores but also a few private reuse actors who distribute the collected textiles to export markets). Big amounts of textiles collected in municipalities are therefore currently exported abroad unsorted or only partially pre-sorted (manually), meaning that the local reuse value or potential recyclables are not fully captured. Collectors

THE AIM IS TO COLLECT

2,000
TONNES OF TEXTILE WASTE
FOR RECYCLING BY 2024

and sorters' collaboration with recyclers is rare and limited in large scale.

Since 2016, the City of Copenhagen has had a collection scheme for textiles at the local recycling stations (nærgenbrugsstationerne) and the bigger recycling stations (genbrugsstationerne). The fraction is collected under the designation "All textiles" and includes clothing textiles, home textiles, shoes, belts, and rugs, etc. Citizens can therefore hand in textiles for both reuse and recycling in this existing scheme. At the local recycling stations, the ordinary collection containers are supplemented by a free exchange facility where citizens can hand over and take various reusable items, including textiles, clothes, and shoes. Once the citizens are no longer interested in them, the site employee puts the textiles in a bag and into the textile container. For more on the collection scheme, please see Appendix B.

Until the start of the ReYarn project, all textiles from this collection scheme were exported as unsorted goods directly after collection. This means that any potentially reusable qualities, in the quantities collected, were not further distributed to the local reuse marked in Denmark, and therefore textile waste and reusable textiles were exported. The fate of the textiles' further journey was therefore transferred to the recipient and any collaboration with recyclers that might occur was not fully transparent for the municipality.

Therefore, practices are needed whereby the maximum value of textiles that are collected in Denmark remain in Denmark. This means that all textiles that can be prepared for reuse locally should remain in Denmark and that all contamination (other types of waste materials that have been wrongly sorted as textiles) is taken out and sent for local waste treatment. After these measures the rest is to be exported for further reuse and recycling abroad in a transparent value chain.

TEXTILE RECYCLING

Recycling of textiles into new textiles is the most desirable end-of-life strategy for non-wearable and recyclable textiles in the circular economy. Unfortunately, recycling of textiles into new textile materials is currently very limited due to the complexity of textile recycling and the lack of sorting and high-quality recycling technologies, as well as the fragmentation and inefficiency of textile value chains. At the same time

post-consumer textiles from households is the most complex stream from a recycling point of view, due to variety of items and fiber blends.

While chemical recycling solutions that have come into the market in recent years bring additional capacity, mechanical recycling is still at present the most suitable and scalable solution, with a high volume potential due to its ability to recycle the complex fraction of post-consumer textiles that consists of multiple fibers.

At the same time, mechanically recycled fibres and materials available on the market face market barriers to scale-up, as mechanically recycled fibres are sensitive to imperfections in market demand (e.g., quality and aesthetics). It is therefore necessary to explore new market opportunities for recycled fibers and the acceptance by the market in order to reach the full volume potential.

PUBLIC PROCUREMENT

The public sector is an important player in the transition to circular economy with a significant purchasing power, hence public procurement has been suggested as an important tool that could drive innovation and stimulate circular practices and business models. The City of Copenhagen regularly sources significant amounts of textile products (the upcoming tender for sourcing workwear to the City of Copenhagen is e.g., set for DKK 10 mio.) and by e.g., integrating recycled fibers into procurement practices, the city can therefore contribute to the development of a circular textile system, help stimulate a market for recycled fibers, reduce its own environmental impacts as well as showcasing circular solution development to other municipalities.

Procurement of textiles with recycled content is a new field of investigation for the City of Copenhagen and better understanding of what materials exist on the market that are applicable for public consumption in terms of e.g., performance in use and durability is needed. Hence, the specifications to be implemented in future tenders to support the market uptake of recycled textiles must be developed in accordance with the market development and testing of new products with recycled content. Further, the large quantities bought in public tenders require large supply of e.g., work wear with recycled content that is economically viable, and that meets the minimum required quality criteria.

CIRCULAR VALUE CHAIN COLLABORATION

Developing and implementing solutions that aim for circularity and transparency in material flows, new ways of collaboration across the value chain needs to take place, which is not a common practice in the current textile system. This collaboration is needed between textile designers, producers, buyers, collectors, sorters, reuse organizations and recyclers. Efficient communication between these stakeholders is critical to develop sustainable and transparent collaboration models and practices that support circular business models and value chains. Designers must better understand the needs of sorters and recyclers to develop suitable products for reuse and recycling and incorporate recycled materials in new products. At the same time sorters, reuse organizations and recyclers must understand the needs and requirements of the market. Finally, the public procurers, who represent a significant possibility for uptake of recycled fibers, must understand the abilities of the market to deliver, and to design the tenders accordingly.

Despite the increasing number of circular initiatives in the textile sector both in Denmark and abroad, multi-stakeholder value chain orchestration initiatives, including the uptake of recycled fibres, are still limited. Experiments with such value chain collaborations provide valuable insights for municipalities and other stakeholders to prepare for future regulatory requirements and market developments.

“We wanted to work with the most difficult stream of textiles as possible. If we could show a case, where we are able to create something meaningful from mixed qualities of post-consumer textile waste from households - we’ve come a long way!”

Tina Winberg, City of Copenhagen

THE VISION OF REYARN

Based on the context described above, the vision of the ReYarn project was to gather strong players in the textile value chain to develop and test circular solutions for post-consumer textiles from the City of Copenhagen with the aim of gaining new insights and practical experience.

More specifically, the ReYarn project focused on developing manual post-consumer textile sorting practices for the local reuse market and for mechanical recycling purposes, and product development from mechanically recycled fibers for public sector use and public procurement. In this context, the ReYarn project was focusing on mechanical recycling, which can recycle different fibre blends.

The ReYarn Partnership consortium took departure from a set of common project partnership goals that aimed for developing and demonstrating a comprehensive solution for handling post-consumer textiles, collected in Copenhagen, which:

- ... was scalable
- ... promoted local resource cycles where possible and ensures transparency and knowledge sharing across the value chain
- ... provided a better understanding of the composition and quality of the waste stream
- ... ensured handling in relation to the waste hierarchy
- ... sharpened environmental requirements for more green and circular procurement

These project partnership goals are further elaborated in Appendix A.

THE REYARN PARTNER NETWORK

The ReYarn partnership team consisted of six partners which covered the entire value chain from the end-of-first-life collection to pre-sorting, reuse, recycling, procurement and/or waste treatment where no other options were possible.

THE CITY OF COPENHAGEN

The City of Copenhagen participated with representatives from two departments:

Firstly, the Technical and Environmental Administration, (Department of Technology, Development and Resources/TUR), initiated a

call for partners, based on the need for more comprehensive textile solutions, as described above and in the Waste Management Plan 2024 Circular Copenhagen. The call was presented via the "Circular Copenhagen innovation platform" and responded by Revaluate (see below). During the project period, TUR functioned as project owner, and co-managed the planning together with Revaluate.

In addition, the City of Copenhagen was represented by The Finance administration, Department of Sustainable Procurement as part of CSR & Procurement Law. With this representation the aim was to actively participate in the uptake/procurement of textile product(s) made from recycled fibres and to investigate more circular criteria for future municipal tenders for textile products.

REVALUATE

Revaluate is an advisory and research company with expertise in circular economy and circular textile value chains. As stated above, Revaluate replied to the call for setting up a project, that could investigate some of the issues which the City of Copenhagen were struggling with regarding sorting and treatment of used textiles. In collaboration with the Technical and Environmental Administration, Department of Technology, Development and Resources, Revaluate designed, planned, and coordinated the ReYarn project. In addition, Revaluate provided their expertise and analytical skills during the project period.

TRASBORG

Trasborg has been operating since 1917 and is the largest textile collection, sorting, and logistics company for textiles in Denmark. They collect between 7 and 8,000 tons of used textiles per year of which approximately 1,000 tons are sorted at the Trasborg premises and hereafter exported as used textiles. The remaining part is exported directly as unsorted "original" to selected collaboration partners. The business is primarily based on own collections but is supplemented by servicing selected municipalities. For the ReYarn project, Trasborg provided facilities, resources, and expertise regarding textile pre-sorting.

SALVATION ARMY

The Danish branch of the Salvation Army is a charity organization that operates their own collection scheme and a smaller sorting facility. This facility sorts a small proportion of the original with a view to take out shop quality for their reuse activities. The remaining from this sorting process is exported as "second grade" and the rest of the collected material as "original". In Denmark, the Salvation Army runs 15 physical second-hand charity shops, supplemented by a small web-shop, and facilitates reuse of used clothing via resell, redesign and repair activities. For the ReYarn project, Salvation Army provided knowledge of the local reuse market, ensuring that local reuse was prioritised and that citizens dialogue around repair and remake was created.

WOLKAT

Wolkat is a family-owned group of innovative, international textile recycling companies. The business was founded in 1948 and today they control the entire textile recycling chain that collects, sorts, mechanically recycles, and re-creates recycled products in a circular and transparent process. The company has operations in the Netherlands and Morocco. For the ReYarn project, Wolkat were to handle all remaining's from the local pre-sorting process that had not been taken out for local reuse or for incineration, including global reuse, wiper production and mechanical recycling into new yarns and fabrics.

BACHER WORK WEAR

Bacher Work Wear has supplied workwear since 1897. Today they are one of the largest workwear suppliers in Denmark and they supply workwear, uniforms, profile clothing, safety equipment and safety shoes of more than 40 brands and 50.000 products. During the project Bacher Work Wear held the contract for supplying work wear for the City of Copenhagen and for the ReYarn project they provided expertise and sparring regarding product development and supply.

ADDITIONAL PARTNERS

In addition to the ReYarn partner network, representatives from Design School Kolding were invited to bring in expertise on design- and product development during the last phase of the ReYarn project from March to April 2022. More specifically, the product development and prototyping of "Product 2" (the light workwear overshirt) was project managed by Mette Julie Bundgaard-Nielsen and developed by Martha von Guenther (both Design School Kolding). This selected part of the project was initiated by the ReYarn project, but further developed and financed as an activity

under Lifestyle and Design Cluster funded by the Danish Agency for Higher Education and Science.

THE REYARN MODEL EXPLAINED

There is currently only few local sorting solutions in Denmark and most collected textiles are unsorted or only partially sorted before they are exported. Further, the collaboration with recyclers is limited. This was also the situation for the City of Copenhagen (see Figure 1) before ReYarn was set up to test different methods that are more in line with circular economy principles:

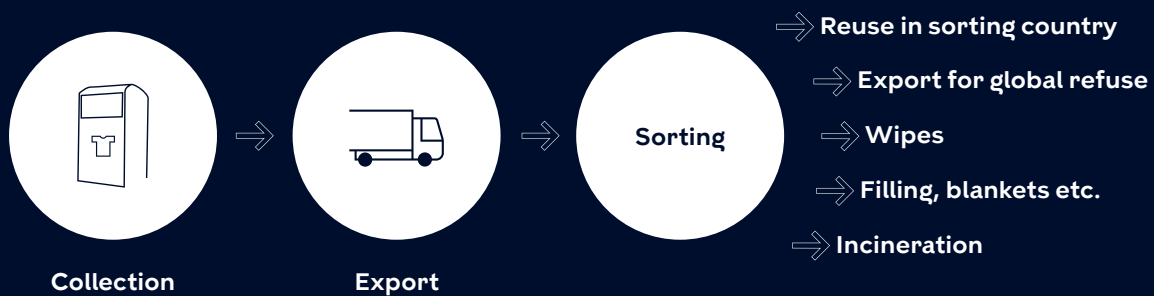


Figure 1 Sketch of the current collection-, sorting, and treatment scheme for textiles, collected at the local recycling stations

Based on the vision from the City of Copenhagen as laid out on the "Circular Copenhagen innovation platform" and the context presented above, the ReYarn value chain model was developed, based on four different focus points:

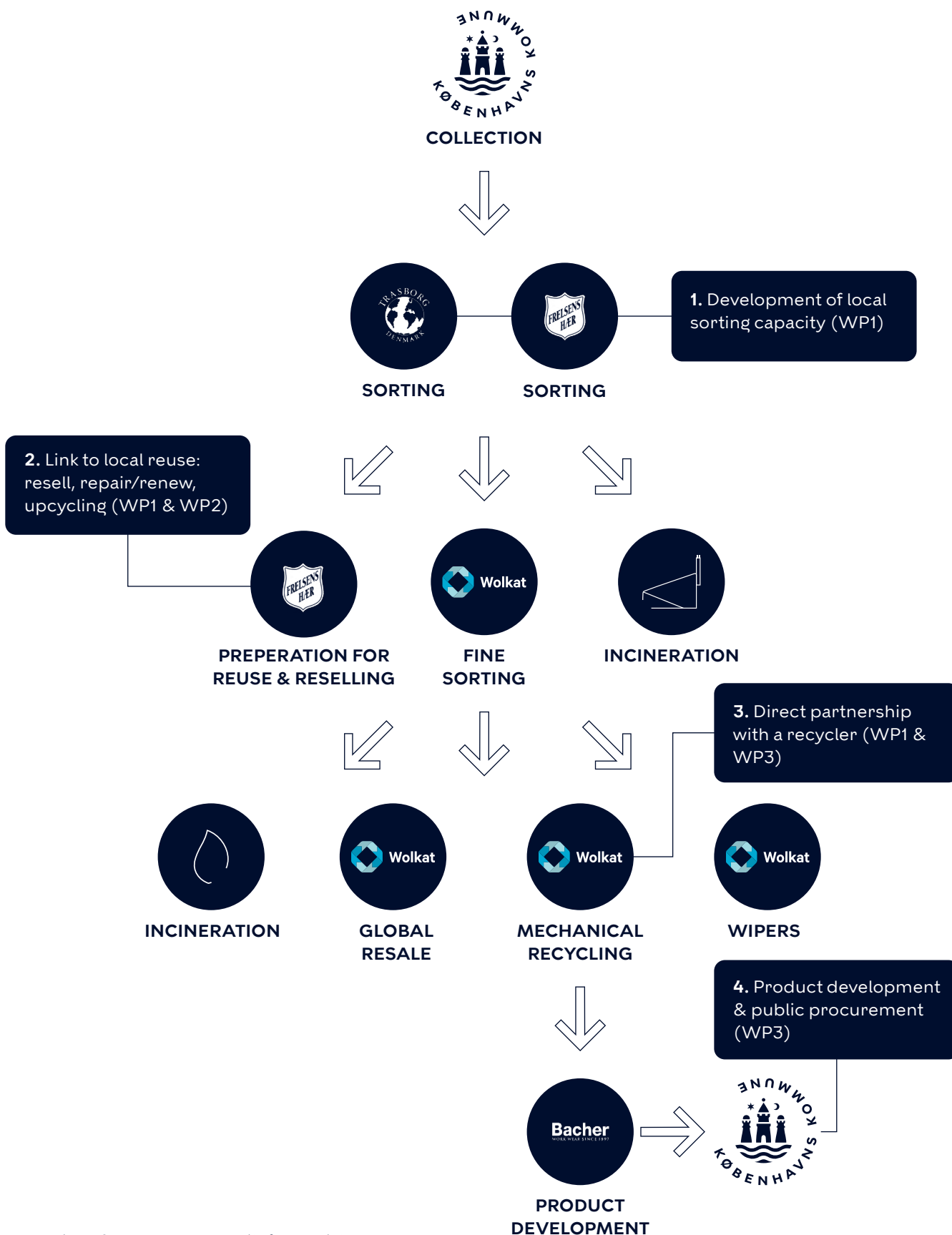


Figure 2 The ReYarn model with focus points

Since national requirements for a separate collection scheme for textiles in Denmark was being formulated during the project period, the first step of the model (collection methods and related issues) was not addressed in the ReYarn project (for more on current collection practice, please see Appendix B). Instead, the project took departure from the collected household textiles from the City of Copenhagen's eight local recycling stations from where they were delivered directly at the sorting facilities in greater Copenhagen.

