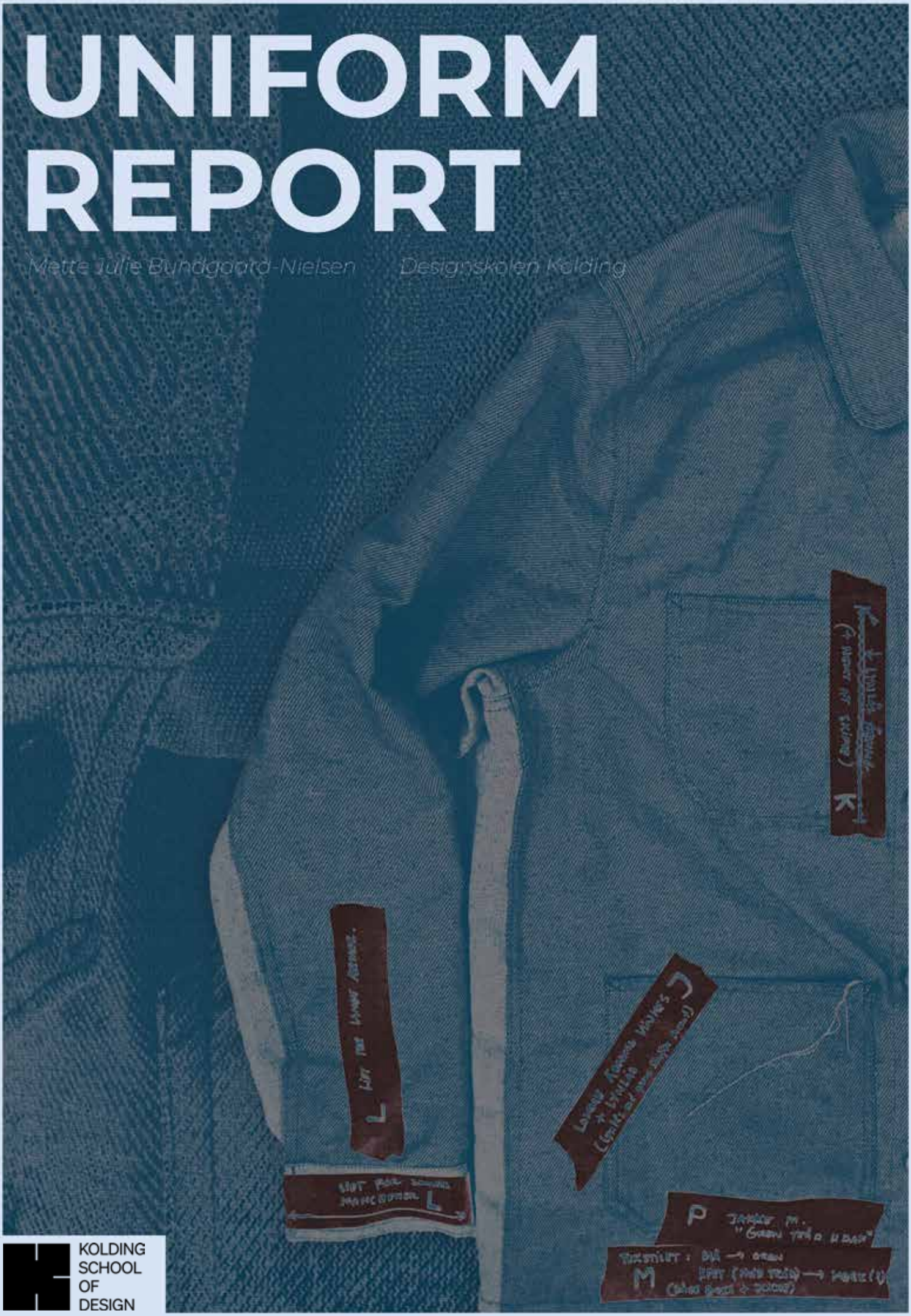
UNIFORM REPORT

Mette Julie Bundgaard-Nielsen Designskolen Kolding



KOLDING SCHOOL OF DESIGN

Abstract

The Uniform Project represents a pioneering initiative to embed circular economy principles within the workwear and textiles industry. By engaging stakeholders across the entire value chain—including public institutions, private suppliers, designers, and end-users—the project tackles systemic barriers to sustainable workwear practices. Through innovative design processes, sustainable procurement strategies, and the establishment of closed-loop recycling systems, the project lays a scalable foundation for achieving circularity while addressing economic, environmental, and functional challenges.

Key Findings:

1. Systemic Procurement Barriers:
Public procurement practices emphasize price over sustainability, limiting the adoption of circular solutions. Current tender frameworks typically allocate only 10-20% weighting to sustainability compared to 40-50% for price. This imbalance discourages innovation in repairable and recycled workwear, despite growing policy ambitions for green public procurement.

2. Design Innovation and Functionality:
The project highlights the pivotal role of designers in creating circular workwear. Through iterative experiments, the initiative prioritized modularity, repairability, and durability while addressing user needs. Modular features, such as detachable layers and replaceable components, enhance garment lifespan and adaptability. User feedback emphasized the importance of functionality, comfort, and weather resistance for practical adoption.

3. Material Challenges and Opportunities:
Mechanically recycled textiles, tested for light to medium-duty workwear, showed promise but require further refinement in durability, shrinkage, and pilling. Innovations in material blending and weaving techniques—such as denser twill structures—offer a pathway to balance circularity with performance standards.

4. User-Centric Systems:
Engaging end-users, such as city employees and facility managers, revealed a lack of emotional connection to workwear, compounded by the absence of repair services. Providing accessible repair systems and integrating cultural and functional design elements were highlighted as essential to foster ownership and extend garment use.

5. Collaboration Across the Value Chain:
Partnerships, such as ReYarn, underscore the potential of closed-loop systems for textile recycling. By collecting, sorting, and repurposing discarded textiles, these systems ensure materials re-enter the production cycle rather than ending up in landfills. However, integrating repair services and overcoming technological barriers in recycling remain critical for scalability.

Recommendations:

• Public Procurement Reform:
Introduce higher priority for lifecycle cost evaluations and sustainability in tenders. Mandate criteria for durability, repairability, and recycled materials to incentivize circular solutions.

• Design and Material Innovation:
Foster collaborations between designers and suppliers to develop modular, repairable, and durable designs. Invest in advanced recycling technologies and enhance material quality to meet rigorous workwear standards.

• User Awareness and Engagement:
Launch repair services and awareness campaigns to promote a culture of responsibility. Incorporate user insights to ensure garments meet real-world demands for practicality and comfort.

• Scaling Circular Systems:
Develop partnerships across the value chain to align stakeholders on circular goals. Improve infrastructure and policy frameworks to enable the large-scale adoption of circular practices.

By addressing these systemic barriers and fostering cross-sector collaboration, the Uniform Project provides a scalable roadmap for creating sustainable, circular workwear systems. It exemplifies how the integration of design, policy innovation, and user engagement can balance economic viability with environmental and functional demands, paving the way for systemic transformation in the textiles industry.

Acknowledgment

I would like to express my deepest gratitude to all the partners who played a vital role in this project.

Thank you for contributing to this report, with your collaboration and efforts reflected throughout the chapters. Your openness to the project and ability to create synergies across the value chain have been key to the success of this initiative. A special mention goes to Tina Winberg and the City of Copenhagen, who facilitated access to the ReYarn partnership. Your dedication has been invaluable in shaping and advancing this initiative, providing critical insights and opportunities. I also want to extend my thanks to the test users, whose feedback and hands-on insights were essential in grounding this work in practical applications and real-world needs. Your contributions have added immense value to the project, ensuring its relevance and impact.

A special thank you to the talented graphic designers, Antonia Fedder and Maximilian Schmidauer, whose exceptional work has truly brought this report to life. Your hard work and thoughtful design have enhanced the clarity and visual appeal of the report, making it a pleasure to share with the broader community.

Finally, I want to acknowledge you, the reader, for engaging with this report. It is my hope that this work not only informs but also inspires further exploration and dialogue. I warmly welcome you to reach out with thoughts, questions, or ideas for further discussions as we collectively work toward a more sustainable future.

Sincerely,

Mette Julie Bundgaard-Nielsen
Project Manager & Designer

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I: Introduction

GREEN PUBLIC PROCUREMENT IN DENMARK

In October 2020, the Danish Government introduced a new strategy for green public procurement aimed at significantly reducing the country's climate footprint. This strategy, titled Green Procurement for a Green Future, seeks to reduce Denmark's greenhouse gas emissions by 70% by 2030 and achieve climate neutrality by 2050. Public sector purchases in 2019 resulted in approximately 12 tons of greenhouse gas emissions, with 4 tons emitted within Denmark. The strategy outlines three key political tracks to contribute to these reductions:

1. Green Action Now: Initiatives with immediate impact.
2. Long-Term Green Development: Efforts that lay the groundwork for future transitions.
3. Green Knowledge and Tools: Initiatives that ensure informed, data-driven decision-making.

Public procurement accounts for DKK 185 billion across various sectors, including construction, healthcare, and IT. While the exact expenditure on textiles and workwear is unclear, the strategy also aims to transform procurement in this domain by emphasizing durability, encouraging the buying fewer products, and a clear focus on sectors with higher emissions.

The report, led by Nicolai Wammen, the Danish Minister of Finance, emphasizes the importance of "buying smarter and greener" in public sector procurement. By 2030, all public purchases must be eco-labeled, including textiles and workwear. Under the strategy's third track, a partnership was established between public institutions, suppliers, and regions to explore how public textile consumption could become greener. This partnership was expected to make recommendations by the end of 2021.

However, a letter from the Ministry of the Environment, dated August 11, 2023, indicates that the current government has yet to finalize its stance on some initiatives, including the textiles partnership. Nevertheless, the government has reaffirmed its commitment to reducing the climate footprint of public procurement (see letter attached in Appendix 3).

THE EU TEXTILE STRATEGY

The textile and apparel industry is widely recognized as one of the most environmentally harmful sectors, contributing significantly to climate change. Despite this, global production and consumption of textiles is projected to increase by 63% by 2030—from 62 million tons in 2020 to 102 million tons. Simultaneously, 5.8 million tons of textiles are discarded annually in the EU, either ending up in landfills or being incinerated. Consumption in the EU generated approximately 270 kg of CO_2 emissions per person, equating to 121 million tons of greenhouse gases overall. Indeed, between 2000 and 2015, clothing production doubled while the average lifespan of garments decreased. This means that Europeans discard about 11 kilos of textiles per person each year, emphasizing the urgent need for change.

The global environmental challenges are further highlighted by measures such as Earth Overshoot Day, which marks the time point each year when humanity's demand for ecological resources exceeds what the planet can regenerate. For Denmark, in 2024, this day occurred on March 16th, one of the earliest dates globally, underscoring the unsustainable consumption patterns in the country.

In March 2022, the European Commission published The EU Strategy for Sustainable and Circular Textiles, which envisions a future where textile products are durable, recyclable, and free from hazardous substances. By 2030, the strategy recommends that textiles in the EU should be made largely from recycled fibers and produced with respect for both social rights and environmental standards. This would significantly reduce textile waste, promote re-use and repair services, and develop fiber-to-fiber recycling capabilities.

CITY OF COPENHAGEN AMBITIONS

Two political plans frame the city's procurement of circular textiles and waste management. The first is the city's procurement policy, which promotes green and climate friendly purchasing practices, reducing

CO_2 emissions aiming to extend product lifespans and stimulate reuse and recycling of valuable resources. In concrete terms, the policy is based on 5 values "Partnerships and innovation" among others. This includes a Climate Fund to promote climate-friendly tenders and purchases.
The second is Circular Copenhagen, the city's Resource and Waste management plan 2024, which sets goals for improved textile waste collection and treatment from 2019 and 2024. The collection of textile waste from households began on July 1, 2023. The aim was to increase the amounts of textiles collected for both reuse and recycling and to support the upcoming market for sorting- and treatment solutions.

NO MANDATORY CRITERIA

Despite the prominent and ambitious national and EU-based targets and ambitions for green procurement in the garment industry, City of Copenhagen currently has no mandatory sustainability criteria in the procurement of workwear. However, as a member of the Partnership for Public Green Procurement, the city is obligated to set sustainability standards for products such as textiles and workwear. These requirements apply to both light and heavy workwear, focusing on minimizing resource consumption and environmental impact throughout the lifecycle of the textiles.

In March 2023, the City of Copenhagen issued a new tender for workwear for its employees, reinforcing its commitment to promote responsible and sustainable procurement. This contract/tender is therefore one of the first to make use of the Climate Fund's innovation clause, that provides the opportunity for additional costs associated with circular purchases, to be covered by the fund. It has the potential to make significant contributions to both national and international sustainability targets.

THE UNIFORM PROJECT

Building on the political objectives and industry trends outline above, the Uniform Project (Design School of Kolding) project aims to create a public-private partnership that fosters circular innovation in the public procurement of textiles and workwear. The project seeks to translate political ambitions into concrete actions, engaging partners from across the textile sector and public institutions within the framework of the EU's Textile Strategy.

In addition to contributing to circular innovation in the public procurement of textiles and workwear, the Uniform Project partnerships are also intended to inspire new business models in the textile industry. Here, public procurement is seen as a potential driver of sustainable textiles and circular business models, implementing the broad consensus among stakeholders about the need for mandatory sustainability criteria and target-setting at all levels of governance.

As part of the Uniform Project, a consortium has been formed, representing partners throughout the value chain, to experiment with public procurement through design practices. By identifying gaps in the linear value chain, the project seeks to generate new knowledge and make recommendations for transitioning towards a circular textile economy. This practice-driven consortium aims to promote a green transition in the textile sector for workwear uniforms while potentially driving broader industry changes.

THE UNIFORM PROJECT OVERVIEW

The Uniform Project, conducted from early 2022 to April 2023, was an activity under Lifestyle & Design Cluster and funded by the Danish Agency for Higher Education and Science. This Project identified potential for circularity in the textile economy, particularly in workwear for public procurement. The two-phase project was built on a collaboration between multiple partners (see below), as well as a product-development-process during the final phase of the Partnership for circular textiles – ReYarn, with the work structured as follows:

- The ReYarn Partnership (Part 1)
- Prototyping Partnership (Part 2)

The present report presents the work from a design perspective, highlighting key experiments in both phases.

Project Partners

- Design School of Kolding (Project Lead)

A higher education institution under the Ministry of Education and Research, Design School Kolding educates designers at the bachelor's, master's and PhD levels.

- Bacher Work Wear A/S

A leading Danish supplier of workwear, uniforms, and PPE, with over 100 years of experience in both public and private sectors.

- City of Copenhagen

With contributions from The Technical and Environmental Administration and Center for Finance and Procurement, professional expertise is represented in the project which covers circular economy an treatment of waste resources, including the promoting of climate friendly requirements in the municipality's green procurement of workwear.

- Coor

A top provider of facility management services in the Nordics, offering comprehensive solutions for both companies and public institutions.

- Copenhagen School of Design and Technology (KEA)

An institution providing practice-oriented higher education in design and technology at bachelor and business academy levels.

- Fristads Kansas Group

A European leader in workwear, with a strong presence across industries, built through innovative entrepreneurship and strategic mergers.

- ReValuate

A consultancy focused on helping businesses and public organizations transition to a circular economy, with a particular focus on fashion and textiles.

- VIA University College

One of Denmark's six vocational colleges, offering a wide range of medium-term higher education programs.

- Wolkat

A family-run business based in Tilburg, coordinating collection, reuse and recycling of textiles across Northern Europe.

PARTNERS

II: Challenging the existing linear value chain: *Why this project?*

Contributors: Lena Bay Højland (Fristads Kansas), Marie Budtz (Bacher Work Wear A/S), Tina Winberg & Josefine Fleron Bourgeat (City of Copenhagen), Kerli Kant Hvas & Nikola Kiørboe (Revaluate), Rasmus Trøst Simonsen (Design School of Kolding) and Penille Dalmose Bruun Christensen (KEA Copenhagen School of Design and Technology).

Public procurement

Both public and private sectors require uniforms and workwear. In the public sector, procurement contracts engage with private suppliers to meet specific requirements. Typically, public procurement entails large volumes of workwear with tenders put out as framework contracts for a duration of 2-4 years. The winning supplier provides workwear for the contract period. In 2023, the City of Copenhagen's workwear tender amounted to 44 million DKR. Figure 1 illustrates the process from the formulation of tender materials to finalizing contracts and decentralized purchases.

Ownership models for workwear also differ. Employers or third-party laundry services may own the clothing, with larger organizations opting for rental services where workwear is supplied, laundered, and eventually discarded. While laundry services can offer repair options, this is usually limited, as the time and cost of repairing used garments often outweigh the price of new clothing.

Figure 1. Illustration of the process for purchase in the city of Copenhagen - from the formulation of tender materials to the conclusion of a contract and the purchase by decentralized users.

The City of Copenhagen's workwear tender is divided into three segments: heavy-weight, lightweight, and sports- and leisure workwear. Heavy-weight workwear is the largest category and includes garments that fulfill specific functional or safety requirements for a range of professions, including workwear for gardeners, guards, parking attendants, and craftsmen. The range includes safety footwear, fluorescent clothing, etc.

Workwear practices

There are varying practices in the workwear industry. Some employers offer workwear from a central pool, while others give employees an allowance to purchase personal workwear. Within the public sector, workwear options are often limited to a pre-selected catalog, as seen in hospitals where hygiene or safety regulations govern clothing choices.