The four focus areas of the ReYarn project were:

1. Development of local pre-sorting capacity (Work package 1). This work package developed and tested a pre-sorting model to improve local pre-sorting capacity that could sort textiles for local reuse and for local waste treatment (to avoid waste export). Additionally, sorting criteria and practices for mechanical recycling at Wolkat were developed and tested.

2. Link to local reuse (Work package 2). In line with the principles of the circular economy, sorters should, as far as possible, give priority to extending the life of products locally. Therefore, ReYarn collaborated with Salvation Army Denmark to ensure that local reuse was prioritised and that citizen's dialogue around repair and reuse was created. Salvation Army provided knowledge of the local reuse market and a retail platform for the locally reusable textiles sorted in the ReYarn project.

3. Partnership with a recycler (Work package 1 & 3). Recycling post-consumer textile products from households into fibre is still a limited practice and cooperation between the municipality and a recycler is rare. ReYarn aimed to strengthen that link to create more transparency in the system and better access to recycled textiles for municipal use. Following the preparing for local reuse and for local waste treatment (incineration) the remaining was sent abroad for fine sorting with a view to separate the textiles into global reuse, wipers, and mechanical recycling.

4. Product development and public procurement (Work package 3). This work package aimed for facilitating procurement of the mechanically recycled textiles back by the City of Copenhagen in the form of new textile products. In addition, this work package provided insight and experience on mechanically recycled materials and their applicability in public procurement, which supported the development of new tender criteria in the City of Copenhagen.

The ReYarn project did not focus on developing global reuse practices or technologies for recycling. **The novelty of ReYarn was to develop and test a circular textile value chain that prioritizes local reuse and local waste treatment and that connects used textile streams from Danish households with a recycling company that can**

deliver output material with procurement potential for the City of Copenhagen.

The partnership model was tested in the period between May 2021 and April 2022 and followed this overall timeline:

COLLECTION OF TEXTILES FROM NEAR RECYCLING STATIONS IN COPENHAGEN

FROM MAY 2021- MARCH 2022 40 TONNES OF TEXTILES WERE COLLECTED IN TOTAL

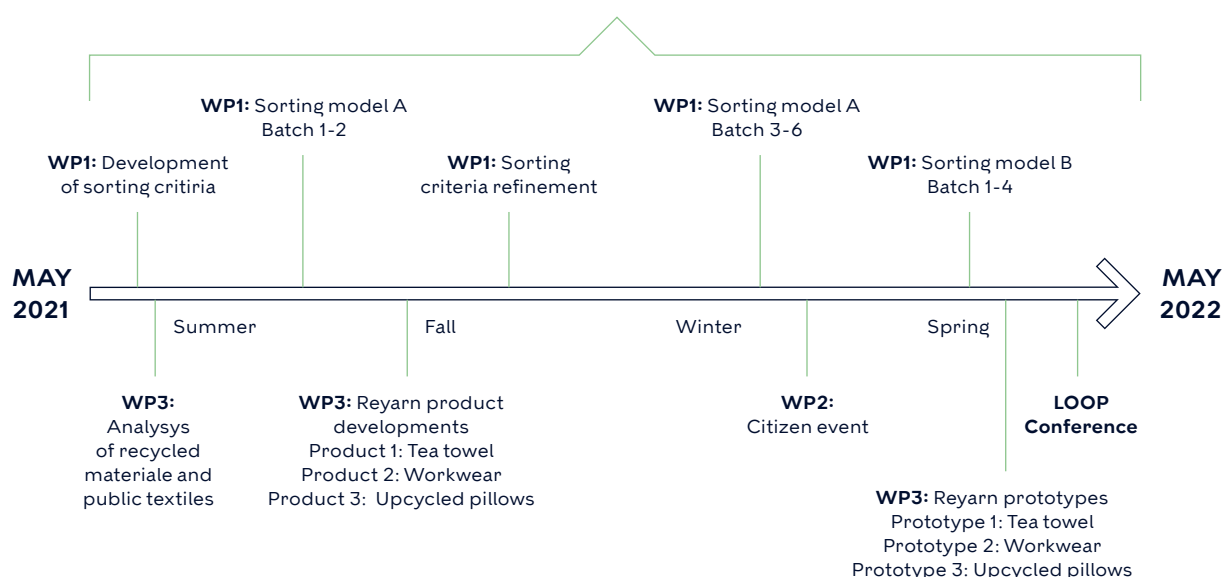


Figure 3 The ReYarn timeline

LOCAL PRE-SORTING AND REUSE

Work package 1 aimed to adapt and develop sorting practices that supported the overall objectives of the ReYarn model:

- increasing local reuse and preparation for reuse
- reducing amounts of textiles being sent for waste treatment
- ensuring local treatment of waste.

In addition, work package 2 aimed to ensure a destination for local reuse and communication and outreach to citizens regarding waste prevention and reuse.



Figure 4 Focus area for Work package 1 and 2

SORTING CRITERIA

The first step of developing the pre-sorting model was to create a set of sorting criteria. These sorting criteria were created as a back-and-forth learning process between the local sorter (Trasborg), the local reuse organization

(Salvation Army), and the mechanical recycler (Wolkat). The process is described in more detail in Appendix C and the results can be seen in the following table:

CRITERIA FOR LOCAL REUSE	CRITERIA FOR TEXTILES TO WOLKAT				CRITERIA FOR WASTE
	REUSE ABROAD (A,B)	RECYCLING (REC)	SHOES	SOFT TOYS	
Shop quality	Reusable textiles that cannot be sold in Denmark (A & B)	Broken stitches	Single shoes	Soft toys	Moist
Vintage	Reusable belts and bags	Wear and tear	Pairs		Wet
Brands with little (easily repairable) holes	Blankets (synthetic, with down)	Holes			Mouldy
Levi's denim with holes (for upcycling)	Reusable linnen, curtains, towels etc.	Stains			Very dirty
All products from pure 100% material such as wool, cashmere, merino, silk etc.		Faded/discoloured			Smelly
Danish football t-shirts		Over-washed			Textiles with paint, oil or heavy coating
All products in real leather, incl. with holes/damages (for remaking). No take leather!		Broken zippers			Fabric leftovers smaller than 1,5 m
All products in thin wool, incl. with holes/damages (for remaking)		Non-reusable linnen, curtains, towels etc.			Elastic bands
All hand knitted products		Fabrics larger than 1,5 m			Carpets
All fur coats		Single gloves, socks etc.			Plastic products (thick rain coats, fake leather)
All vintage bedding w. colours and patterns incl. with holes and damages (No wet/mouldy)					Non-textile waste (e.g. plastic bags, broken shoes and bags, packaging)

Figure 5 The ReYarn sorting criteria for pre-sorting in Denmark

It is worth noting, that these criteria were created specifically to and by the ReYarn partners and might not be applicable for other local reuse partners and/or mechanical recyclers as they might operate with different business models, customer segments, markets, or recycling technologies.

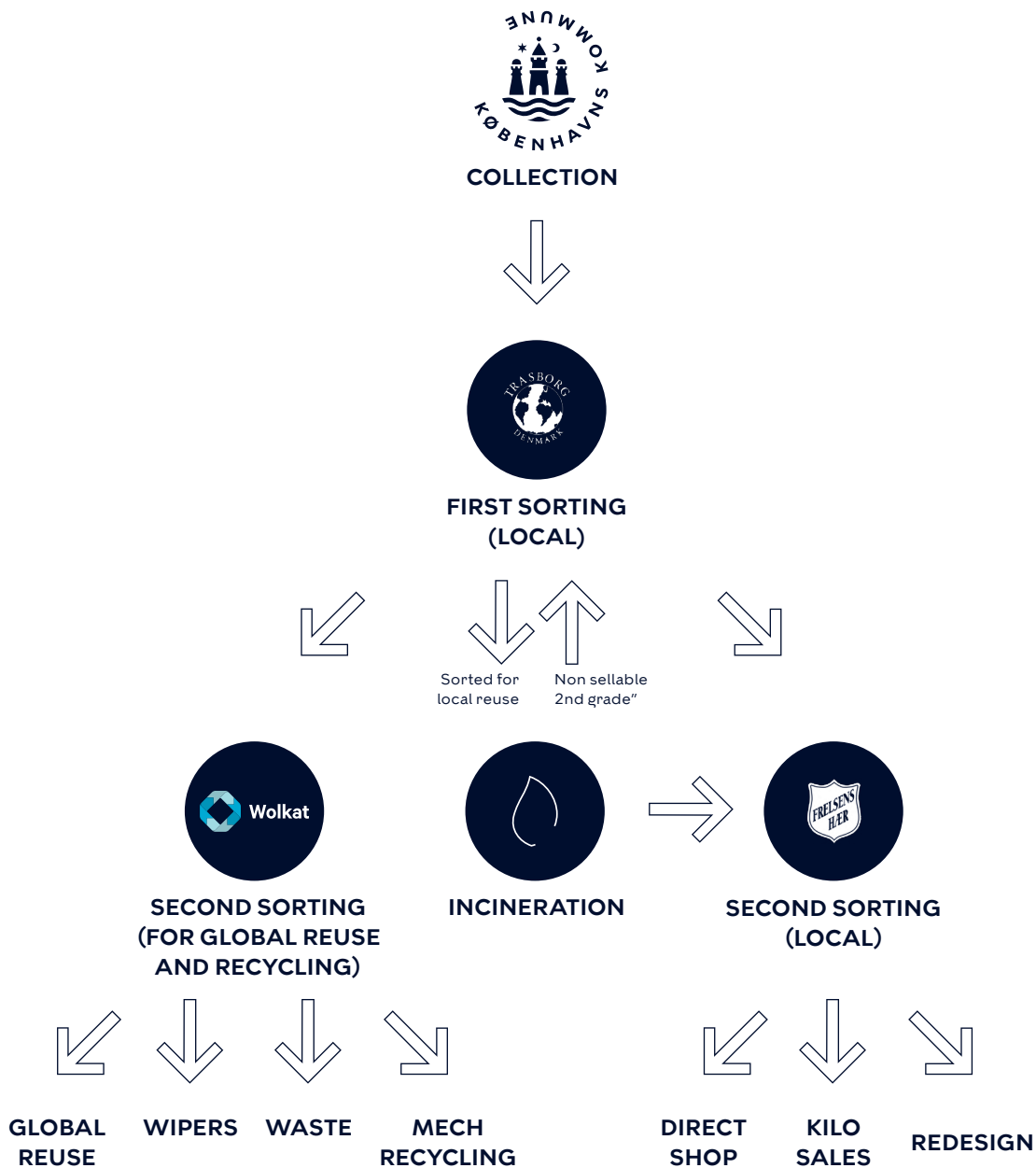
SORTING PILOTS

Based on these sorting criteria, the local pre-sorting model was investigated in two different sorting pilots (A and B). Both pilots were designed with a view to support circular principles, i.e., local reuse, local preparation for reuse (renew, repair and remake), global reuse, material recycling and incineration in this prioritized order. The pilot projects adhered to these principles and were supported by the ReYarn partners' existing knowledge, resources and practices on local and global reuse markets and recycling.

The sorting pilots were created as a collaboration between Trasborg, Salvation Army and Wolkat. Trasborg currently has the largest manual sorting facility in Denmark but has up until the ReYarn project, maintained their focus on sorting for export reuse markets and has therefore not been active on the local (Danish) reuse market. On the other hand, the Salvation Army has extensive experience with collecting, sorting, and selling textiles for reuse, particularly with a focus on both B2B and B2C in Denmark but did not have sorting and storing capacity sufficient for the full ReYarn test and for larger scale flows in general. The two actors were therefore engaged in ReYarn to test and investigate local pre-sorting practices and market needs with the aim of ensuring as high local reuse as possible.

SORTING PILOT A AND TESTS

In pilot A, Trasborg received original textiles collected from the local recycling stations which they pre-sorted in six different categories based on the ReYarn sorting criteria as described above in Figure 5 (one fraction for local reuse, four fractions for Wolkat and one for incineration). Textiles sorted out for local reuse was then sent for Salvation Army for further sorting into different reuse categories (direct shop, kilo sale, redesign, and second grade). The "second grade" category are textiles which were not considered sellable in the Danish market after all and were therefore sent back to Trasborg for further processing in the ReYarn value chain. The waste for incineration was sent for treatment and the remaining were sent to Wolkat for further processing in their current set-up (for more on this, see the section on "Sorting for global reuse and recycling").



First sorting: Trاسبorg **Volumes sorted:** 39.095 kg

Second sorting (local reuse): Salvation Army **Time:** 38 weeks

Second sorting (global reuse & recycling): Wolkat **Sorting criteria:** see Figure 5

Sorting process: see Appendix D

Figure 6 Sorting pilot A

¹As mentioned, the textiles were collected in local recycling stations where there was also an option for citizens to exchange goods prior to collection. Therefore, for this pilot, the fraction was named "CPH original" and should not be confused with the quality and composition as the usual term "original".

The results from sorting Pilot A are presented in the following figure:

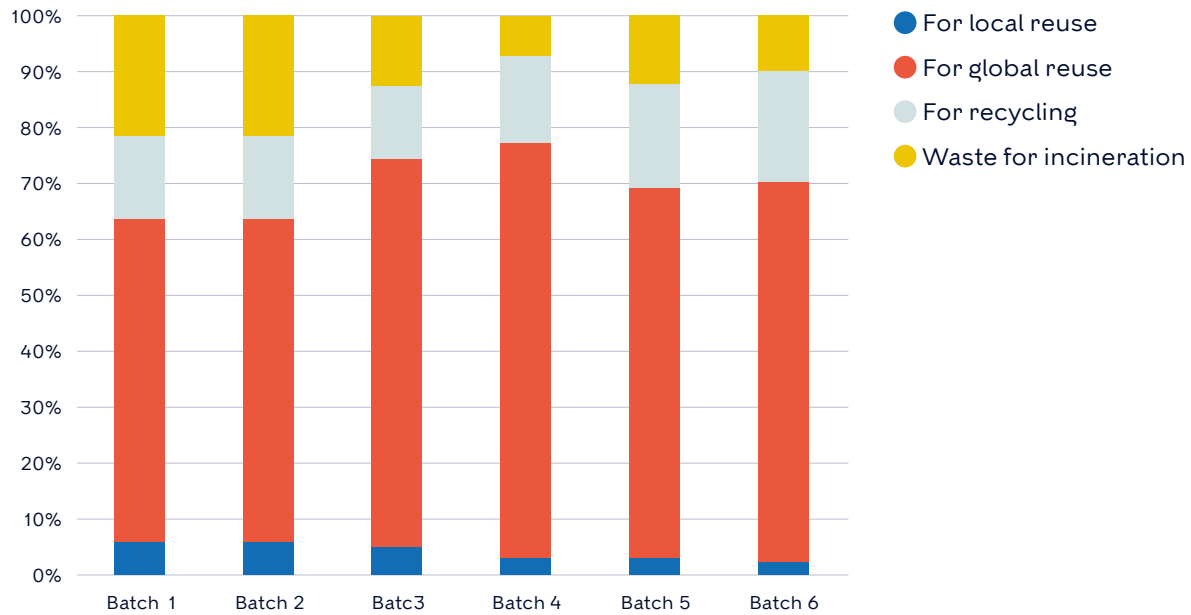


Figure 7 Sorting pilot A results

First results of the pilot showed that sorting for local reuse rates were relatively low (between 2.6 and 6.3%). This can be explained in several ways. Firstly, textiles collected in local recycling centres are generally considered to be of lower quality than those collected from textile containers on the street. Secondly, Trاسبorg had limited local reuse market knowledge and translating the ReYarn sorting criteria into practice needed more time and closer collaboration with a local reuse organization than what was

allowed in this pilot. It was therefore decided to do two tests (in week 19 and 28) where local reuse expert, Salvation Army, conducted the first sorting (pre-sorting of the CPH original), to investigate whether this could increase local reuse levels. In these two tests, the Salvation Army received the collected textiles and sorted out all textiles for local reuse, while the rest were sent for further sorting with Trاسبorg and finally with Wolkat.