Textile waste

When workwear is worn out, it is typically discarded by the worker or employer, often ending up in landfill or incineration due to the absence of recovery logistics or waste management systems within the current value chain. Even at the end of a framework contract, garments are discarded regardless of their condition, as new contracts bring new uniform requirements, leading to significant additional textile waste. For example, in 2021, Danish railway company DSB replaced uniforms and disposed of 25 tons of used uniforms. This quantum of textile waste highlights the environmentally unsustainable impact of current practices regarding to the use of workwear, where discarded textiles are rarely recovered, reused, or recycled, and ends up for incineration or in landfills.

The linear value chain

Michael Porter first introduced the concept of the linear value chain in 1985 as a strategic management tool, the later applied in the textile and clothing industries to support product flow from raw materials to the end-product. A linear value chain describes this flow as a one-way process, where materials move through development, use, and ultimately end up in landfills, with no consideration for resource recovery.

In a linear model, the resources and energy invested in production are lost once the product is discarded, resulting in resource depletion and unsustainable consumption patterns. As the EU Strategy for Sustainable and Circular Textiles states:

"...these negative impacts have their roots in a linear model characterized by low rates of use, reuse, repair, and fiber-to-fiber recycling of textiles, and that often does not put quality, durability, and recyclability as priorities for the design and manufacturing of apparel."

Gaps or potentials with circularity

Notions of circularity in production offer an alternative to the Linear Value Chain, but the implementation of circularity is not without challenges. Insights from, for instance the ReYarn Partnership Project, which explored a closed-loop model for public textile procurement, indicates that there are significant difficulties in integrating circular procurement criteria and waste management measures to collect, reuse or recycle. These two functions—procurement and waste management—often operate in silos, leading to poor communication and collaboration, which complicates the adoption of circular solutions.

Implementing a fully closed circular model within some organizations can be challenging because procurement and waste management departments not always coordinate effectively. This lack of alignment makes it hard to establish a holistic circular system. As a result, offering a more "open" model, where suppliers or product owners provide reused products or items made from recycled fibers, without integrating waste management services, tends to be more viable under current frameworks. However, even this approach can encounter barriers. For example, traditional public procurement requirements often include environmental standards or certifications that are not yet adapted to address the specific characteristics of reused or recycled textiles.

Service providers that aim to offer textile reuse or recycling, without requiring a buy-back of the materials, also face obstacles. When tenders do not prioritize the waste hierarchy, circular options like reuse and recycling become less attractive due to higher costs compared to linear solutions like incineration or landfill. The underlying challenge is that circular business models generally involve higher costs than linear ones, in the short term, making it difficult for them to compete within the constraints of current procurement systems. To promote circularity more effectively, it is essential to introduce changes not only at the level of local practices but also within the broader policy and procurement frameworks that govern these processes.

Recommendations:

To foster greater circularity in public procurement, changes are required at multiple levels:

- Local practices should reduce the demand for new products and prioritize circular services, such as reuse and recycling.
- Public entities should minimize waste and demand reused and recycled fibers, integrating new requirements and labels/brands that support circularity.
- External costs should be factored in, such as through taxing resources rather than labor, which is essential for sorting, reuse, and repair services.

While significant action is occurring at the EU level, through initiatives like the regulations and policies supporting the EU Textile Strategy, continued efforts are required to implement circular practices throughout the value chain.

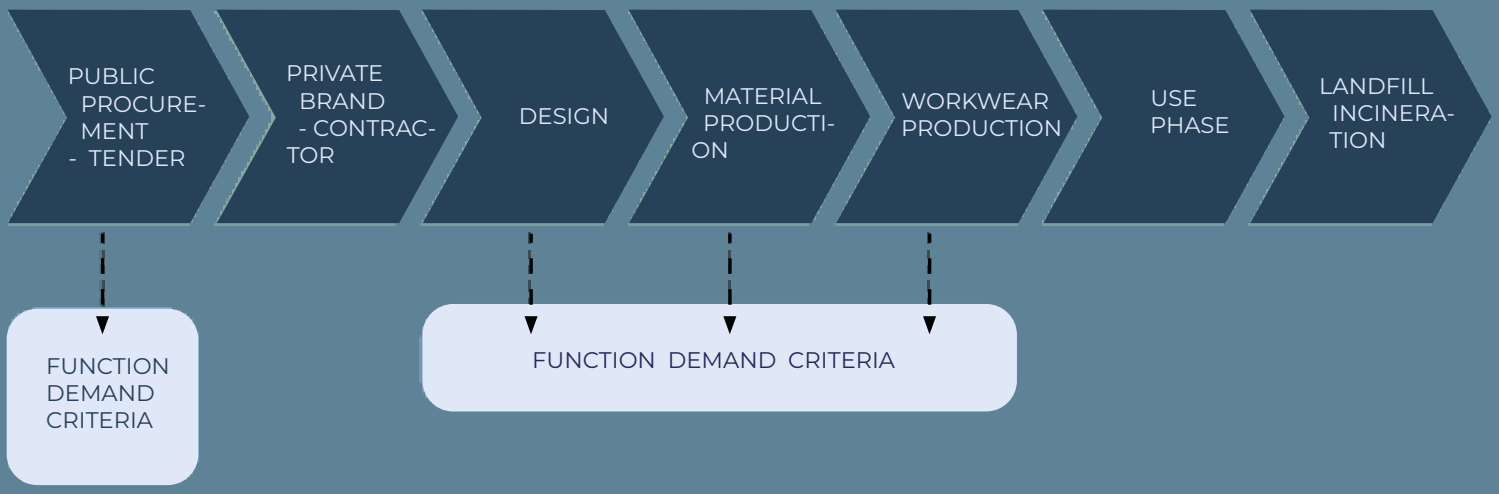


Figure 2. Illustration of the linear value chain.

III: Design experiments:
How to turn the linear value chain into a circular one? Part 1

Contributors: Martha Von Gunther (Design School of Kolding)

Design experiment #1: Historical developments

This design experiment aimed to investigate how workwear and uniforms function as visual markers of hierarchy and profession in Western culture. This exploration helped shape the design principles of the project by grounding the work in a historical understanding of how uniforms communicate status and roles.
Although the project joined the ReYarn partnership after the recycled textiles were selected, the chosen fabrics had a significant impact on the research. The texture and colour of the textiles, particularly the blue and white twill weave that closely resembled denim, became a key point of inspiration. This connection to denim influenced both the aesthetic direction and the examination of how familiar materials carry historical and cultural meanings in workwear.

When the project joined the ReYarn partnership, it inherited recycled textiles, including twill weave fabrics that closely resembled denim. These fabrics, with their indigo-like color and characteristic weave, echoed the historical uses of denim in workwear, such as the U.S. military's “working blues” from 1919-1945.

Figure 3. Research by Martha Von Gunther

Workwear and textiles

The design experiment began by investigating the historical evolution of workwear and uniforms, focusing on their origins, aesthetics, and functionality. A key aspect of this exploration was the role of materials like denim, a fabric historically valued for its durability and strength. Denim was developed as a worker’s fabric, used in garments such as firemen’s jackets due to its thick and sturdy structure, and later became widely associated with workwear. Over time, it transitioned into mainstream fashion, symbolizing both utility and rebellion.

A visual timeline was developed to illustrate the historical development of workwear, featuring iconic garments like the French “Bleu de travail” and the denim jacket, showing how these pieces have shaped the cultural significance of workwear. Denim's evolution from a worker’s textile to a global fashion staple was a critical part of the research. Initially introduced with indigo dye from Japan in the 1850s, it quickly became the fabric of choice for laborers due to its durability. From its use in U.S. military uniforms during World War I and World War II to its adoption by various industries, denim eventually transformed into a symbol of youth and rebellion, becoming one of the most iconic textiles in modern fashion. The research highlighted how workwear, originally designed for functionality, has continuously adapted to cultural shifts, maintaining its relevance across generations and time.

Uniforms in Denmark: historical context

The tradition of uniforms in Denmark dates to the 17th century, a time when the centralization of state power was gaining momentum. Influenced by French military traditions, the Danish monarchy initially introduced uniforms within the army. Historically, menswear has played a key role in shaping uniform design, serving as a source of inspiration for both aesthetics and functionality, influencing the overall structure, practicality, and style of uniforms.

Over time, this practice extended to civil services such as the Danish State Railways (DSB) and Postal Service, establishing uniforms as a symbol of authority and organization. By the 19th century, color-coded uniforms became a common way to visually distinguish between roles within public and civil sectors. For instance, "the customs service introduced them in green in 1845, while the army and postal service introduced them from 1848, in blue and red respectively," creating a clear, structured system of identification.

The DSB offers an important case study in the development of uniforms. In 1887, DSB introduced its first formal uniform system, mandating specific guidelines for employees in customer-facing roles. These early uniforms were highly structured and formal, reflecting societal norms of the time.

However, by the 20th century, as societal attitudes began to shift, so too did the design of uniforms at DSB. They moved towards more practical, user-friendly designs that better suited the needs of the workers. As noted in historical records,

> ***"at this time it was otherwise normal for coat and trousers to have different colours. Trousers typically wear out faster than the coat, and the visible difference between new and old clothing items is less if they have different colours."***

This practice was not unique to DSB but was also common in the army, customs, postal service, and the Zealand Railway Company (SJS).

The transition from formal, hierarchical uniforms to more functional workwear reflected broader societal trends toward democratization and practicality. As Denmark modernized, uniform requirements across various sectors adapted to meet the growing demand for functionality, inclusivity, and comfort in occupational attire. This transition reflected changing workplace standards and the evolving expectations of public service roles. Over time, uniforms became less about enforcing hierarchy and more about providing practical solutions that aligned with the workers' daily needs and the public's expectations for accessibility and service.

Modern workwear and the influence of uniformity

Uniforms for work, though varied in style and accoutrements, often draw on three primary sources of design: military uniforms, ecclesiastical garb, and the dress of service workers. Across different sectors in modern Europe, uniforms reflect varying levels of formality—from the strict, classic designs of military and civil service roles to more relaxed quasi-uniforms in blue-collar industries, and casual workwear in less formal settings. Uniforms continue to act as important visual markers of occupational roles, but their design has shifted over time to prioritize practicality and adaptability for modern workers.

Uniforms can be categorized into three distinct types: formal uniforms, quasi-uniforms, and casual uniforms. Formal uniforms, such as those used in the military or certain civil service roles, are characterized by strict protocols and an obligatory dress code. A notable contrast is the "quasi-uniform", a term coined by Jennifer Craik in 2005 to describe standardized workwear that mimics the uniform aesthetic but is less formal and more practical for everyday tasks. As Craik explains, quasi-uniforms apply not only to work clothes but also to sportswear and other forms of standardized attire. They represent a blend between mandatory dress and more flexible, informal garments that still provide a professional appearance. For instance, *"standardized apparel for work: In research on uniforms a distinction is made between uniforms, quasi-uniforms, and casual uniforms"* (Bjerck, 2017). In blue-collar sectors, these quasi-uniforms often take the form of work jackets, overalls, or other functional garments that balance professionalism with comfort.

A key feature of quasi-uniforms is their adaptability. Unlike traditional uniforms, which are deeply rooted in hierarchy and symbolism, quasi-uniforms emphasize comfort and practicality without sacrificing the professional appearance needed in many jobs. This shift reflects broader societal changes where workwear is now more fluid and responsive to the demands of the job rather than being tied to symbols of authority. For instance, workwear in the Navy is described as a strict uniform due to its "obligatory and protocolled dress", but in contrast, standardized workwear in other sectors allows for greater flexibility and is less bound by rigid guidelines.

Furthermore, the evolution of uniforms highlights a balance between maintaining classic design elements and integrating modern fashion influences. As the typology of uniforms demonstrates, *"the greater the departure from classic design, the sooner the imperative to restyle a uniform."* This is particularly evident in fields that rely heavily on classic, easily recognizable uniform designs, such as academic, judicial, or funeral director attire. In these professions, classic elements serve to maintain occupational specificity and status ranking through well-established vestimentary codes, which resist frequent restyling. In contrast, industries that adopt quasi-uniforms or casual workwear experience more flexibility in both style and function, allowing for adaptations that meet the evolving needs of the workforce.

In summary, the transition from formal, hierarchical uniforms to more functional and inclusive quasi-uniforms reflect the changing dynamics of modern work environments. As the need for adaptability grows, particularly in blue-collar and manual labor sectors, uniforms are no longer just about representing authority but about providing practical solutions for workers' everyday tasks. This blending of functionality, professionalism, and comfort is at the core of modern workwear, as seen in the rise of quasi-uniforms across various industries.

Recommendations for advancing circular workwear practices

To successfully transition from a linear to a circular value chain in workwear, the following recommendations are proposed:

1. Adopt quasi-uniform workwear for flexibility and longevity:
Workwear in blue-collar sectors functions as a quasi-uniform, which, while not strictly enforced, serves as an important visual and functional element of various professions. It is recommended to formalize this understanding, allowing workwear to blend professionalism and practicality. Furthermore, considering how workwear design also could be extended to private use when work functionalities decline over time. This approach could potentially maximize garment lifespan and reducing waste.

2. Embrace Inclusive, Non-Gendered Design Inspiration:
Historically, menswear has been a significant source of inspiration for uniform design, influencing both aesthetics and functionality. Workwear design could improve on inclusivity by moving beyond traditional gender-specific influences in example for the sizing system and focus on creating garments that are functional and comfortable for all, regardless of gender. By adopting a non-gendered approach, the design can ensure equality in both form and function, offering clothing that accommodates diverse body types and work needs. Prioritizing practical elements like pockets, fit, and materials in a way that is adaptable for everyone promotes a more inclusive work environment where expression and comfort are accessible to all workers, fostering equality and reducing gendered distinctions in professional attire.

3. Prioritize durability and timeless design:
The longevity of uniforms depends on balancing classic design elements with contemporary fashion trends. Adopting durable designs that resist rapid obsolescence can significantly reduce the need for frequent uniform replacements, thereby supporting circular practices.

4. Leverage color for occupational identity:
Color plays a vital role in distinguishing occupational roles and professions. Public procurement systems could consider using color as an identification of trade where appropriate, while also exploring how colors can be reused or recycled in circular systems.
5. Integrate circular design elements for repairability and recyclability: Future uniform/workwear designs is recommended to include easily repairable or replaceable components to extend the garment's lifecycle. Further implementing circular design principles, such as using recycled or recyclable materials, can reduce environmental impact and contribute to long-term sustainability in public procurement.

6. Promote circular procurement practices:
Public procurement is recommended to incentivize suppliers, and partners to adopt circular business models, prioritizing products made from recycled fibers or those that are designed for reuse and repair. Adjusting procurement criteria to account for the environmental benefits of circular systems will help bridge the gap between cost and sustainability.

7. Adopt open uniform/workwear systems:
A flexible approach to workwear systems, allowing for quasi-uniforms or partial uniform obligations, could enhance sustainability by reducing unnecessary workwear production. This also means ordering workwear with no logos/ removable logos. Differentiating between roles that require strict uniform codes and those that can utilize more casual, functional workwear can drive cost and material efficiency.

Contributors: Tina Winberg & Josefine Fleron Bourgeat (City of Copenhagen), Kerli Kant Hvas & Nikola Kiørboe (Revaluate), Marie Budtz (Bacher Work Wear), and Martha Von Gunther (Design School of Kolding).

Design experiment #2: Emerging systems

This section explores the systems relevant to the Uniform Project, both within the project itself and in the broader context of circular economy practices. It focuses on how waste recovery systems, design for longevity, and innovative services can contribute to circularity in the textile industry, particularly in workwear. The first part of this experiment is connected to the ReYarn Partnership, which aims to rethink the value chain through a circular lens.

The ReYarn Model

The ReYarn Partnership focuses on creating a closed-loop system for textiles through the collection, sorting, and treatment of textile waste within the City of Copenhagen. The ReYarn model is built around a waste management system that collects discarded textiles from households in Copenhagen and channels them into new textile categories for reuse and for recycling production processes, thus extending their lifecycle. The fine sorting process plays a critical role in separating textiles by color and material, ensuring that the reusable or recycled fabrics retain their quality and usability in new flows and products. For example, Wolkat, a key partner in the project, works with resource stocks, focusing on color sorting to optimize textile recycling for future production.

The ReYarn model was a collaboration between several partners, each contributing to different stages of the value chain. By mapping out who and what influences design decisions, the partnership highlights the complexity of creating a circular system that includes textile waste recovery, recycling processes, and the production of new textiles and workwear design. This integrated approach seeks to ensure that non-wearable-textiles are not lost in incineration or landfill but instead re-enter the production cycle.

Product development in the ReYarn Project

The ReYarn project incorporated product development as a key element to demonstrate the potential of mechanically recycled fibers for municipal use. This initiative aimed to close the loop on textile waste by transforming non-wearable post-consumer textiles into scalable and functional products. The project focused on three product tracks: tea towels for municipal facilities, light workwear such as unisex overshirts, and upcycled cushions.

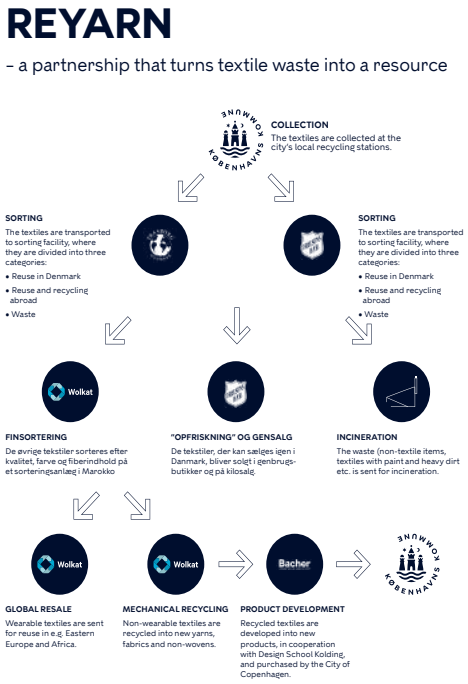


Figure 4. The ReYarn Model

The product development process emphasized close collaboration among the City of Copenhagen, recycling experts, and workwear suppliers. These partnerships facilitated iterative testing, material analysis, and prototyping to align product functionality with circular design principles. Key features included the use of post-consumer textiles, timeless and unisex designs, and enhanced circular strategies to extend product lifecycles.