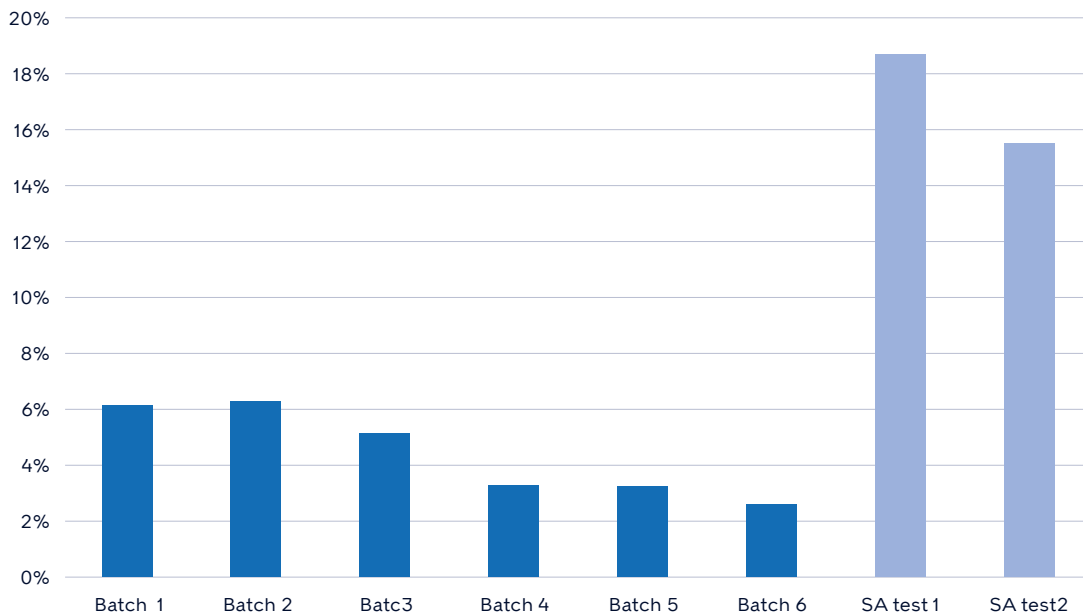


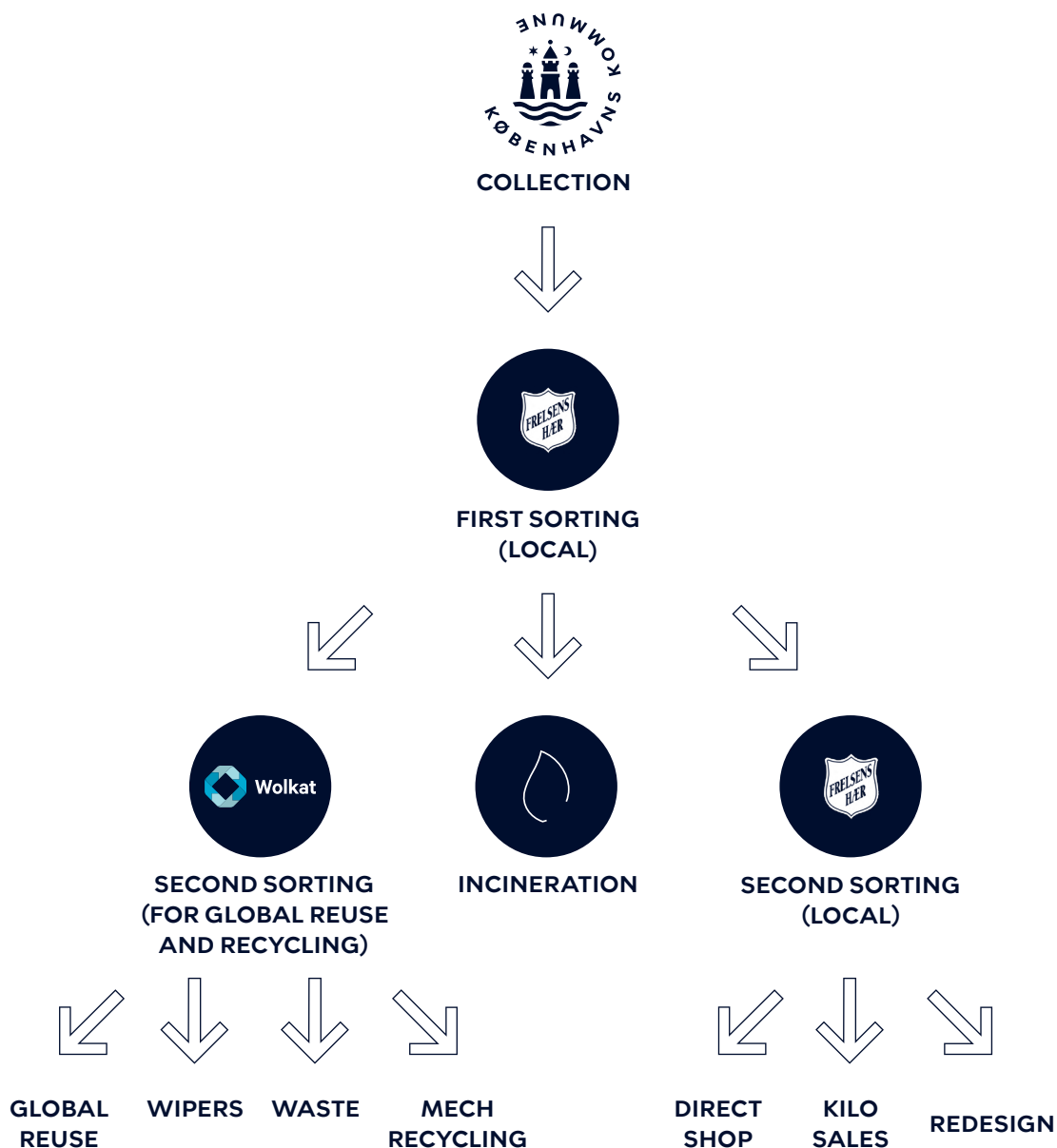
Figure 8 Sorting for local reuse in Pilot A and two tests

The test results (Figure 8) show that significantly higher levels of local reuse could be achieved when local reuse expertise was directly involved. With these results sorting pilot B was planned.

SORTING PILOT B

In Pilot B, the Salvation Army received the CPH original textiles and conducted the first sorting. Trasborg did not participate in this sorting and once waste had been separated and sent for local treatment, the pre-sorted goods were

either further sorted and processed by Salvation Army (textiles for local reuse) or transported directly to Wolkat (textiles for global reuse and textiles for recycling):



First sorting: Salvation Army

Second sorting (local reuse): Wolkat

Volumes sorted: 6.383 kg

Time: 10 weeks

Criteria: see Figure 5 but with three fractions rather than six (global reuse, REC, shoes, and soft toys in one category)

Sorting process: see Appendix D

Figure 9 Sorting pilot B

Pilot B thus investigated whether local reuse levels similar to the earlier tests could be achieved, if local reuse expertise was included. In addition, a simplified pre-sorting model was applied for the fractions received by Wolkat. For this sorting pilot the same sorting criteria were used as in Pilot A, but here, the textiles were only pre-sorted into three different fractions, meaning that all textiles for Wolkat (reuse abroad, REC, shoes, and soft toys) were sorted as one, rather than four separate fractions. This was done to simplify the model as non-profit organisation’s resources are limited.

REYARN SORTING EXPERIENCES

Sorting for local reuse took departure in the sorting criteria as presented in Figure 5 and the textiles from this step were channelled into Salvation Army’s current practices of selling, renewing, and upcycling of used clothing in Denmark (work package 2). Current Salvation Army activities include (limited) sorting of clothing, shoes, and accessories for local reuse

and in this process, garments are to a limited extent cleaned and repaired, focusing on sewing in buttons, smaller holes, or seams. In Denmark, Salvation Army operates a multichannel retail model with 5 different channels and ReYarn were sold through these channels:

- 15 physical second hand shops
- Web shop
- Live sales on Instagram
- B2C kilo sales
- B2B kilo sales

Figure 10 in the following page covers both pilot A (first sorting performed by Trasborg), the two tests and pilot B (first sorting performed by Salvation Army), and illustrates that the sorting data for local reuse varied significantly from batch to batch:

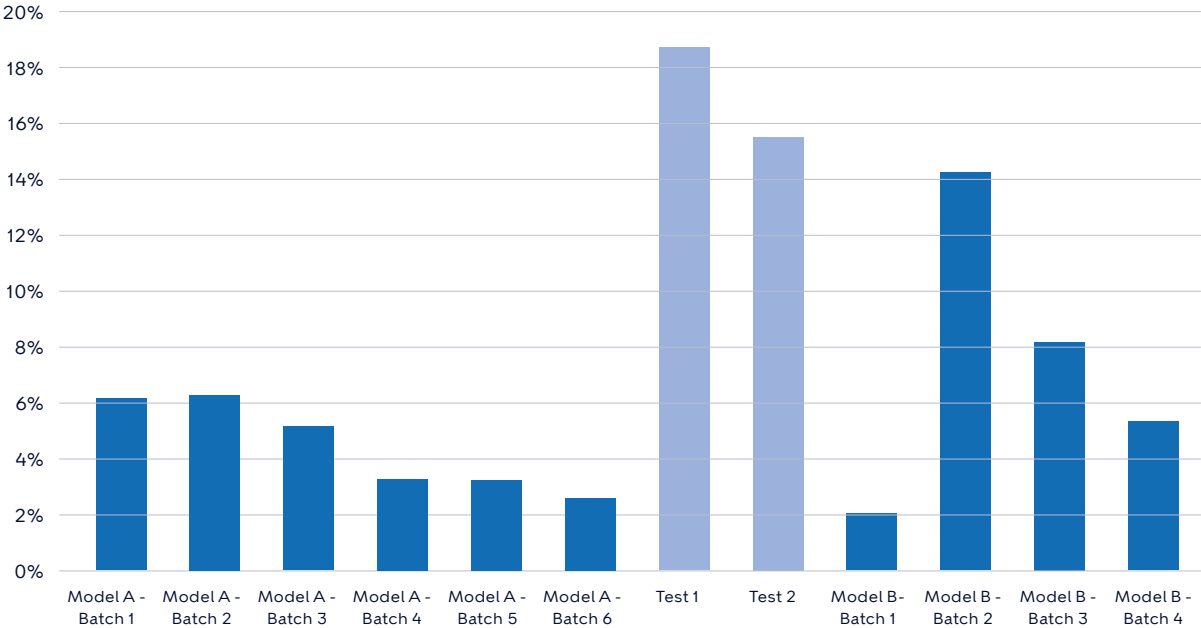


Figure 10 Share of total collection sorted out for local reuse

The sorting results show that local reuse levels were relatively higher in the two test batches and Pilot B compared to Pilot A, indicating that direct knowledge of the local reuse market is needed to increase the share of local reuse. This was true on average, but also for most individual batches, except for two (Pilot B, Batch 1, and Pilot B, Batch 4). For these two batches the data were significantly skewed: the first batch due to a local storm having ruined most of the collected

textiles with rainwater and the fourth batch due to many wet duvets and pillows having ruined much of the textiles from this batch. Leaving these two batches out, the data proves the point even clearer.

It was also discovered that around half of the textiles that Trasborg pre-sorted for local reuse could not be sold locally by the Salvation Army after all (the second-grade category in Figure

“The Danish market is so different from the markets we usually serve, and we needed time to better understand the preferences and trends here. Changing both our sorting set-up and serving a new market was heavy on our staff and required more time and resources than we had firstly anticipated.”

Steen Trasborg, Trasborg Denmark

6), meaning that Salvation Army had to return a significant amount of textiles back to Trasborg so they could be channelled to global reuse via Wolkat. This supports the notion that direct knowledge of the local reuse market is needed in the first sorting step (either by assigning more time for learning/training or by assigning the task to market-experienced staff).

Overall, the experience of the two pilot projects showed that sorting local reuse categories requires experience and continuous up-to-date knowledge on trends and consumer preferences within the market in focus and is therefore difficult to obtain on project-basis. Although Trasborg has significant experience and deep knowledge with sorting for reuse, their expertise currently lies with export markets and this knowledge and experience are not easily transferred to a local Danish market. The sorting model needs further development and testing, but it can be concluded that without the involvement of local reuse expertise in the

definition of criteria and the delivery of training, the local reuse potential will not be fully utilized.

SORTING OUT WASTE

The second goal for Work Package 1 was to reduce levels of collected material going to waste. This cannot be a target for the professional sorting alone, as it is also closely connected to citizen sorting practices. Thus, this ambition can be reached by combining good citizen communication (to avoid sorting errors and non-textile waste put into the collection bins) with an effective and well-functioning value chain, that can make use of as much material as possible from the collected batch. As described in further detail in Appendix C, the waste fraction was defined as materials and products that could not enter the mechanical recycling process (see defined waste criteria in Figure 5) which was used in this project. The results from sorting out waste in the two pilots is presented in the figure below:

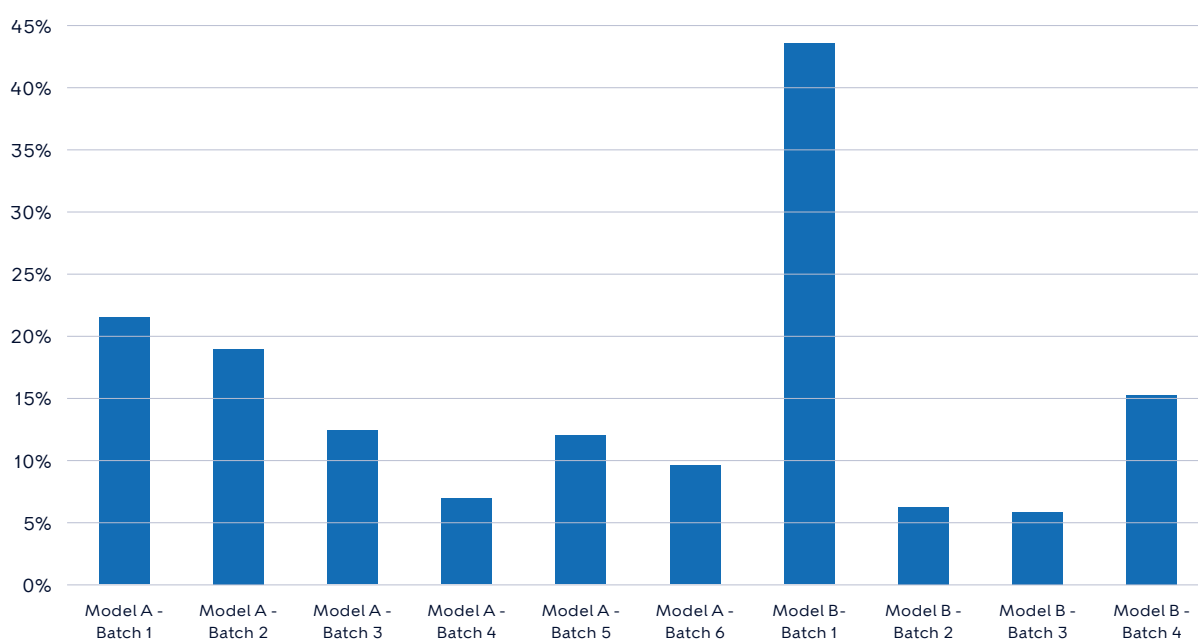


Figure 11 Share of ReYarn textiles sorted out for incineration in Denmark

“Understanding what was waste and what wasn’t, was definitely a learning process for us. It took time and needed several dialogues with the recycler, since it was so different from our usual operations. However, once we understood, it was really motivating to see lesser volumes going to incineration.”