Challenges of repairability in workwear systems

The test users for the user study (Nikolaj, Morthen, and Solbjørg), provided valuable insights into the challenges and opportunities within workwear systems, highlighting how design, functionality, and user behavior intersect. Nikolaj and Morthen are both gardeners for COOR and frequently uses workwear in demanding physical environments. Solbjørg is employed in outdoor public maintenance at ByOasen.

User studies revealed that the workers often discard garments with minor tears or wear, as there is little attachment to the clothing (feels no responsibility) and replacements are readily available. As Solbjørg pointed out: "We don't have a repair service, and most of the time it's easier just to discard the worn-out workwear." This highlights a key issue in the current system, where damaged garments are simply thrown away without consideration for repair or reuse.

Since no formal repair service is offered and workwear is viewed purely as functional, users do not seek to repair or maintain their garments. Nikolaj confirmed this by stating: "It can't be repaired. They just get thrown out, or they are kept for private use." This lack of emotional connection to the garments, combined with the ease of replacing worn items, fosters a linear system where workwear is discarded rather than repaired.

Moreover, the complexity of workwear designs adds to the challenge. Many styles feature intricate construction and assembly methods that complicate repair efforts. Morthen emphasized the issue of wear and tear in high-stress areas, noting that "[w]hen they start to wear out, it's mostly at the bottom of the pants, near the shoes, and on the knees." Without a straightforward way to repair these common damage points and given the lack of personal attachment to the garments, workers are less inclined to attempt repairs themselves.

Public procurement presents a critical opportunity to advance circular practices, such as integrating repair services and durable design requirements. However, current procurement frameworks often prioritize price over sustainability, creating challenges for suppliers who are ready to offer repair solutions but face competitive pressure to minimize costs. For example, tenders frequently allocate only 10-20% of evaluation weight to sustainability while focusing 40-50% on price. This misalignment discourages investments in circular services, as suppliers are compelled to prioritize cost over quality and innovation.

The challenge, therefore, lies in developing a system where repairs are not only feasible but also prioritized within the lifecycle of the garment. Shifting the focus towards repairability could help transition workwear systems from their current linear model to a more sustainable, circular approach.

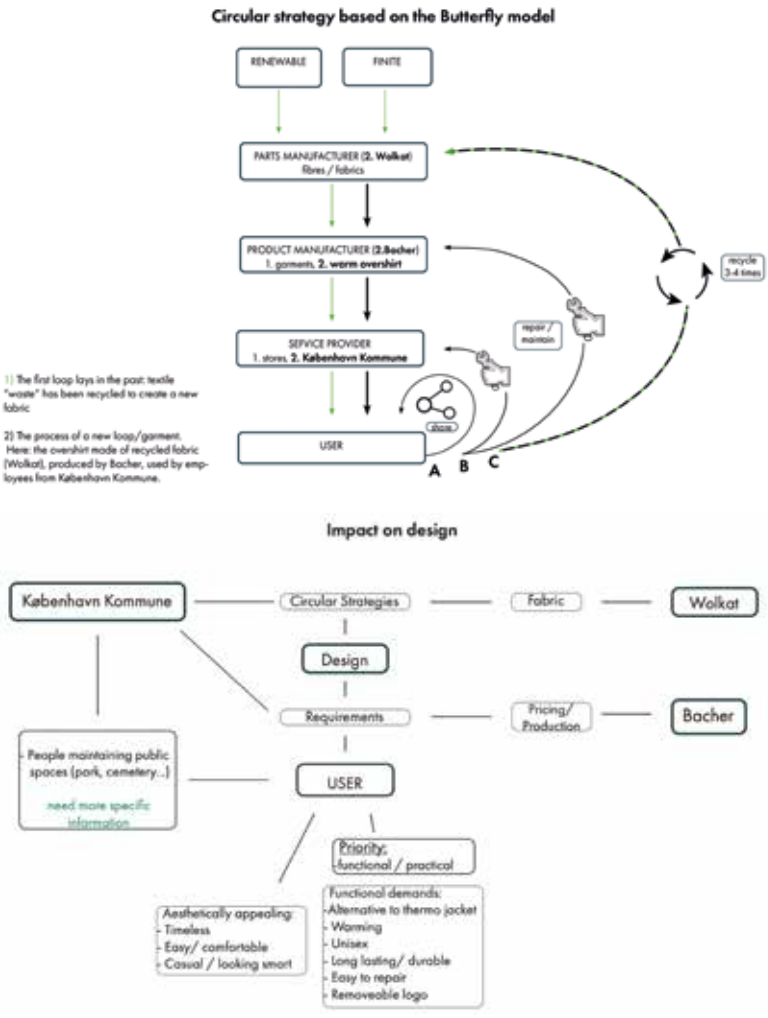


Figure 5. Mapping of stakeholders and circular strategies for the Uniform Project.

Recommendations for emerging systems and circular workwear

Based on these findings, there is a clear need for new systems within the workwear value chain that support circularity. This includes:

1. Prioritize design for repairability and durability:
Designers play a critical role in shaping garments that are not only functional but also easy to repair and recycle. Modular designs, such as garments with detachable or interchangeable components, could facilitate repairs in high-wear areas like knees and cuffs. For instance, incorporating snap-on waterproof layers or detachable insulation can enhance the usability of workwear across varying conditions while extending its lifecycle.

2. Reassess public procurement frameworks:
Public procurement policies can be a key driver for promoting repair services and durable design. However, current procurement criteria often overemphasize price at the expense of sustainability. To address this, procurement contracts should:

- Incorporate lifecycle cost assessments to evaluate the long-term savings of repairable and durable workwear.
- Allocate a higher weight to sustainability, ensuring that repairability and durability are incentivized alongside cost and quality.
- Avoid overly broad sustainability requirements by focusing on a few high-impact areas, such as repairability or durability.

3. Encourage user responsibility and awareness:
User behavior is critical to the success of circular systems. Creating awareness about the benefits of repair and providing easy access to repair services can encourage users to extend the life of their garments. Educational campaigns and repair services embedded in workwear contracts can shift the culture from disposable to sustainable.

4. Establish repair services as part of the value chain:
Repair services should be integrated into the workwear lifecycle, both in design and in public procurement policies. For example, tenders could require suppliers to include repair services or provide modular garments that are easier to maintain. To ensure adoption, public procurement frameworks must balance these requirements with realistic cost structures to avoid penalizing suppliers willing to invest in circular solutions.

5. Develop user-centric circular systems:
Engaging users in the design process can help align circular systems with practical needs. This involves tailoring workwear for ease of maintenance, comfort, and modular upgrades. User studies can guide the development of garments that balance functionality with sustainability, ensuring that circularity does not come at the cost of practicality.

6. Develop partnerships across the value chain: Collaboration between designers, suppliers, and public entities is essential for building circular systems. Transparent communication and shared goals across stakeholders can ensure that each stage of the value chain contributes to circularity.

Design experiment #3: Material qualities

The quality of materials was a focal point from the begging of the Uniform Project, as the project sought to build on both the visual characteristics of textiles and their functional properties. Hands-on testing and industrial evaluations were conducted to understand how different textiles would perform when applied to workwear. This approach provided insights into the durability, strength, and aesthetic qualities of recycled textiles in relation to their suitability for workwear products.

Wolkat process and material testing

Wolkat supplied two types of mechanically recycled textiles with distinct compositions and weave structures: Oxford (PES) and Oxford (CO). These textiles were pre-selected by the City of Copenhagen and the ReYarn partnership based on their color and construction. The goal of testing these textiles was to assess their suitability for workwear, particularly in terms of durability, washing performance, and aesthetic appeal:

- Textile 1 (Oxford PES):
  This fabric features a basket weave/Panama weave structure. It is composed of 47% rPET (recycled polyethylene terephthalate), 42% recycled post-consumer textiles with a high synthetic content, and 11% PES (polyester).

- Textile 2 (Oxford CO):
  This fabric uses a twill weave structure. It consists of 40% recycled post-consumer textiles with a high cotton content, 35% pre-consumer recycled cotton, 12.5% rPET, 10% PET, and 2.5% other fibers.

A range of tests was carried out, including Martindale abrasion tests performed by VIA University College, as well as washing and sewing trials by the Design School of Kolding. The Martindale abrasion test is a standard method used to evaluate a fabric's resistance to wear and pilling by subjecting it to repeated friction in an oscillating motion. The fabric is rubbed against a standard abradant, such as wool or wire mesh, and the test continues until visible wear, such as yarn breakage, occurs. The result is measured in cycles or rubs, with higher scores indicating better durability and suitability for heavy use.

The findings highlighted differences between the two textiles, particularly in terms of fluffiness, softness, and robustness. The Martindale test showed that both textiles met the basic requirements for light uniform workwear but exhibited a higher-than-expected pilling tendency. This pilling was due to the loose weave structure, which reinforces the need for modifications in the textile construction to meet workwear standards more effectively.
The washing test results showed no shrinkage for either textile after washing at 40°C, even though the recommended washing temperature is 30°C. Both textiles showed slight color changes and became fluffier on the front side compared to the back, suggesting that the weaker recycled yarn is primarily on the front side, while the stronger rPET fibers are mainly concentrated on the backside. Textile 1 appeared softer, while Textile 2, with its more robust twill weave resembling denim, was recommended for further use in prototypes due to its durability and similarity to traditional workwear fabrics.

Figure 6. Uniform project/ Wolkat textile /test by Martha Von Gunther

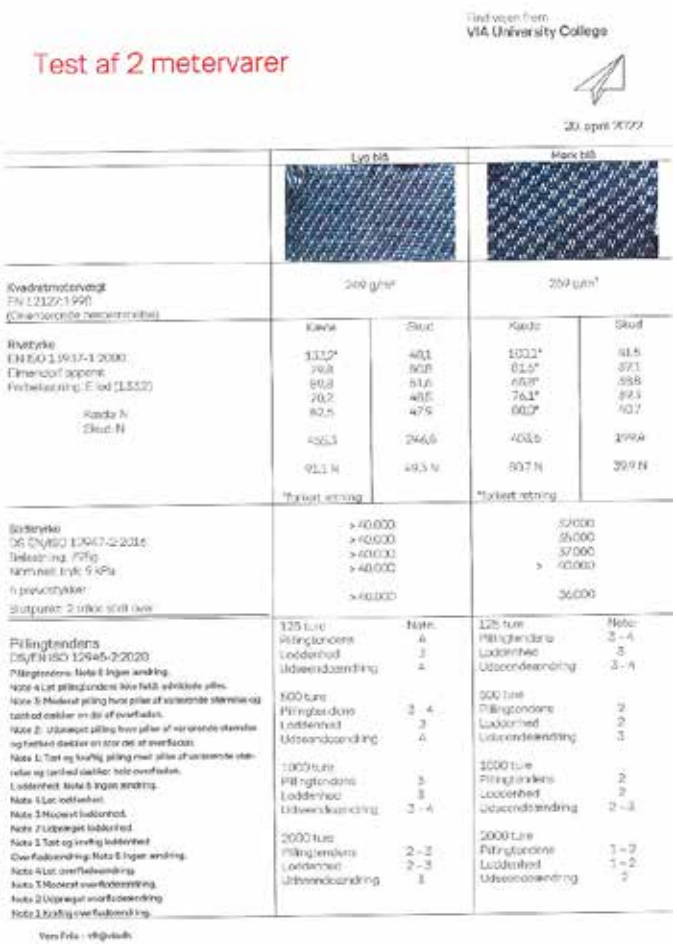


Figure 7. VIA University College / Test by Poul-Erik Jørgensen

The conclusion from these tests was that one of the textiles, with a twill weave resembling denim, performed better overall. This weaving construction is historically known for its durability in workwear, further reinforcing its suitability for medium-duty use.

Mechanical recycling: challenges and opportunities

Mechanically recycled textiles are gaining attention as a scalable solution for circular textile systems. The process of mechanical recycling involves breaking down textiles into fibers, which can then be spun into new yarns.

However, this process presents several challenges:

1. Shortened fibers:
Mechanical recycling reduces the length of fibers, which weakens the material. As a result, new fibers must be blended with virgin fibers to ensure sufficient strength and durability.

2. Color sorting:
Color sorting is essential because the recycled fibers are typically not over-dyed. Achieving consistent color results can be difficult, which leads to batch variations. However, this minimizes additional energy consumption associated with dyeing.

3. Material contamination:
Especially with post-consumer textiles, contamination by harmful substances can complicate the recycling process, potentially affecting the final product.

Despite these challenges, mechanical recycling is an attractive option due to its scalability and relatively low energy consumption compared to other recycling technologies. In comparison, chemical recycling—though promising—requires significant infrastructure investment and is not yet ready for large-scale implementation.

Potentials in textile construction for workwear

The tests revealed several key insights into how the production process affects the durability of mechanically recycled textiles. Adjustments to the spinning and weaving methods could significantly improve the performance of these textiles in workwear applications. Specifically, the following elements were highlighted as potentials:

- Weaving structure:
Twill weaves, like those used in denim, showed better wear properties than other weaves like basket weave. However, the twill fabric tested in this project was slightly loose. Increasing the thread density could create a tighter weave, improving durability and resistance to pilling.

- Spinning process:
Wolkat used open-end (OE) spinning, which is cost-effective but results in looser, less uniform yarns. A switch to ring spinning could produce stronger, more regular yarns, although it is more resource-intensive, expensive and require a better quality of recycled fibers.

- Fiber blending:
To compensate for the shorter, weaker fibers created during mechanical recycling, blending with new long fibers (such as rPET in this case) is necessary with the current technology. The right mix of fibers could improve both the strength and appearance of the final product, making it suitable for workwear.

Washing and durability considerations

The tests also examined how the textiles held up after repeated washing. Mechanically recycled textiles require specific washing instructions to maintain their qualities over time. Notably, washing at higher temperatures, such as 60 degrees, resulted in significant shrinkage of 1-2 sizes in both the trousers and jacket prototypes, as observed through repeated tests. Additionally, tumble drying appeared to exacerbate this issue. These findings suggest further testing to evaluate the long-term effects of high temperature washing and drying. The textiles were also observed to become less fluffy after washing, particularly on the reverse side, where rPET fibers were more prevalent, further highlighting the importance of optimized care guidelines for maintaining material integrity.

The users were also tasked with assessing how the textiles performed after repeated washing. However, some of the users encountered practical challenges with the recommended washing instructions. For example, Solbjørg explained,

"We haven't washed it yet because our washing situation is so complicated. We must wash at Nørrebro parken, which is about a kilometer away, and it must be quick because we are borrowing this space temporarily. So, the fact that it needs to be washed at 30 degrees is a problem."

The recommended washing temperature of 30 degrees was particularly problematic for workers, as noted by Nikolaj, who said, "Washing at 30 degrees is a no-go. They will never get clean. Normally, it's between 40 and 60 degrees for workwear, and that's what it needs." Morthen added: "It says 30 degrees, but that's not going to cut it. It needs at least 40 or 60 degrees, especially with how dirty the clothes get from work. It's not practical."

Higher washing temperatures need further testing to evaluate their long-term effects on the durability of the fabrics. The textiles were observed to become less fluffy after washing, particularly on the reverse side, where rPET fibers were more prevalent, indicating potential wear concerns.

Recommendations for material qualities in circular workwear

1. Increase thread density in weaves:
To improve the durability of mechanically recycled textiles, especially in high-wear applications like workwear, increasing the thread density in the weave—particularly in twill fabrics—could help achieve tighter, more robust constructions. This could reduce pilling and enhance fabric durability.

2. Adopt ring spinning for stronger yarns:
While OE spinning is currently used due to its cost-effectiveness and the possibility to use shorter fibers, ring spinning would produce stronger, more uniform yarns. This method should be considered for workwear textiles where durability is paramount. Additionally, twisting the yarn post-spinning could further improve strength and appearance.

3. Blend recycled fibers with new fibers strategically:
The performance of mechanically recycled textiles depends heavily on the blend of new and recycled fibers. Blending in long fibers at the right ratio (typically between 50-70%) can improve the strength and durability of the final product, making it more suitable for medium-duty workwear.

4. Refine washing instructions for recycled textiles:
The unique composition of mechanically recycled textiles requires tailored washing instructions. Testing higher washing temperatures and analyzing the effects of repeated washing will help refine guidelines that ensure the longevity of recycled workwear.

5. Consider mechanical recycling for light-medium workwear:
The current generation of mechanically recycled textiles is suitable for light weight workwear. However, further development is needed to meet the more stringent durability requirements of medium to heavy-duty applications.

6. Develop standards for recycled textiles in public procurement:
There is an opportunity to align public procurement standards with the goals of resource recycling. Setting minimum quality requirements that account for the characteristics of recycled materials, while also supporting innovation in recycling technologies, could accelerate the adoption of circular textiles in public sectors.

7. Support the scaling of mechanical recycling:
Mechanical recycling technologies offer a scalable solution that can be quickly deployed to meet the growing need for textile recycling, particularly considering the EU's textile strategy and the increasing collection of textile waste. Investing in infrastructure and research to enhance the mechanical recycling process will be crucial for long-term success in circular textile systems.

8. Textile Durability:
When working with a textile weaving construction where yarns have different strength qualities distributed between the front and back, it is recommended to use the stronger side, like in this case the reverse side (where the more durable rPET fibers are concentrated) in high-wear areas like under the arms or on the knees. This strategic use of the reverse side will help reinforce these sections and extend the overall lifespan of the garment.