Ergün Arkin, Trasborg Denmark

It is common to experience e.g., “poor” or ruined batches as well as fluctuations in the volumes and qualities, which is all due to external factors that cannot be affected nor controlled and that has not been investigated in this project. For the same reasons as was mentioned above, the two batches (Pilot B, Batch 1, and Pilot B, Batch 4) therefore disturb the picture, but there could be more factors that influence both volumes and qualities. However, the dataset does show that it was possible to get near 5% waste for incineration which was perceived to be an acceptable level for the City of Copenhagen. It also shows, that during the project period, there was an overall decrease in waste levels which indicates how sorting for recycling rather than waste was an ongoing learning process for the sorters. With Wolkats capabilities in handling big volumes of textiles in different qualities via global reuse and mechanical recycling of textiles into different materials, it resulted in a positive scenario where fewer textiles went to incineration and instead got recycled into new materials and products. The results show that clearly defining waste and integrating recycling into sorting criteria allows to reduce the fraction of waste sent to incineration. However, it is still important to highlight, that the data collected during the pilot project was limited, thus only providing general conclusions. For more comprehensive conclusions, more data and closer investigation is needed.

SORTING FOR GLOBAL REUSE AND RECYCLING

As shown in Figure 6 and Figure 9, all textiles that were not sorted out for local reuse or for local waste treatment were exported for Wolkat for further sorting and processing:



Figure 12 Sorting for global reuse and recycling

Figure 13 shows the results from this next sorting step and thus the split between textiles sorted out for global reuse, cleaning wipers, recycling, and waste. It is important to note

that the global reuse and recycling data merely represent Wolkats current business model and the existing practices in their global value chain, which ReYarn did not interfere with.

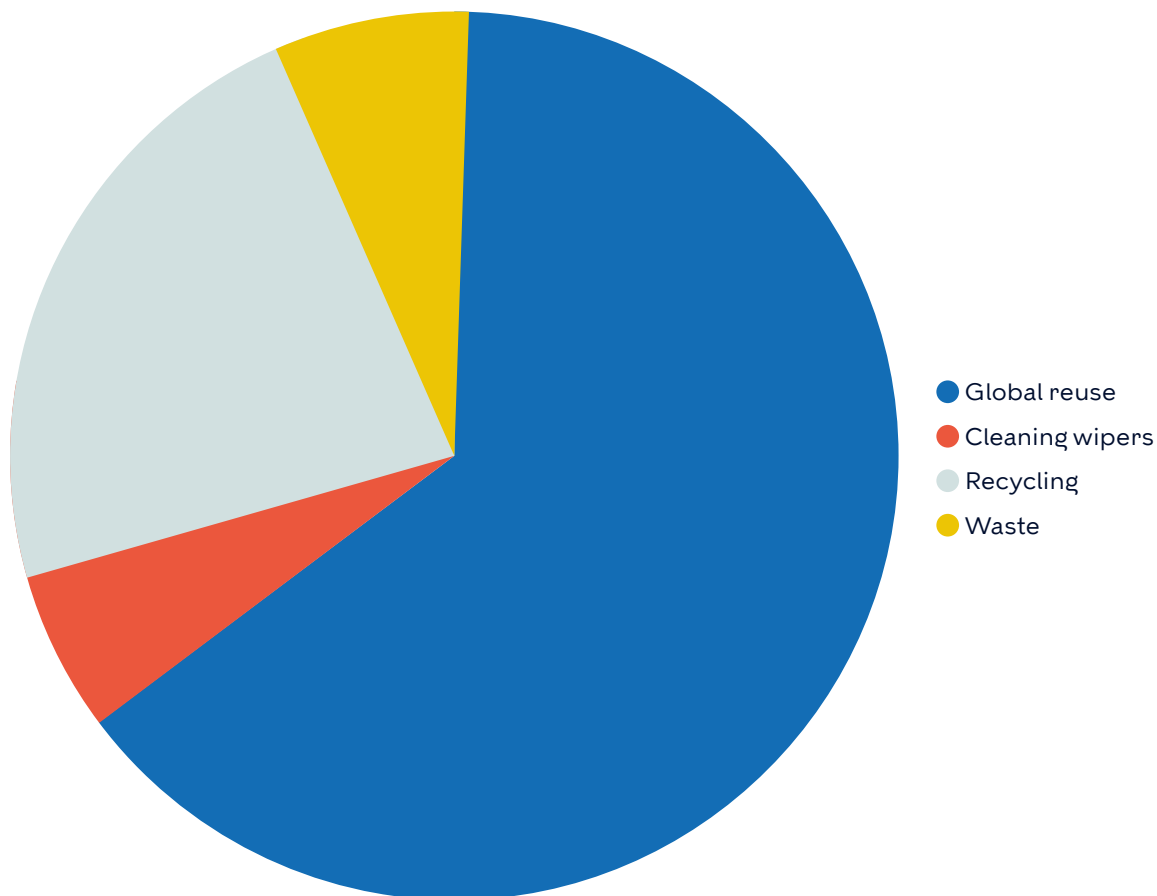


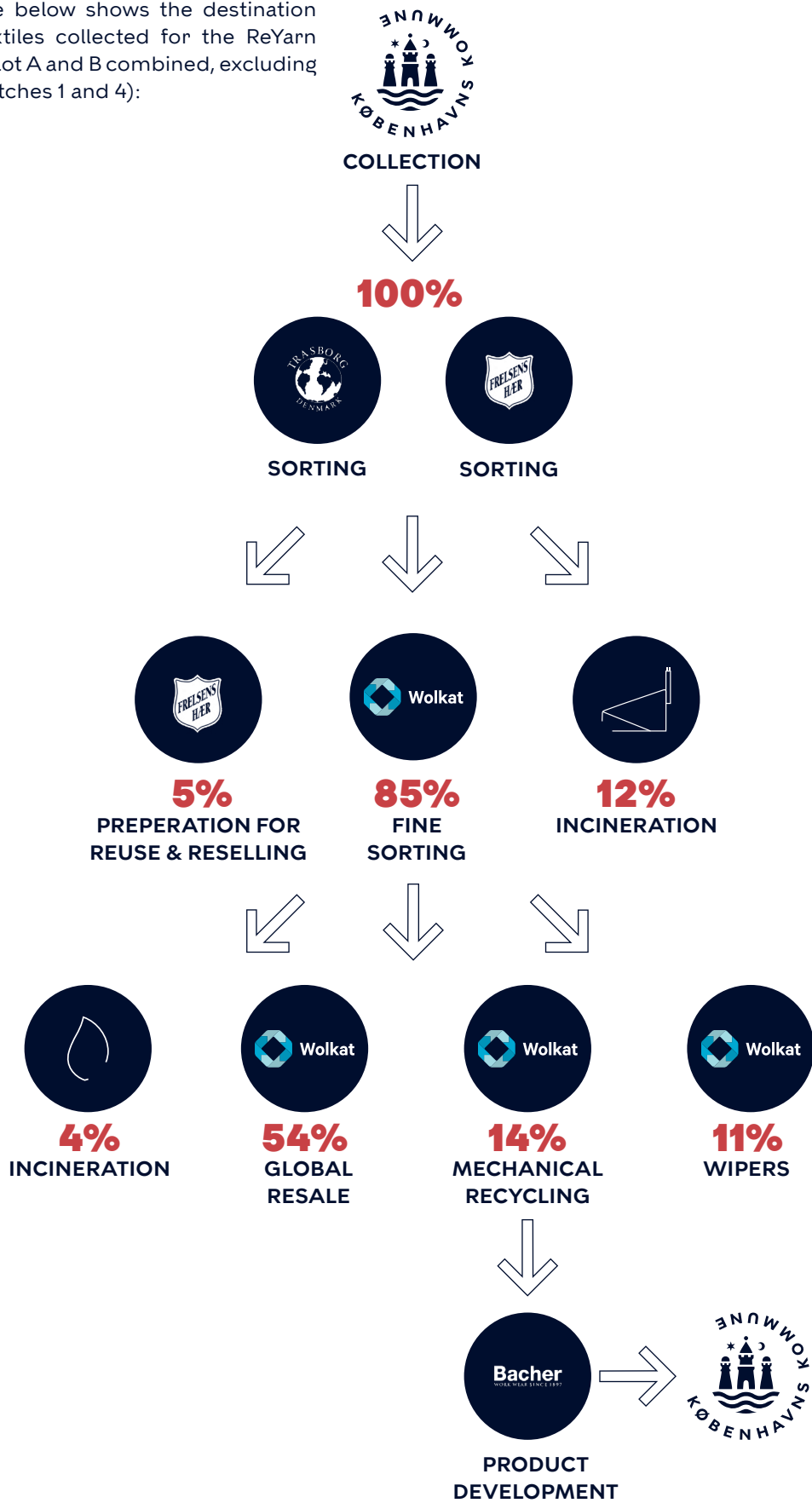
Figure 13 Destination of ReYarn batches processed by Wolkat

It was pointed out that this pre-sorted fraction was perceived to be of better quality than Wolkats usual collections which at first glance could be a bit surprising since the best fraction (the textiles for local reuse) had already been taken out. However, waste had also been removed and it was also pointed out from all three partners, that textiles from Copenhagen is generally of a

“really high” quality. Again, as mentioned above, the partners found it necessary to have more volumes to test before being able to draw more firm conclusions.

**KEY LESSONS REGARDING
PRE-SORTING AND LOCAL REUSE**

The figure below shows the destination for all textiles collected for the ReYarn model (Pilot A and B combined, excluding Pilot B, Batches 1 and 4):



The results illustrate a sorting model where local reuse is prioritized, the share of waste to incineration is minimised where possible, and where global reuse and recycling are integrated into a single model. In this model, the value of the used garments is defined from the perspective of several actors in the value chain, thus allowing to capture the maximum reuse and recycling value of the used textiles while minimising waste.

Working with the ReYarn pre-sorting and local reuse project activities resulted in a few highlights:

- **Development of pre-sorting practices.** Adapting existing sorting practices to new ones is resource demanding both physically and operationally – at least on project basis. Physically in the sense that the facilities and sorting lines had to be cleared out and changed since the sorting set-up was different from the usual business model (particularly in Pilot A where the usual sorting practice is significantly different from the ReYarn model) and operationally since sorting staff had to change practice and mind-set every time ReYarn original entered the sorting line. Both sorting actors confirmed that they expect that the ReYarn pre-sorting model would run more smoothly if larger amounts and a more permanent set-up was established.
- **Local reuse.** To maximise the proportion of textiles destined for local reuse, it is necessary that sorting facilities involve local reuse expertise. This can be done in several ways like e.g., assigning more time for learning/training of current staff or by assigning the task to market-experienced staff.
- **Value and waste.** Clearly defining the difference between textile waste and waste and integrating recycling into sorting criteria allows to reduce the fraction of waste sent to incineration while increasing the volume of textiles sent for recycling. However, the project also illustrated that the definition of reusable textiles, non-reusable and textile waste varies according to each actor's business model and customer segments and that value in used garments are perceived differently. This indicates that when cross value chain collaboration is built, priority needs to be given to make sure that value is defined and understood in the same way by all partners.
- **Value chain collaboration.** The ReYarn project illustrated, that circular collaboration models not only require that a set of partners start collaborating, but often it requires working in a different way and disrupting their current business model. Not only does each actor need to collaborate with new partners – potentially even competitors, but also do they need to focus internally and adjust their own, current practices. As the surrounding markets are still functioning on a linear foundation, it is not possible for the actors to go full circular at once and alone. This means that often, in these collaborative innovation projects, actors must work in two parallel tracks in order to learn, experiment and prove circular practices. This is most likely to be perceived at time- and resource demanding and can therefore become a significant barrier to the circular transition.

REYARN SORTING MODEL LIMITATIONS

The ReYarn model has its limitation as this was a first pilot study with limited time and data collection. Therefore, the ReYarn sorting data should not be used as a basis for general conclusions and comparisons with other studies, as the data describe the real situation in the context of specific partners, their operational capacity, and experiences. The model is novel with several parts of the value chain having to work from circular economy perspective and the aim was to create this value chain, to test necessary processes, to measure and describe the development within the project period and to give an indication of the obtainable levels from this fraction.

The project showed that current practice of collecting data of their operations varies significantly between the actors. The project showed that actors across the value chain collect some data on their processes, mainly to support their own business practices, but that these methods are not streamlined and that there are gaps to serve a fully transparent circular value chain. It highlights the need for standardized data collection methods and tools to facilitate circular value chain developments.

According to ReYarn partners, it was a valuable learning project where processes and mindsets were challenged, and new perspectives were gained along the way. The partners discussed that for future sorting and treatment, they believe that the potential to leverage local reuse levels is even higher than results from the ReYarn project show (relative to the City of Copenhagen's current model but also more generally to the national levels in Denmark), and that there is a potential for decreasing levels of waste going to incineration. This can happen by longer and closer collaboration between the ReYarn value chain actors and by exercising better communication to the citizens.

The partners also pointed out that over time, global actual reuse levels must decrease. This is linked to the fact that some global reuse chains are malfunctioning, which means that textiles sent for global reuse end up in uncontrolled landfills due to a lack of market, thus creating a false picture of global reuse levels. What is needed is better data and transparency on these supply chains, and full integration of the recycling industry to handle the volumes which, in the end, are not being reused in the global market.

PRODUCT DEVELOPMENT AND PUBLIC PROCUREMENT

Work package 3 aimed to facilitate market uptake of post-consumer recycled fibres and to test a transparent model for the City of Copenhagen, where the non-wearable textiles could be sourced back as products with recycled textile content for municipal use. Here, the City of Copenhagen's Procurement Department (The Finance administration, Department of Sustainable Procurement as part of CSR & Procurement Law/ØKF) worked with Wolkat and workwear supplier Bacher Work Wear, supported by the project managers, to develop new circular products that would be relevant for the City of Copenhagen.

The process helped to map the market potential for mechanically recycled textiles, including the barriers for public procurement of circular textiles at the current development level, in a municipal (public) context. This knowledge was used to qualify criteria for future tenders.

THE FOLLOWING FIGURE ILLUSTRATES THE FOCUS AREA OF WORK PACKAGE 3:



Figure 15 Focus area for Work package 3

Wolkat is a leading company in mechanical recycling of post-consumer textiles of various fibre compositions. With 30 years of experience in technology and product development they have a range of materials on offer made from recycled textile fibres (i.e., home-wear, accessories, garments).

However, in the context of circular economy, where all textile users should commit to source textiles with recycled content, Wolkat entered the ReYarn consortium to improve the understanding of the needs and requirements of public textile procurement and benefit from the collective product development process. At the same time, it was a



“Often, it is difficult to even begin the dialogue with buyers, since we present a fibre which is so different from the standard on the market. Of course, our recycled fibres are different, and we know that they have their pro’s and con’s. But we do believe that our fibres can serve many uses and have therefore really been seeking the necessary dialogue and feedback in order to make them more fit for the market. This was possible in the open and honest environment which was created through the ReYarn partnership”

Kimberley van der Wal, Wolkat

new opportunity for both the City of Copenhagen and the workwear company Bacher Work Wear, to work with textile products made from mechanically recycled fibres. It provided a level playing field to start the process and together explore which materials could be used in which products.

Having the above in mind it was still the ambition to investigate how the most complicated textile waste fraction – post consumer textiles from households – could be recycled into high value fibre-to-fibre textile products for use in the public sector. The project did not develop new recycling technologies but instead took departure from Wolkat’s existing production and materials on offer.



The following figure illustrates the process and timeline of what activities were conducted throughout the ReYarn pilot:

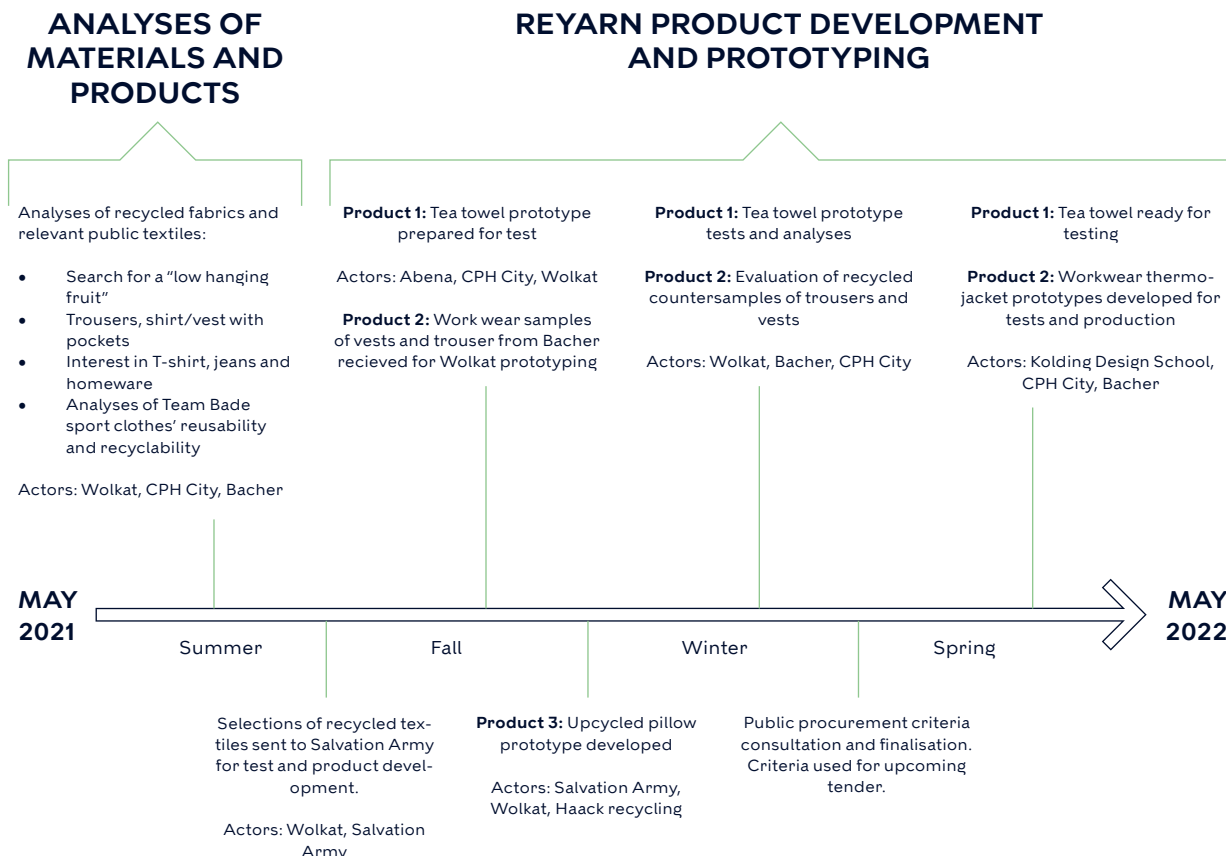


Figure 16 Process and timeline for Work package 3

The process was split in three key activities:

- Analyses of materials and products
- Product development and prototyping
- Consultation on public procurement criteria for textiles

The work package took departure from analysing the mechanically recycled materials offered by Wolkat and the list of textile products that the City of Copenhagen procures for public use by asking the following question “what is the applicability of mechanically recycled fibres in publicly procured textiles and what products could be selected for test”? The aim was to find product groups that could be produced from mechanically recycled fibres and have the potential for scalability.

ANALYSES OF MATERIALS AND PRODUCTS

A major disadvantage of mechanical recycling, currently the most used form of recycling, is that it shortens the length of fibres, reducing the quality of the recycled output. During the first months of the project a back-and-forth process therefore took place, where the Wolkat’s mechanically recycled materials and product catalogue were evaluated in relation to the current procurement needs from the municipal side. Approximately ten different materials were introduced by Wolkat for consideration.

The ReYarn project aimed to test the applicability of the mechanically recycled materials as broad as possible. Therefore, the City of Copenhagen firstly searched their procurement database

for product (groups) that were procured in large quantities, paired with the ideas from the product samples Wolkat had provided for the team, making it more realistic to find product(s) that Wolkat would be able to deliver within the timeframe of the project period. The search was structured in two main categories (below) and evaluated based on procurement volume, presence of strict quality and/or design criteria, specific needs for e.g., reflective parts, and/or the possibility for Wolkat to produce alternatives:

- Workwear (heavy workwear such as jackets with reflective parts, protective gear etc. and light workwear such as t-shirts, vests, pants)
- Home wear (cushions, blankets, tea towels, napkins)

In general, The City of Copenhagen has a high demand for workwear, but as heavy workwear has many strict design- and material requirements and is generally not suitable for recycling, this product group was quickly ruled out. Instead, "light-workwear" was considered. In this respect, Copenhagen has a high demand for t-shirts, but as Wolkat at the time of the ReYarn project was

involved in a heavy development process for t-shirts, it did not seem realistic to be able to present a product within the given timeframe. T-shirts were therefore also ruled out. Instead, other samples of garments and home-wear were considered.

PRODUCT DEVELOPMENT AND PROTOTYPING

The material and product analyses process resulted in three different product "tracks":

- Product 1: Tea towels (for which Wolkat already had a ready sample that could immediately be tested)
- Product 2: "Light workwear" (vests, trousers, and jackets) (of which Copenhagen procure relatively large quantities)
- Product 3: Upcycled cushions (which the Salvation Army could produce to demonstrate the possibilities with local upcycling)

A set of requirements for product development were defined by the ReYarn partners, which were used for analysing and selecting the materials for the ReYarn products. These can be found in Appendix F.

**PRODUCT 1:
HOME WEAR - TEA TOWELS**

WHAT Tea towels made of 42% post-consumer textile, 26% post-industrial recycled cotton, 21% Recycled PET, 11% PET.

WHO Wolkat, Abena, the City of Copenhagen

PROCESS

Tea towels was an existing product in Wolkat’s product portfolio and was perceived as a product with high potential for procurement within the ReYarn project, since they can be produced in large quantities, with relatively little design effort and comparatively small additional expenses in comparison to e.g., light workwear. The process included starting up the dialogue with the current provider of tea-towels for the City of Copenhagen (Abena) in order to investigate whether the Wolkat tea-towels could be included in the current contract. In addition, washing tests were performed to investigate whether the quality lives up to the current procurement requirements or if adjustments were needed (please find the results in Appendix G). Finally, the process also involved internal dialogue in the municipality regarding existing requirements and whether there were any barriers to procuring tea-towels made from post-consumer textiles.

RESULT

Even though the tea-towel-case were considered a “low-hanging fruit” and easy to implement, it was not entirely straightforward. Mainly due to the price of the ReYarn tea-towels that was twice as high, compared to an Oeco-Tex certified alternative, made from 100% virgin fibres.

As a result of the ReYarn project, the tea towels have now been taken in for a testing phase. This means that the City of Copenhagen will test them in practice, in order to gain experience and compare them with conventional alternatives. The additional cost that currently is a condition in circular procurement, still stands as an issue that needs to be addressed.

KEY TAKE-AWAYS FROM THE DEVELOPMENT OF TEA TOWELS

The main lesson from the ReYarn work with tea towels has been, that even with a rather simple innovative product, which had been developed and designed beforehand, the price premium has proven to be the main barrier to large scale procurement. Hence, according to the City of Copenhagen, public procurement needs to include a stronger focus on innovation, to reflect political will to invest in new solutions and to support emerging markets which should then, in the long run, help drive down prices and make them competitive with products made from virgin fibres





**PRODUCT 2:
"LIGHT WORKWEAR" OVERSHIRT**

WHAT Four design proposals and two prototypes of unisex multifunctional "overshirts" for test and future production.

WHO Wolkat, Bacher Work Wear, Design School Kolding, the City of Copenhagen.

PROCESS With respect to "light workwear" a vest and a pair of trousers was firstly discussed for product development and prototyping. The two products were initially chosen as they are widely used by the city of Copenhagen, which was one of the initial selection criteria. However, as the first samples for these products were not satisfying in terms of design and fit, it was

decided that a more comprehensive approach to design was needed. Therefore, Design School Kolding was invited to collaborate in the ReYarn consortium to complement the project consortia with additional expertise in design and material knowledge for the development and prototyping phase.

To take the process further, a unisex and multi-functional workwear jacket was chosen for prototyping. This process took departure from a design proposal from the City of Copenhagen who was also interested in an alternative to the widely used thermo jacket.

KANSAS THERMO JACKET

TECHNICAL

- Ful length front zip
- High collar
- Narrow fit
- Chest pocket with zip
- 2 sidepockets with zip
- Extended back
- Insulating
- OEKO-TEX® certified



The prototypes were to be designed from circular principles, i.e., by making it possible to reuse the workwear after use, and by contributing to the workwear being more recyclable. The following criteria were defined by the City of Copenhagen:

- Use of post-consumer mechanically recycled textile materials as raw material
- Timeless, multifunctional, and unisex design
- The prototypes should meet the same functionality requirements as the product the conventional thermal jacket, or be comparable

- Consideration should be given to developing removable and recyclable logos
- Repairability and mechanical recyclability after use phase.

However, as the process developed, the functionality requirement was deviated from as the thermo jacket's mid-layer function was exchanged with a warmer one-layer overshirt.

Looking back, the process was very iterative and, in the end, primarily focusing on creating a product that would be visible both internally to the municipality's employees and externally to citizens to "tell the circularity story" of used textiles.

On this foundation, Design School Kolding created four design suggestions for an 'overshirt' (see these four suggestions in Appendix H). Two

different Wolkat materials were considered for these product prototypes (see specifications below):



FABRIC 1 OXFORD (PES)

- No shrinkage after washing (40°C, 20cm x 20cm), but the color changed slightly
- Front side fluffier than before (more than back side)
- Fabric seems softer than the other

General product specifications

	47% RPet
Raw material fabric	42% recycled postconsumer textiles high synthetic content
	10% Per
Coating	n/a
Weight	270g/m ²
Cuttable width	140-180 centimeter
Available colors	See Wolkat colour chart

Product characteristics

Basket-weave/Panama-weave.

Frontside and backside are the same.

Test specifications

Tensile strength EN ISO 13937-3	Warp 1514 Newton Weft 697 Newton
Tear Growth resistance EN ISO 13937-3	Warp 198.9 Weft 51.2 Newton
Resistance to seam slippage EN ISO 13936-2	Warp 5.1 mm Weft 3.5 mm
Abrasion resistance EN ISO 12947-1 & 2	>100,000 cycles before yarn breakage
Piling test EN ISO 12945-2	Grade 3 at 2000 cycles
Color fastness to light EN ISO 105-B02	Grade >5
Color fastness to rubbing EN ISO 105x12	Grade 4-5 dry Grade 4 wet

PHOTOS PRODUCT WITH OXFORD FABRIC (PES)

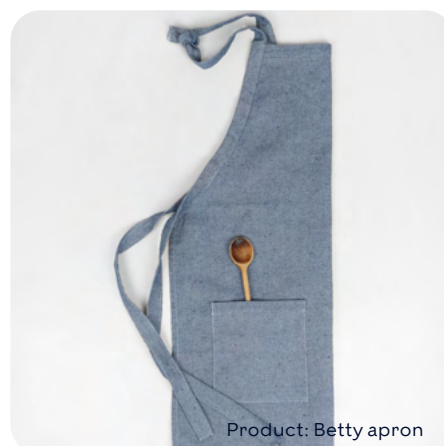
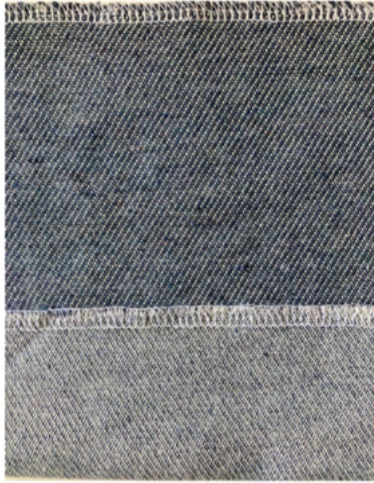


Figure 17 Wolkat fabric #1 (Oxford - PES)



FABRIC 2
OXFORD (CO)

- No shrinkage after washing (40°C, 20cm x 20cm), but the color changed slightly
- Front side fluffier than before (more than back side)
- Fabric seems softer than the other

General product specifications

Raw material fabric	40% recycled postconsumer textiles high cotton content, 35% pre consumer recycled CO, 12,5% Rpet, 2,5% other fibers
Coating	n/a
Weight	270g/m ²
Cutable width	140-180 centimeter
Available colors	See Wolkat colour chart

Product characteristics

Basket-weave/Panama-weave.
Frontside and backside are the same.

Test specifications

Tensile strength EN ISO 13934	Warp 613 Newton Weft 588 Newton
Tear Growth resistance EN ISO 13937-3	Warp 66.1 Newton Weft 39.7 Newton
Resistance to seam slippage EN ISO 13936-2	Warp 4.6 mm Weft 3.8 mm
Abrasion resistance EN ISO 12947-1 & 2	45,000 cycles before yarn breakage
Piling test EN ISO 12945-2	Grade 2-3 at 2000 cycles
Color fastness to light EN ISO 105 - B02	Grade 5
Color fastness to rubbing EN ISO 105x12	Grade 5 dry Grade 5 wet

PHOTOS PRODUCT WITH OXFORD FABRIC (CO)



Product: Jodi dishcloth

Figure 18 Wolkat fabric #2 (Oxford - CO)

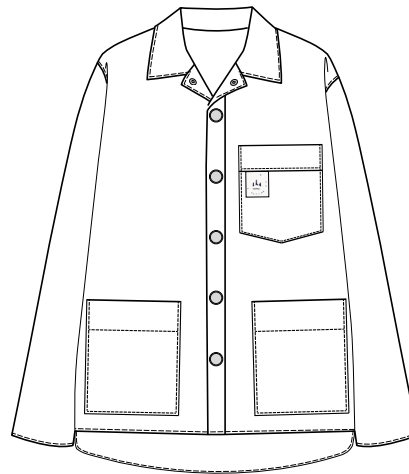
RESULT Working and testing the textiles showed an overall applicability in relation to workwear and function garments for medium heavy duty. Based on the process, four design

proposals for an overshirt were developed, and two prototypes were selected for prototyping (see below). The two prototypes were exhibited at LOOP Forum in Copenhagen in April 2022.