Contributors: Tina Winberg (City of Copenhagen) and Martha Von Gunther (Design School of Kolding)

Design experiment #4: Development of workwear styles

This design experiment focused on developing workwear styles based on circular design principles, following a brief from the City of Copenhagen. The project aimed to create workwear that not only met functional and aesthetic requirements but also integrated circularity into every stage—from design to end-of-life management. This design sprint, conducted in April 2022, had the goal of presenting finalized designs at the LOOP Forum Conference in Copenhagen later that month.

Design proposal

The City of Copenhagen suggests the following for the development of workwear prototypes: The prototypes should be based on circular workwear principles, serving as an alternative to the traditional thermal jacket. This overshirt-style garment should be designed with circularity in mind, allowing for reuse, recycle or repurposing after its initial lifecycle. Key features include the use of post-consumer recycled textiles, a timeless and multifunctional design (e.g., unisex), and the ability to substitute for a thermal jacket in terms of functionality. Additionally, the workwear should feature removable logos to facilitate reuse and recycling, and the production costs should remain feasible, if possible, without a significant increase.

Figure 8. Design briefs, and trend research and aesthetic expression. Tina Wiinberg & Marha Von Gunther,

Workwear design considerations

The design process began with trend research to ensure that the workwear would not only be functional but also appealing for both public and private sector use. Workwear must strike a balance between looking professional while being practical. Details such as collars, cuffs, pockets, and trims serve as visual markers of cultural codes, status, and historical references in clothing. These elements also help convey authority and trust, which is particularly important in roles that involve public representation. The aesthetic balance of both the professional and practical as well as having a modern expression, where tested in samples.

The test concluded the following:

- Collars:
  The formality of the collar was a key consideration. A more formal collar might be appropriate for roles with a public-facing or authoritative aspect, while an informal collar could be suited to more practical, labor-intensive roles.

- Pockets:
  Inspired by historical research, symmetrical square pockets were chosen for ease of production and practical use. This decision also considered the production efficiency of the assembly line, where simpler designs tend to result in better manufacturing quotes.

- Trims and Circularity:
  Trims such as elastic bands, Velcro, and metal press buttons were scrutinized in terms of their impact on fiber-to-fiber recycling. Less trim simplifies recycling and reduces sorting challenges during textile production.

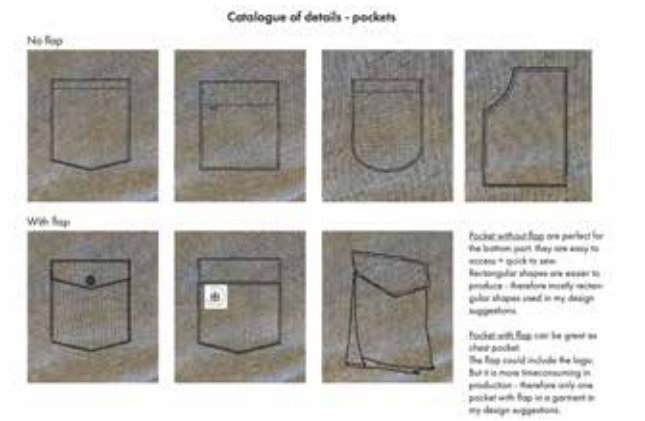


Figure 9. Pocket design. Martha Von Gunther

Figure 10. Cuff design. Martha Von Gunther

Functional and circular design elements

Workwear must also be highly functional, with considerations for durability, ease of movement, and comfort. This includes designing garments that can withstand the demands of physical labor while being easy to repair or recycle. The design team prioritized the use of materials that could be easily recycled, with a particular focus on reducing the complexity of trims and threads. Simplifying these elements can significantly improve the recyclability of the garment, which is critical for circular workwear systems.

Logo placement and circular challenges

The placement and attachment of logos were another central focus. Logos are often a requirement for uniforms, especially in the public sector, to ensure easy identification of roles (e.g., Danish Police or DSB). However, logos can also pose challenges for recycling and upcycling because they need to be removed to prevent misuse of discarded uniforms/workwear. The project explored solutions that would allow logos to be detachable, making it easier for garments to have a second life after their initial use phase. For example, logo placement was evaluated against security concerns, where uniforms with logos from government institutions must have logos removed before being reused, recycled or repurposed. This poses significant obstacles to achieving circularity, which is why innovative methods for applying logos in a more removable format are essential.

Throughout the user interviews, participants emphasized the importance of logos in helping them establish their presence and role within their work environments. Nikolaj noted: “No logo is a big minus. Clearly missing a company logo. People look at me and think, ‘Who the hell is he? And why is he messing with my garden beds?’” This sentiment highlights the confusion that can arise when uniforms lack visible identifiers, making it harder for workers to be recognized in their official capacities.

Similarly, Solbjørg expressed the need for easily recognizable logos to help workers engage with the public: “We would really like something that says ByOasen, either on the chest or the back. You know, it would be nice to have something recognizable, especially for people who visit.” Morthen also pointed out the practical benefits of logo visibility: “It’s hard to tell who we are without a logo. If there was at least a badge or something that showed we work here, it would help a lot.”

These insights underscore the vital role logos play in ensuring that employees are easily identifiable, particularly in sectors where public interaction is frequent. However, the need for logos also presents a challenge when aiming to create circular workwear solutions. Logos often need to be removed from garments to prevent unauthorized use when the clothing is discarded, complicating efforts to reuse, recycle or repurpose the items. Developing solutions that allow for easy removal or reattachment of logos is essential to balancing the need for both identification and sustainability in the workwear after-use-phase.

Figure 11. Logo solutions. Picture by Martha Von Gunther

Logo suggestions

- Suggestion 1:
  Logo can be sewn on a belt look. The loop can be placed anywhere on the garment. If the logo needs to be changed, it can be removed without leaving any visible traces on the garment itself.

- Suggestion 2:
  Logo can be sewn under the flap of a pocket. Under the flap runs a ribbon, which makes any exchange of logo invisible.

Final design proposals

The project resulted in four design proposals, with two being selected for further development (Designs 2 and 4). The choices of the designs were done in agreement with the partners of the project, but with The City of Copenhagen as the decisive voice in this matter.

Figure 12. Design suggestion 1 & 2. Martha Von Gunther

Design 2 was focused on using a twill fabric, known for its durability and resemblance to denim, this design prioritized strength and longevity, requiring 1.8 meters of fabric per garment. The decision to use minimal trims and detachable logos ensured that the garment could be easily recycled at the end of its life.

Figure 15. Final design #2. Martha Von Gunther.

Design 4 was made from a loose-weave fabric, this design used 2.87 meters of fabric due to the inclusion of padding for added warmth. Like the first design, it incorporated detachable logos and simplified trims to ensure ease of recycling.

Both designs highlighted the importance of clear communication between partners throughout the design and production process. Collaboration with fabric suppliers like Wolkat and feedback from public-sector partners such as the City of Copenhagen and Bacher Workwear ensured that the final designs met the project's goals for circularity and durability.

Figure 13. Design suggestion 3 & 4. Martha Von Gunther

Figure 16. Final design #4. Martha Von Gunther.

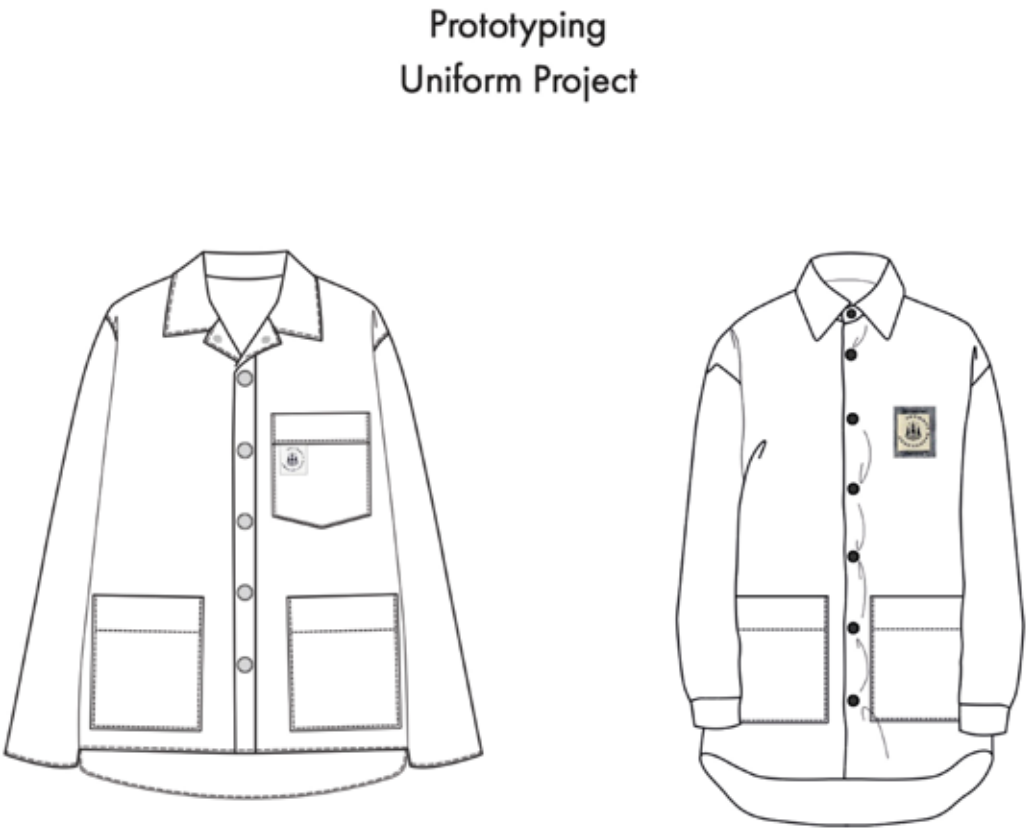


Figure 14. Chosen designs. Martha Von Gunther

Recommendations for developing circular workwear

1. Clarity in the design brief:
It is essential to establish a clear framework at the outset of the design process. This ensures that all partners, including fabric suppliers and manufacturers, work towards the same circular goals, and that design decisions can accommodate the entire lifecycle of the garment.