Prototype 1:

Padded overshirt with classic collar:

- Fabric 2
- Warm due to padding (comparable to thermo Jacket)
- lightly deeper sleeves: casual fit (oversize look for women, whereas normal size for men)
- Jeans button on the side with a band to adjust the width of the garment (fitted for women/ men)
- Longer backside for warmth/comfort
- Jeans buttons
- 2 rectangular pockets in the bottom
- Logo on front, left side (with loop)
- Normal seam (top stitching option)



Prototype 2

Overshirt with pyjama collar:

- Fabric 2
- Slightly deeper sleeves: casual fit (oversize look for women, whereas normal size for men)
- longer backside for warmth/comfort
- Push buttons
- 2 rectangular pockets in the bottom
- Logo on the left sleeve (with loop)
- Felled seam

As can be seen in the comments above, the designer suggested that the product development was done with fabric #2 (Oxford - CO). However, as there was some pilling from the surface due to the mechanical recycling, it gives the textile a slight furry surface texture that through use will become more evident. Over time this means that smaller fibers will fall out

due to wear and washing, making the textile more vulnerable to abrasion and tears. This called for a pilot test period with users in their right functions as to discover where reinforcements and other design solutions might be necessary to be implemented at the design level, for the designs to meet the contextual quality criteria of the specific "light work wear".

Since such a pilot was not possible during the ReYarn project period, the so-called "Prototyping partnership 2.0" was created. The project is a collaboration between original ReYarn partners the City of Copenhagen, Wolkat, Bacher and Revaluate and new partners Design School Kolding, Kansas/Fristad (workwear suppliers), COOR (facility managers) and KEA (Copenhagen School of Design and Technology). The consortia will develop and test the prototypes in order to improve the product even further and make them ready for the market. In brief, the purpose of this project is to research workwear quality and functionality in a circular textile economy, through user studies and material driven research:

- Partly to investigate how the textiles containing mechanically recycled textile fibres perform compared to conventional fibres/metre goods.
- partly to investigate where design can be adjusted for solutions that prolong the lifetime of the workwear in relation to function, textile quality and sizing for unisex.

Based on the results of these tests and studies, the aim is to develop circular and

collection-strategic recommendations and guidelines with a particular focus on longevity in terms of quality and functional requirements for the workwear and the textile industry. The project will run from September 2022 to January 2023.

LOGOS The use of logos in workwear and the complexity they bring in the reuse and recycling phase has been documented before and this topic also arose throughout the ReYarn project. Hence, a special focus was put on logos when developing the design proposals and prototypes. More specifically, fixed logos on workwear and uniforms makes it difficult in both public and private organisations to move clothing from one part of the organisation to the other, or after end-of-first-life, a great task to reuse due to the logo. Hence discarded clothing could end up being incinerated even though they were suitable for a second life.

For the ReYarn project, Design School Kolding therefore suggested two different solutions for easily removable logos to make the garments suitable for reuse in e.g., other departments, municipalities, organisations and/or for recycling. The two suggestions are presented below:



Figure 19 Logo-suggestion 1

Logo-suggestion 1 is to sew the logo on a belt loop. The loop can be placed anywhere at the garment and if the logo needs to be changed, it can be removed without leaving any visible traces on the garment itself.

ECAP, 2017 <http://www.ecap.eu.com/wp-content/uploads/2018/10/ECAP-Workwear-Report.pdf>



Figure 20 Logo-suggestion 2

Logo-suggestion 2 is to sew the logo under the flap of a pocket. Under the flap runs a ribbon, which makes any exchange of logos invisible.

KEY TAKE-AWAYS FROM THE DEVELOPMENT OF AN OVERSHIRT

- **Integrated product development:** Developing circular products with recycled content for public sector use is a relatively new area where R&D and experimentation is still at a high level. **A holistic integrated product development strategy needs to be implemented to ensure that recycled products with a high level of innovation succeed in the market. Firstly, this means more actively working with customers, producers, and end-users to define product requirements, while considering design and other constraints.** In ReYarn, several stakeholders were involved in the design and prototyping process, but during the project period there was no time to actively involve a workwear producer and the end-user. In future product development processes, they should be involved from the beginning, as will also be the case for the continuation of the overshirt prototype development (the Prototyping partnership 2.0). Secondly this also means ensuring close dialogue and collaboration between textile professionals and the recycler, creating crucial feedback and dialogue on the recycled materials, making it more fit for the end-use.
- **Learning-by-doing environments** are needed for capacity building in organizations: Working with mechanically recycled fibres and circular product development is not common practice in workwear organizations. Projects such as ReYarn, which provide a learning-by-doing environment, are needed to build knowledge and capacity within the field.
- **Involvement of research and design expertise:** Working with circular product development involves a lot of complexity and innovation (both product, manufacturing, and process innovation). The ReYarn project demonstrated the value of involving an external academic partner to complement existing industry knowledge with holistic thinking and tools for product and process development and to facilitate the product innovation process between involved stakeholders.
- **Contextual quality criteria in circular work wear:** The ReYarn project also revealed a need for discussing whether current textile standards and requirements could be adjusted to better include the properties of materials from recycled fibres. One solution could be to lower the current requirements or to work with other concepts that involve multiple lifetimes in a circular business model, where cascading of products and service of products could initiate a different model of use through work function definitions. By this the concept of a core collection could emerge. This collection could be a way to start reducing large work wear ranges to a simple work wear system, cutting down on complexity and resources where possible, through a conjunction of material and user-led design development, aiming towards more circular products.

“An important learning from this process is that we should have a greater focus on innovation in the purchases we make and be aware that “it costs” in the short term. It will help to stimulate the market for circular solutions and in the long run help drive prices down so that CE materials become more competitive”

Lena Riechert Ewald, City of Copenhagen

**PRODUCT 3:
HOME WEAR - MIX OF RECYCLED AND
UPCYCLED CUSHIONS**

WHAT In the ReYarn project, additional ideas of circular products were discussed and developed for a market outside the City of Copenhagen. Since Salvation Army has design capacity and a small sewing room, they were also invited to develop ideas on how Wolkat’s mechanically recycled materials could be used in upcycling.

Salvation Army developed upcycled decorative cushion prototypes as seen below. These cushions were made partially from the mechanically recycled fabrics from Wolkat (beige fabric), partially from black denim cut-offs from the existing Salvation Army remake-production. The cushions were filled with Danish start-up HAACK (www.haackrecycling.dk) recycled filling material, which consists of a mix of shredded industry fabric and foam leftovers from Denmark.

WHO Salvation Army, Wolkat, HAACK

PROCESS Salvation Army received a set of samples of different Wolkat fabrics for testing. Based on sense and feel, which was a bit rough, they decided that the material could be right for creating (non-weather-proof) cushions - primarily thought for outdoor furniture. The staff played around with the fabrics in different ways and decided to mix it with black denim which was cut-offs from non-reusables from the sorting. Mixing it with another used material allowed the staff for testing the fabric in several different ways.

When first testing the recycled fabrics, Salvation Army provided some feedback regarding the way the recycled fabrics were produced. As it (for the pillows) was cut in several different sizes and shapes, it quickly became evident, that the current fabric tests were too loosely woven with a thread that was too smooth/sleek. This resulted in heavy fraying, even when cutting the fabric parallel to the thread. When cutting parallel to the thread and crosswise, the threads were not parallel to the selvage either, which meant that when trying to cut the fabric into a square, there were always two sides that were skewed. Further, the fabric rolled diagonally, which meant that when holding a strip at one end, it made a spiral / twist. According to the Salvation Army staff, this could indicate that the trend on the fabric loom was fastened too tight. Both issues made it

unnecessarily time consuming to cut the fabric, pinning needles and sewing, making these fabric samples unfit for large-scale production.

This direct feedback from the sewing room to the recycler resulted in valuable adjustments in the fabric production set-up, creating a new set-up which has made the fabric better suited for large-scale production.

RESULT The cushions were showcased at the LOOP Forum in Copenhagen in April 2022 and have also been presented to two larger furniture retailers in Denmark who showed great interest in them. Bringing the cushions to the market on a bigger scale would require larger production facilities and an agreement with a purchaser.

**KEY TAKE-AWAYS FROM THE
DEVELOPMENT OF CUSHIONS**

- This demonstration showed how important the direct contact between the recycler and a designer/producer is to ensure direct and concrete feedback to facilitate necessary improvements in the value chain.
- The demonstration also proved that the recycled material can be used for a range of different applications but also, that a producer and/or purchaser is needed to take good ideas from the demonstration level to an up-scaled level.





UPDATE OF PROCUREMENT CRITERIA

The City of Copenhagen has focused on circular textiles since 2019. The contract on workwear for the City of Copenhagen is expected to be put out for tender again in 2022, and there is therefore a focus on how public procurement can support circularity within the textile category.

One sub-goal of the ReYarn partnership was to gain experience and knowledge on how to set tender requirements that can promote circular textile and workwear procurement. The ReYarn project identified the following aspects that are relevant for the planning of public procurement of mechanically recycled fibre-to-fibre textiles:

- The use and definition of post-industrial vs. post-consumer vs. virgin materials and the weighing of the respective content types in the evaluation model (i.e., higher points for including post-consumer recycled material in textile products)
- The need for an innovation clause in tenders to stimulate product-, process- and technology innovation and to create the necessary space in the value chain for collaborative innovation and experimentation
- The need for an updated approach to workwear logos in order to support reuse and recycling of textiles while also still serving its purpose
- The need for including aspects such as needs for the given purpose, quality, circularity, and social and environmental sustainability in the purchase price
- The need for considering circular textiles and -materials as equally important as eco-labelled textiles
- The need for political support in procurement of innovative (textile) products, including the will to pay a premium, even for smaller volumes.

KEY LESSONS REGARDING PRODUCT DEVELOPMENT AND PUBLIC PROCUREMENT

Several lessons were drawn from working with market uptake of post-consumer recycled fibres in a public procurement setting:

- Mechanically recycled fibres have their advantage as they can be processed based on relatively complex feedstocks and produced in large volumes. In this value chain, the recycled fabrics proved to primarily be relevant for home wear and light work wear (as opposed to e.g., heavy work wear).
- To develop circular textiles that are relevant for public procurement it is required to bring together the entire value chain in designing and testing the products.
- Public tenders can play a significant role in creating a market for recycled textile fibres but needs to be designed in such a way, so they support innovation and a market which is still not in full scale and function.
- This also means that pricing should consider the full life cycle of the product which is procured – e.g., though a life cycle assessment. This would mean that the procurer does not choose the lowest initial purchase price but instead the lowest full lifetime cost, which includes issues such as the material content of the product, product lifetime, repair-ability and possible end-of-life strategies. This, however, requires intensive use of product data which is in current times out of the scope for many municipalities.
- Further, as current tenders can be quite comprehensive, containing a long range of textile products (which are likely to be very different in composition, design and so on), it should be considered whether tenders with fewer product categories to a greater extend could meet circular material requirements.
- Although the issues with logos have been discussed in several projects and fora prior to this, it proved to (still) be a hindering barrier for further processing in the reuse value chain. More conscious design and/or use of logos is thus needed.

PROJECT OUTREACH

CITIZEN EVENT AND RENEW CARDS

In November 2021, the ReYarn team hosted a citizen event on circular textiles at the Copenhagen City Hall. The primary purpose of the event was to generate general citizen information on waste prevention of textiles by e.g., extending the life of textiles by longer use and better care. The event also introduced citizens the afterlife and destination of textiles that have been collected via municipal collection in the context of the ReYarn project. The event presented various 'stations' that explained parts of the circular textile value chain, such as sorting, textile renewal and preparation for reuse, second-hand shopping and subscription-based renting, mechanical recycling opportunities for non-wearable textiles and the ReYarn partnership where citizens could ask questions and learn more about various practices.

For the station that were to inform the citizens on prolonging the life of garments, a set of renew cards (small information cards, printed out on cardboard for the citizen to take home) were created. During the sorting pilots many high-quality clothes with minor faults were identified which illustrates the common problem in reuse. Giving consumers practical advice on how to easily fix them helps to prevent clothes ending up in the bin. With brief and easy-to-understand text and illustrative pictures, these inspiration cards explained how to remove fluff, loose threads and ends, paint, oil, and grease. They also showed how to sew in a button and a broken seam. Please see Appendix E for more details on the renew cards. After the event, the remaining renew cards have been placed in one of the Salvation Army stores for customers to take home.



LOOP CONFERENCE

In April 2022, LOOP Forum, the leading Nordic event for resource management and circular economy took place for the first time ever in Copenhagen. The ReYarn partnership was present at the event, which was a good opportunity to showcase preliminary results from the partnership's efforts to create a circular value chain for post-consumer textiles from municipal textile collection.

The ReYarn stand gave an excellent opportunity for the conference visitors and participating organizations to meet the ReYarn partners and discuss the work of developing circular value chain for used textiles and promoting textile-to-textile recycling of non-wearable textiles.

Participants got the opportunity to see and touch the various textile products that the ReYarn partnership is working to manufacture based on post-consumer textiles from households collected in Copenhagen. This included two prototypes of workwear jackets developed with the help from Design School Kolding and what represent the first step in Copenhagen's efforts to include mechanically recycled textiles in future procurements. The workwear jackets are mechanically recyclable and have logos that can be easily cut off so that they do not stand in the way of later reuse and recycling.

As part of the LOOP Forum's overall program, the ReYarn partnership had organized a seminar on "Circular textiles in a Danish context". The seminar featured presentations from Danish Standards, the European Environment Agency and representatives from the partnership. In addition, two panel debates were organized, where issues of sorting and high-quality recycling were addressed.



GENERAL LEARNINGS AND FUTURE IMPLICATIONS

ReYarn was born from a need in the City of Copenhagen to investigate and test new circular solutions for handling post-consumer textile waste. However, the ReYarn project did not only serve this municipal need, but also provided new insights and learnings for the entire partner

network. In addition to providing concrete insights on developing pre-sorting practices and issues related to procurement of products with recycled content, the ReYarn partnership also revealed several qualitative insights on collaboration and circular value chain development.

“The experiences and learnings that we take away from ReYarn are very valuable but not very measurable nor tangible and difficult to communicate and use for PR. But participating in the partnership provided us with a lot of new knowledge on what’s currently possible and what is needed to get there.

Our ReYarn experience has meant that we have avoided some possible collaborations which could give us something that looked like a “quick fix”, but which we can now see would not solve the bigger issue of textile waste in the long run. We’ve realized that circularity is possible, but also that it requires a lot of patience and hard work.”

Marie Budtz, Backer Work Wear

Throughout the ReYarn project, members of the partnership highlighted several aspects that are relevant to underline for the future development of similar value chain collaborations:

- Need for a safe knowledge creation and sharing space. The partners stressed the importance of meeting and discussing ambitions, goals, processes, and experiences together and preferably in person, where textiles could be touched, and partners could be met. It was emphasized

that it was valuable that all partners met regularly, even at times when not everyone were directly involved in the agenda, since it allowed knowledge sharing across the partnership consortium and diverse feedback by all participants. Several partners noted that if there had been no COVID related restrictions and if they had been geographically closer to each other, processes and collaboration could have been established quicker and more smoothly.

- High level of trust is needed for circular value chain experimentation. The ReYarn experience has shown that building trust between partners is essential for creating a pre-competitive collaboration environment, experimenting with new processes, and exploring circular business opportunities. In-person meetings were perceived as being important for building the necessary trust between partners. As the partnership gathered several actors who used to consider themselves as competitors, building trust was perceived as one of the most important foundations for making the partnership work. It was noted by several of the partners that trust-building needs time and patience and that it is a crucial step that cannot be rushed.
- Clear definitions and common language. Partners highlighted, that it is necessary to speak a common language to work towards a shared goal. ReYarn's partners represented different parts of the value chain, and this was also reflected in their professional (sometimes technical) language and the way they understood and practiced circularity in their organizations. On several occasions, it turned out that definitions were not equally understood across the partner network. Therefore, there was a need for setting aside time and being open to clarify common goals, defining words (as e.g., waste meant different things to different partners), and understanding the details of challenges and barriers, each of the partners faced. This was also perceived as an important part of the wider trust-building.
- Partners need to be motivated and committed to the partnership. Developing and implementing circular solutions can

be slow and require additional resources. Allocating the time and resources to participate in innovation projects in each partner organisation may seem obvious, but in practice it can be challenging. ReYarn took place during COVID time and was a project with limited time and budget. In parallel, partners had to run their daily business operations. Hence, at times it was challenging to get all partners equal commitment which at times hindered data collection and project activities. For the collective effort to succeed for all, ideally all actors need to dedicate the needed time and resources which requires top management support for participating in such a partnership and properly allocated resources for delivering results. In addition, it is important that there is a designated person in each organization who takes responsibility for the necessary actions – both internal processes and external communication.

Finally, the ReYarn's partnership model showed that experimenting with circular value chain cooperation needs external coordination. Bringing together multiple actors in the textile value chain to work towards a common circular economy goal is a challenging task and requires coordination, expectation management and alignment. Although the circular economy is on the agenda of many organizations, its understanding and practice varies. ReYarn showed that it is important to have a facilitator to coordinate collaboration and ensure progress, as partners are usually busy with their day-to-day activities. Thus, for circular economy collaboration to work smoothly, it is desirable to have an external knowledge partner (e.g., a consultancy firm or academic partner) to facilitate the partnership to better coordinate and create a proper space for learning and interaction.

“The ReYarn partnership meant that we were challenged on our current practice as we were sort of put in the spotlight. I think it was good for us – we “upped our game”

Jette Skov, Salvation Army

FUTURE IMPLICATIONS

The ReYarn project showed that it is possible to create a circular collaboration model based on the project ambitions, but also, that this is not easily achievable in the short run. It also showed that further development in pre-sorting, reuse, recycling, and circular product development is needed in order to reach to viable collaboration- and business models. Based on the ReYarn experiences and learnings, dialogue between the project partners is continuing after the project end date in search of more circular and viable solutions for all.

In a wider context, the implementation steps towards a municipal collection scheme for textile waste is being taken in Denmark, in the Nordics as well as in the EU. At the time of writing the collection requirement is to be implemented in all Danish municipalities no later than July 1, 2023, and several municipalities have tested various solutions for collection schemes and partnership solutions. These pilots have had different focus areas and different prerequisites for developing solutions and results should therefore serve as inspiration rather than for comparison.

WORD LIST

Circular economy	the circular economy is based on three principles, driven by design: Eliminate waste and pollution, circulate products and materials (at their highest value) and regenerate nature.
Circular product design	a design concept where the product is designed to be durable for reuse and can be used for the same purpose over and over again or is made from renewable- or secondary raw materials which after use breaks down easily or can be recycled in a circular loop.
Circular textile value chain	the full cycle of a product or process, including material procurement, production, consumption and disposal/recycling processes. A circular value chain keeps the materials and products in the cycle as long as possible.
Green public procurement	public green priorities via procurement can move and create new markets, products and services – with a reduced climate and resource footprint. Green priorities not only have an effect on the public purchasers, but can create solutions that private companies/private sectors can also demand, thus scaling the climate and resource effect. Public green procurement contributes to the transition to green circular innovation.
Mechanical recycling	end-of-life materials can be processed via mechanical recycling where it is shredded and transformed into secondary raw materials for a new application. Manufactured from recycled material, the secondary raw material enters its new use-phase before the next end-of-life phase.
Nærgenbrugsstationer	are small recycling stations which are placed in dense settlements with the aim of bringing the service of “ordinary” recycling stations closer to the citizens. Here citizens can hand in items for reuse and the most common waste fractions.
Post consumer	households and companies/industry who are end users of a product that can no longer be used for its intended purpose. Including materials that are returned within the distribution chain or via a deposit or take-back scheme.

Pre-sorting	manual sorting step where the full load is sorted in a set of few, specified categories before fine-sorting.
Recycling	when waste materials are reprocessed into new products/materials or substances.
Recycled content	the amount of recycled material in a product or fabric.
Reuse	process by which the products are used again in it's original form for the same purpose for which they where firstly intended.
Sorting-terms	here used as a manual action, where a trained person takes out "certain" textile qualities as required.
Textile collection	is the first step when collecting the textile waste from the local recycling stations until delivered at the sorter's facilities.
Textile waste	recyclable qualities of non reusable textiles, defined as textile waste in the national guideline for sorting criteria.
Waste hierarchy	adheres to the Waste Framework Directive (Directive 2008/98/EC) which defines a 'hierarchy' to be applied by EU Member States in waste management. Waste prevention and re-use are the most preferred options, followed by recycling (including composting), then energy recovery, while waste disposal through landfills should be the very last resort.

APPENDIX A

PROJECT DEVELOPMENT GOALS

By initiating the Partnership for circular textiles "ReYarn" we aim for developing and demonstrating a comprehensive solution for handling post-consumer textiles, collected in Copenhagen, which:

1.... IS SCALABLE

As a result of the recently presented political agreement for the Danish waste sector, Danish municipalities must collect textile waste from households by 2022. The amount of textile waste collected nationwide is therefore expected to increase considerably. Each year, in the City of Copenhagen alone, approx. 6,000 tons of textiles ends up in the residual waste and is therefore currently destined for incineration. The partnership wants to demonstrate a circular solution for textiles, which can be scaled with a view to being both environmentally and economically sustainable and which in the long run can also include the growing amount of textile waste which is collected from public institutions, municipalities, and businesses. The aim of this project is also to help pushing the individual partner's business models towards circularity, as well as to test and analyse the economic feasibility of the activities derived from the partnership.

2.... PROMOTES LOCAL RESOURCE CYCLES WHERE POSSIBLE AND ENSURES TRANSPARENCY AND KNOWLEDGE SHARING ACROSS THE VALUE CHAIN

It is expected that a smaller part of the textile waste from Copenhagen can be prepared for reuse and sold on the Danish market, with a view to replacing new textiles, for the benefit of the environment. In Denmark, there is a long tradition of collecting and selling used clothes/textiles, but the partnership wants to create a common overview and understanding of how large a share of the reusable textiles can be sold locally in Denmark and whether the share can be increased in relation to the current level.

Further, the partnership aims for demonstrating a model that ensures transparency and traceability throughout the value chain.

3.... PROVIDES A BETTER UNDERSTANDING OF THE COMPOSITION AND QUALITY OF THE WASTE STREAM

Part of the textile waste is neither suitable for being sold as reuse (either directly or as a re-design) nor to be recycled with current technologies. The partnership will help to spread knowledge about which blends, and which designs that create problems in the (mechanical) recycling link in order to promote design and procurement for a circular economy.

In addition, the aim of the partnership is to show the value of the different qualities in the textile waste and what they can be transformed and marketed to.

4.... ENSURES HANDLING IN RELATION TO THE WASTE HIERARCHY

It is difficult to find markets for the large, and ever-increasing, amount of textile waste. The markets for textiles for reuse and recycling are close to saturated or flooded and there is a lack of demand for recycled fibres and products. Therefore, textile waste often ends up being incinerated or landfilled within or outside Europe.

The partnership wants to demonstrate a solution that ensures that post-consumer textile waste from the City of Copenhagen is, as far as possible reused locally and, where local or international reuse is no longer possible, is recycled and processed into new textile raw materials/yarns/products by use of existing technologies. This project focuses on mechanical recycling, which can recycle different fibre blends.

5.... SHARPENS ENVIRONMENTAL REQUIREMENTS FOR MORE GREEN AND CIRCULAR PROCUREMENT

Many public institutions and businesses wish to promote innovation and development in their tenders and also aim to make an extra effort for the environment. But this kind of development requires close collaboration and many resources. The partners in "ReYarn" wants to stimulate this development via demand for textiles/products that are based on fibres from (post-consumer) textile waste via their procurement. The aim is to identify specific material and product requirements for circular textiles/textile raw materials, which the City of Copenhagen (and possibly other actors such as retail and the fashion industry, etc.) can use in their future tenders. In addition, the partnership will work to identify possible barriers for increasing the demand for recycled fibres and, if any are identified, how to lower/remove them.

APPENDIX B

COLLECTION AND TRANSPORT

During the project period, the national requirements for the separate collection scheme for textiles in Denmark were still being formulated. Therefore, the specific collection method was not explored in detail in the ReYarn project. Instead, the project was based on household textiles collected via current practice from the City of Copenhagen's eight near recycling stations. The following appendix describes this current practice.

All textiles for the ReYarn project were collected from households in the City of Copenhagen via eight municipal local recycling stations (nærgenbrugsstationer). These are small recycling stations which are placed in dense settlements with the aim of bringing the service of "ordinary" recycling stations closer to the citizens. They partially function as "ordinary" recycling stations, servicing the citizens by providing waste services for the most common waste fractions, but are also equipped with an exchange area where citizens can leave and pick-up various reusable products such as books, clothes, tableware, toys etc. for free. The local recycling stations are thus partially set up to supplement the larger recycling centres and to make it more convenient for the citizens to dispose of their waste, but partially also to increase reuse. However, due to their limited size they can only be accessed by foot or bicycle, resulting in smaller amounts of waste (and fewer fractions) being delivered than at the "traditional" and larger recycling stations. These recycling stations have limited opening hours, typically only three days per week and are manned with both hired personnel and volunteers.

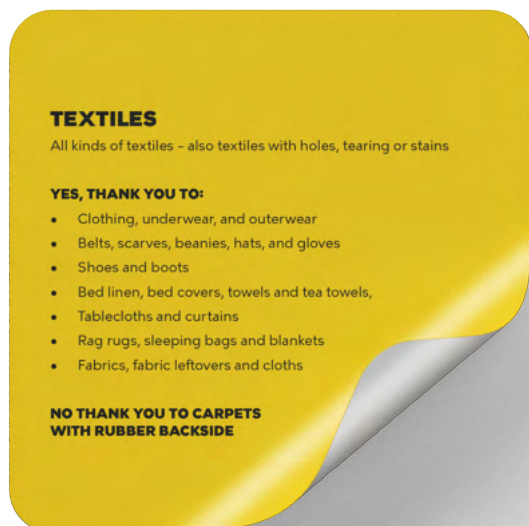
All collection containers for the ReYarn project were placed at local recycling stations. There are eleven collection containers in total.



Figure 21 Collection containers at three different local recycling stations

The containers are provided by local NGO UFF-Humana, which was the organization that collected the textiles from the local recycling stations prior to the ReYarn project start. It is also UFF-Humana who provides the service of transport to the Trasborg premises during the ReYarn pilot.

On each of the containers there is a sticker with the following text:



As mentioned above, there is an open space for exchanging goods at each of the recycling stations where citizens can leave well-functioning products of all sorts (including clothing, shoes, and accessories) for other citizens to take for free.

Figure 23 Close-up of content from an exchange area



Figure 22 Exchange areas in two different local recycling stations

When citizens arrive at the local recycling station, they are free to deliver their textiles at either the exchange area or the collection container, as they wish. On a weekly basis the personnel collect the remaining from the exchange area for which there no longer seem to be interest. The remaining is collected in larger clear plastic bags and placed in the bins. The content of the collected ReYarn material is therefore a mix of original from the citizens and bags of the collected remainings from the exchange areas. The ratio between the two is unknown. When visiting two of the local recycling stations on December 9, 2021, the personnel was asked, and their best estimate was something around 50-50 between the two options. When the textiles were inspected by Wolkat at the Trasborg sorting facility it was estimated to be something closer to 60-40 in favour of leftovers from the exchange area.

APPENDIX C

DEVELOPMENT OF SORTING CRITERIA

SORTING CRITERIA FOR REUSE

The sorting criteria were developed throughout the beginning of the pilot period as a back-and-forth learning process. The first set of reuse criteria were developed in May 2021, based on discussions between the local reuse expert (Salvation Army) and local sorter (Trasborg). At this point in time, the criteria were primarily based on experience, combined with a visual orientation of a sample batch. Once the criteria were specified, they were written down and hereafter communicated by the sorting manager to the sorting staff. The first set of criteria were applied with the first sorting batch on June 1 and on June 23, whereafter a manual assessment of the first pre-sorted batch was performed.

This first assessment resulted in further refinement of the criteria, mainly by adding more concrete examples. This second set of criteria was applied throughout the rest of the sorting in pilot A.

For sorting pilot B, the same sorting criteria were in principle applied. But, as they were based on the existing Salvation Army business model, the sorting for local reuse was performed "as usual". This means a more qualitative assessment based on experience with the Danish market and current trends rather than on the specific written criteria.

This first assessment resulted in further refinement of the criteria, mainly by adding more concrete examples. This second set of criteria was applied throughout the rest of the sorting in pilot A.

For sorting pilot B, the same sorting criteria were in principle applied. But, as they were based on the existing Salvation Army business model, the sorting for local reuse was performed "as usual". This means a more qualitative assessment based on experience with the Danish market and current trends rather than on the specific written criteria.



SORTING CRITERIA FOR MECHANICAL RECYCLING

As with the reuse sorting criteria, sorting criteria for global reuse (A & B) and recycling (REC) were developed as a continuous process throughout the first half of the ReYarn project period. The criteria were developed as a collaboration between the sorter (Trasborg) and the global reuse and mechanical recycling handler (Wolkat). In their current business model, Trasborg sorts out selected fractions of global reuse and recycling based on specific customer's needs, supplemented with export of original, but up until now, Trasborg has not had a direct collaboration with a mechanical recycler. Further, in their current business model, Wolkat collects, sorts, and recycles textiles from various partners and the two actors therefore have several overlapping activities. The reason for introducing a local sorter to do the pre-sorting step was to ensure local reuse and local management of non-recyclable waste.

Again, for this project, the criteria were specified for Trasborg by written criteria which were communicated by the sorting manager to the sorting staff.

The first set of A & B and REC criteria were developed in May 2021, based on discussions between the handler of these two fractions (Wolkat) and the sorter (Trasborg) as well as on experience. These criteria were applied with the first sorting batch on June 1. Then, on June 23, a manual assessment of this first sorted batch was performed.

At this point it became clear that a significant fraction of the textiles which had been sorted out for waste, should have been sorted out as REC. At an in-person meeting where an example batch that had been sorted out for waste, was re-opened, and re-sorted by the mechanical recycler for the local sorter to understand the criteria better. Hereafter the criteria were further refined in writing and re-communicated to the sorting staff.

The sorting manager had participated in this process and thus already seen typical items of incorrect sorting. When pilot B started the sorting manager thoroughly went through the written set of criteria with the sorting staff.

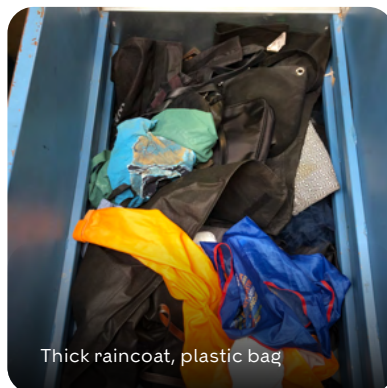
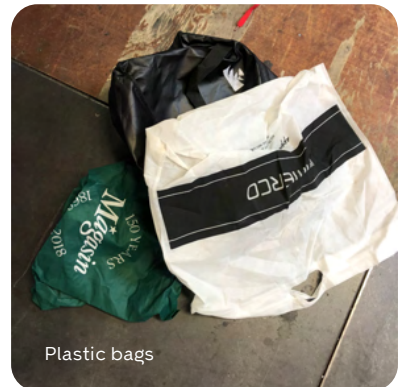


SORTING CRITERIA FOR WASTE

The sorting criteria for waste were simply developed as a residual from the recycling criteria meaning, that whatever couldn't be received for mechanical recycling was considered waste. According to the ReYarn criteria (see Figure 5) textile waste for incineration was defined as follows:

- moist, wet, mouldy, very dirty, smelly or with paint, oil, or the like
- broken synthetic and leather accessories
- carpets (mainly due to the backing material) and fabric leftovers smaller than 1.5 metres, since they get tangled up in the shredding process
- items that are often seen in textile collections since they tend to "follow" discarded textiles as e.g., packaging such as elastic bands, plastic bags, hangers, and other non-textile items like broken shoes and bags
- plastic products such as thick raincoats and fake leather (which are not suitable for reuse). These items are not accepted in the mechanical recycling process.

Some examples of these items can be seen in the following pictures:



THE REYARN SORTING CRITERIA

CRITERIA FOR LOCAL REUSE	CRITERIA FOR TEXTILES TO WOLKAT				CRITERIA FOR WASTE
	REUSE ABROAD (A,B)	RECYCLING (REC)	SHOES	SOFT TOYS	
Shop quality	Reusable textiles that cannot be sold in Denmark (A & B)	Broken stitches	Single shoes	Soft toys	Moist
Vintage	Reusable belts and bags	Wear and tear	Pairs		Wet
Brands with little (easily repairable) holes	Blankets (synthetic, with down)	Holes			Mouldy
Levi's denim with holes (for upcycling)	Reusable linnen, curtains, towels etc.	Stains			Very dirty
All products from pure 100% material such as wool, cashmere, merino, silk etc.		Faded/ discoloured			Smelly
Danish football t-shirts		Over-washed			Textiles with paint, oil or heavy coating
All products in real leather, incl. with holes/damages (for remaking). No take leather!		Broken zippers			Fabric leftovers smaller than 1,5 m
All products in thin wool, incl. with holes/damages (for remaking)		Non-reusable linnen, curtains, towels etc.			Elastic bands
All hand knitted products		Fabrics larger than 1,5 m			Carpets
All fur coats		Single gloves, socks etc.			Plastic products (thick rain coats, fake leather)
All vintage bedding w. colours and patterns incl. with holes and damages (No wet/ mouldy)					Non-textile waste (e.g. plastic bags, broken shoes and bags, packaging)

APPENDIX D

RECEIVING, STORING, AND SORTING REYARN TEXTILES

RECEIVING AND STORING

During the project period, the ReYarn textiles were collected once a week (every Wednesday) for a total period of 48 weeks (May 1, 2021 – March 31, 2022). In both pilots, UFF Humana performed the collection, transportation and unloading of the goods. As the ReYarn project was not to explore new collection methods, it was decided not to change current collection practice for the project but instead continue with UFF Humana, who were providing the collection service up to the ReYarn project start. The ReYarn flow thus begins when the textiles are delivered at the sorting facility doorstep.

In pilot A, the collected goods were brought directly to the Trasborg premises where the batch was weighed by use of truck-weigh. A receipt with date, total amount and signature was created for every batch and sent to the project management once per month. Hereafter the textiles were collected in a separate corner of the Trasborg facilities and pre-sorted when enough were collected (approximately five-ten tonnes).

In pilot B, the collected goods were brought to the Salvation Army premises. As there is no truck-weigh here, the collected textiles were weighed manually. At the SA premises, the textiles were also collected in a separate corner of the sorting facilities to be pre-sorted when sufficient amounts were collected.



Figure 24 Storage of the collected ReYarn material prior to sorting (Pilot A and B respectively)

SORTING PROCESSES

The sorting process in pilot A was performed by selected Trasborg sorting staff. The existing sorting line was cleared from "ordinary" Trasborg collections, and instead set up for ReYarn

textiles. The textiles came in as a continuous flow and were pre-sorted along the production line meaning, that what one staff didn't have time to sort, the next or third in line would handle:

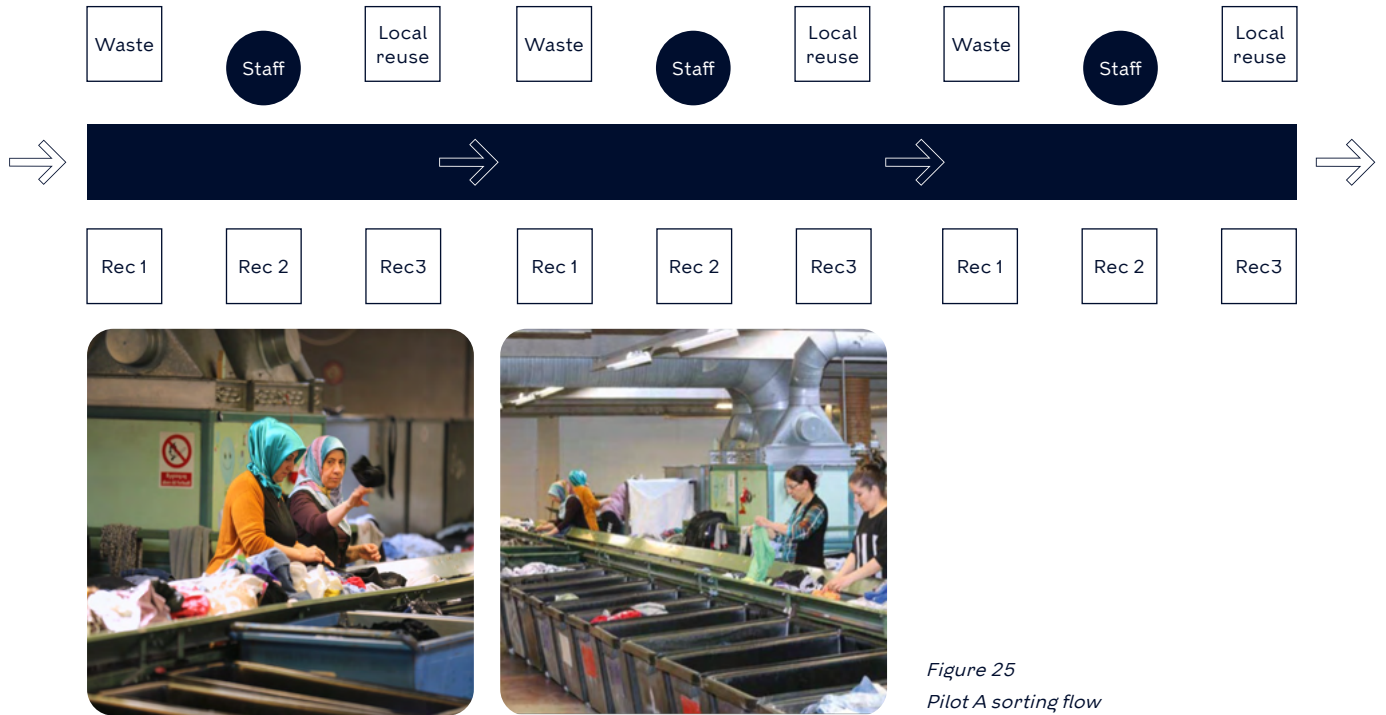


Figure 25
Pilot A sorting flow

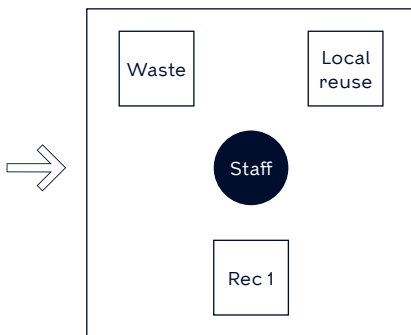


Figure 26
Pilot B sorting flow

In pilot B the textiles were sorted on "islands" meaning, that each island sorted a full load from "beginning to end" into the agreed fractions, not being able to send any of the textiles further down the line to a colleague:

From Trasborg, all textiles for local reuse were loosely packed in big bags and transported to Salvation Army (with existing return logistics). From Salvation Army they were sent out directly with existing logistics. All textiles for further sorting were stored and shipped in three different shipments (twice in pilot A and once in pilot B). Waste was continuously packed and sent for local incineration.



APPENDIX E RENEW CARDS



APPENDIX F

REYARN FABRIC AND PRODUCT REQUIREMENTS

FOR FABRIC/YARNS:

1. Fiber composition of the garment:
Polyester/ Cotton
2. Kind of fabric (Oxford, Denim twill, plain weave etc.): Twill
3. Weight per m² of fabric: 180-220 gr, M''
4. Density of the fabric or indication of threads per cm for warp and weft: 30/30
5. Quality demands (testing requirements): Martindale app. 30.000
6. Finishing (fire retardant, steam wash etc.): Pre-Shrunk



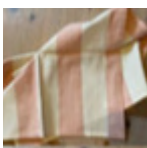


FOR PRODUCTS/GARMENTS:

7. Designs and details of product (potential extra trims)
8. Prints: NA
 - a. Pantone colors: Individual
 - b. Quality demands: Washable to 60 Celsius
 - c. Sizes: S- 3XL - depending on the product
9. Measuring charts male/female
10. Labeling instructions: DK/ EU Sizing, Care label
11. Packaging instructions: Individual packaging - eco friendly
12. Incoterm: DDP
13. Target price: Depending on the product.

APPENDIX G

WASHING TEST RESULTS

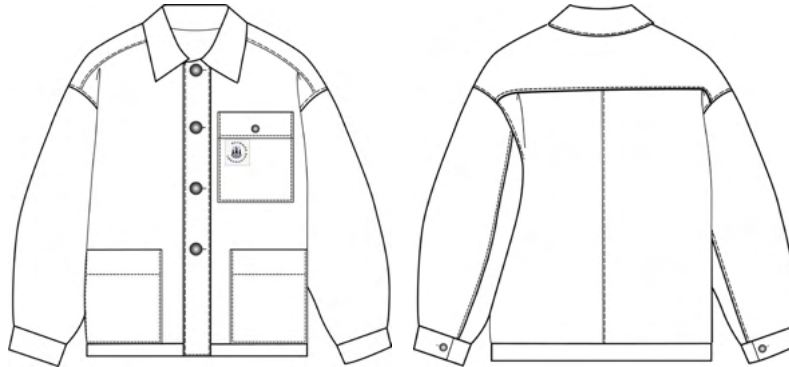
(TEA TOWEL)

		Mål før vask cm	Efter 1. vask	Efter 2. vask	0	1	2	Krymp efter 1. vask	Krymp efter 2. vask
1		50x100 cm	50x88 cm	50x87 cm	150	138	137	8,70	9,49
2		46x67 cm	44x59 cm	44x58 cm	113	103	102	9,71	10,78
3		48x64 cm	43x61 cm	42x61 cm	112	104	103	7,68	8,74
4		45x46 cm	41x44 cm	40x44 cm	91	85	84	7,06	8,35
5		46x65 cm	43x61 cm	42x61 cm	111	104	103	6,73	7,77

APPENDIX H

DESIGN PROPOSALS BY

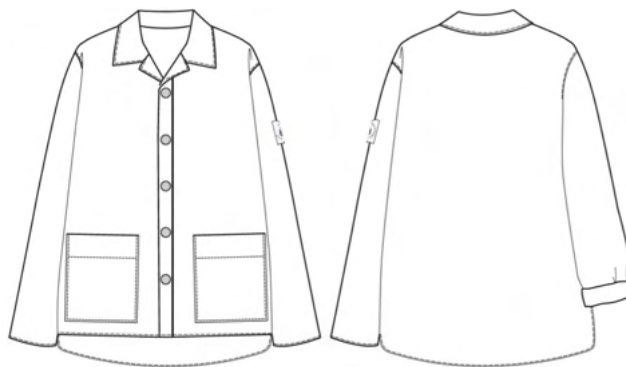
DESIGN SCHOOL KOLDING



DESIGN SUGGESTION 1

Jacket with classic collar

- Fabric 2
- Low insert of sleeves: easier for unisex fit
- Shoulder yoke + 1 part of sleeve can be with 2 layers of fabric
- Jeans buttons
- 2 rectangular pockets in the bottom
- 1 rectangular chest pocket with flap and logo
- Felled seam



DESIGN SUGGESTION 2

Overshirt with pyjama collar:

- Fabric 2
- Slightly deeper sleeves: casual fit (oversize look for women, whereas normal size for men)
- Longer backside for warmth/comfort
- Push buttons
- 2 rectangular pockets on the bottom
- Logo on the left sleeve (with loop)
- Felled seam

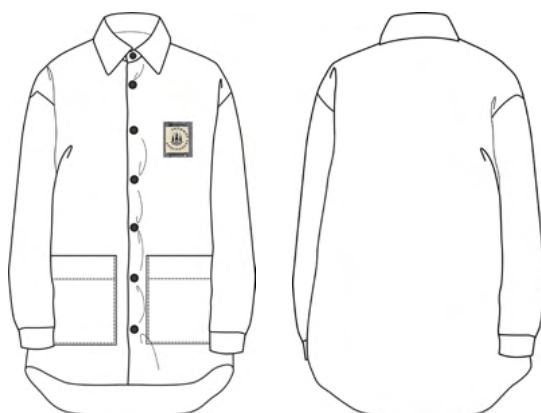




DESIGN SUGGESTION 3

Jacket with high neck collar:

- Fabric 1
- Casual fit, functional (keeps warm, elbow padding)
- Half-length button bar
- Low insert of sleeves: easier for unisex fit
- Velcro, push buttons
- 2 pockets in the bottom
- Logo on the left sleeve (with logo)
- Felled seam



DESIGN SUGGESTION 4

Padded overshirt with classic collar:

- Fabric 2
- Warm due to padding (comparable to Thermo Jacket)
- Slightly deeper sleeves: casual fit (oversize look for women, whereas normal size for men)
- Jeans button on the side with a band to adjust the width of the garment (fitted for women/men)
- Longer backside for warmth/comfort
- Jeans buttons
- 2 rectangular pockets in the bottom
- Logo on front, left side (with loop)
- Normal seam (topstitching optional)



Reference picture



Detail on the side to adjust the width of the garment