2. Involve partners early in the process:
Engaging all stakeholders early, particularly those involved in textile production and recycling, ensures that circularity can be integrated from the start. This also reduces issues related to trims, padding, and logos, which can complicate recycling efforts.

3. Simplify trims for easier recycling:
Using fewer trims and ensuring they are based on recyclable materials reduce the complexity of sorting and recycling workwear at the end of its life. This simplification can have a major impact on the garment's potential for circularity.

4. Design logos for easy removal:
Logos are a critical element in workwear but often hinder circularity due to security concerns. By designing logos as detachable components (if needed), garments can be repurposed or recycled more easily, supporting circular strategies.

5. Consider textile durability and reverse-side use:
Reinforcing high-stress areas of the garment with the fabric's reverse side can extend the life of the product. This approach maximizes the utility of the fabric while reducing the need for premature disposal.

6. User feedback is essential:
Incorporating user knowledge and behavior into the design process is critical. Understanding how workers interact with their garments, and what aspects of the design are most valued, can inform improvements that enhance both functionality and circularity.

Part 1 Conclusion: circular workwear experiments

The ReYarn Circular Product Development Partnership aimed to develop a circular workwear prototype for the City of Copenhagen, focusing on applying circular design principles throughout the process. The experiments highlighted both the challenges and potential of using mechanically recycled materials to create durable, functional, and aesthetically pleasing workwear.

Figure 17. Exhibition @LOOP Forum Conference, April 2022

Key insights from the experiments include:

- Material performance:

Mechanically recycled textiles demonstrated light to medium-strength durability, suitable for light workwear. However, surface pilling remains a significant challenge. Despite this, the strength and authenticity of the fabric were not compromised, and integrating pilling management into the design could be a viable solution for future development.

- User-centered and functional design:

The design process was driven by a deep understanding of user needs and functional requirements. User studies played a crucial role in identifying stress points on garments and ensuring that the workwear could withstand the demands of its intended use. By reinforcing areas prone to wear, the longevity of the garments can be extended, aligning with circularity goals.

- Design for circularity:

The design was guided by the qualities of the materials, focusing on creating long-lasting, multifunctional products. Aesthetic sustainability was prioritized through timeless design, ensuring the garments remain relevant across multiple use phases. Circularity was further integrated by minimizing trims and using components designed for reuse or recycling, such as detachable logos, making it easier to handle the garments at the end of their lifecycle.

- Value chain transparency:

Open communication and collaboration across the value chain were essential for identifying opportunities and challenges related to circular textile production. This transparency helped clarify the necessary adjustments in production processes and highlighted the importance of scalable solutions.

Recommendations for future development

1. Pilling management:
Incorporating design solutions to manage surface pilling could improve the overall durability of the recycled textile fabrics, ensuring they meet functional requirements for workwear.

2. User testing:
Further testing with end-users is needed to refine the functionality and performance of the designs, ensuring that they meet practical and aesthetic expectations in real-world scenarios.

3. Cost and scalability assessment:
A thorough analysis of the cost and scalability of production is recommended to determine how circular workwear can be economically viable and scalable for broader use.

4. Logo and tax considerations:
Exploring the impact of logo placement in relation to tax regulations is necessary to ensure that the detachable logo system aligns with legal requirements while supporting circularity.

5. Life cycle assessment (LCA):
Conducting a full LCA of the workwear would provide insights into its environmental impact and help quantify the benefits of circular design compared to traditional workwear products.

In conclusion, the experiments demonstrated that it is possible to create mechanically recycled textile fabrics with sufficient strength for workwear, while also highlighting the importance of user-driven and material-driven design development in achieving circularity.

III: Design experiments:
How to turn the linear value chain into a circular one? Part 2

Introduction to project part 2: Expanding circular workwear development

The second phase of the The ReYarn Circular Product Development Partnership was initiated to build upon the insights gathered in the first phase. The project expanded to include additional partners, Fristads Kansas and COOR, both bringing expertise in workwear production and facility management services.

The focus of this phase was to deepen the material-driven research and apply it through user studies, with the goal of providing concrete recommendations for the industry. One of the key learnings from the initial phase was the importance of transparency and open communication across all partners in the value chain. This approach is essential to uncover opportunities for circular strategies, particularly in the workwear supply chain, where collaboration at every stage—from material sourcing to end-of-life management—can drive more sustainable practices.

By continuing to explore these collaborative approaches, the second phase aimed to refine the circular workwear designs and offer valuable insights that could be applied across different parts of the value chain. This phase not only sought to create more sustainable products but also aimed to influence how the industry approaches circularity in production, design, and recycling processes.

Figure 18. Picture by Rasmus Trøst Simonsen


C34
ISTADS
C34

Contributors: Lena Bay Højland (Fristads Kansas Group), Rasmus Trøst Simonsen (Design School of Kolding), and Berit Konstante Nissen (KEA Copenhagen School of Design and Technology).

Design experiment #5: Prototype sample production with Fristads Kansas Group

In this phase of the project, we focused on scaling the circular workwear design for production with Kansas/Fristads, one of the project's key partners. The primary aim was to explore how the design proposal from the first phase, particularly Design 2 from the ReYarn Partnership, could be adapted for production in various sizes and for both genders. Additionally, we aimed to gather production pricing to compare with similar conventional workwear, ensuring that circular products could remain cost competitive.

Prototype development and testing

The selected prototype for production was based on the Design 2 model from the first phase. This decision was made to ensure continuity in testing and refining the workwear, allowing enough time for quality checks, user feedback, and adjustments before moving to full production.

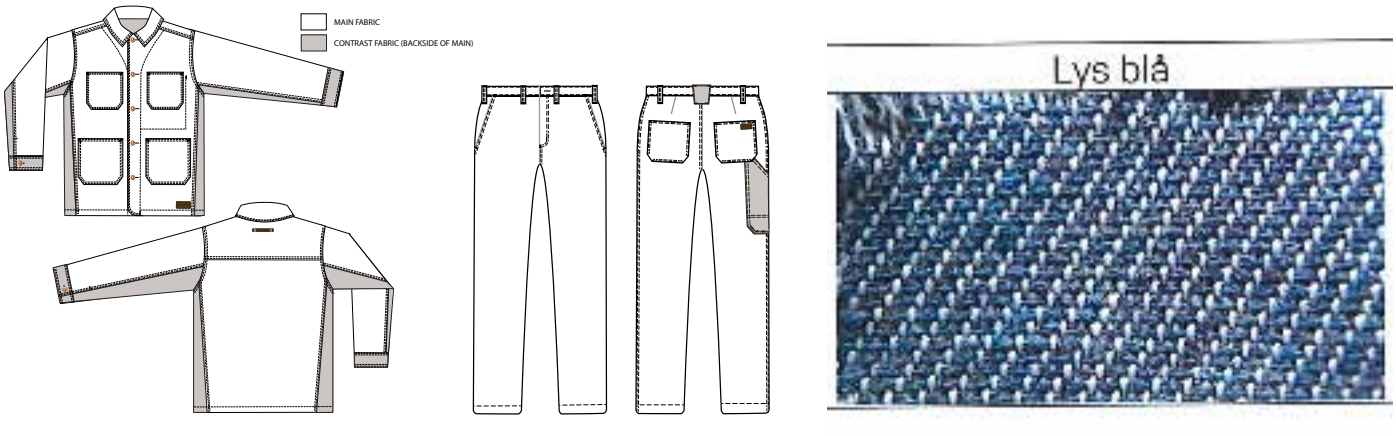


Figure 19. Prototype 2 fabric.

Quality check and measurements

During the prototype review, several key issues were identified that required adjustments before moving forward with production:

• Buttonholes too large:
The buttonholes were initially too loose, and there was concern that they would become even looser over time, compromising the garment's durability.

• Button and buttonhole placement:
In the small size (S) for a unisex design, the buttons and buttonholes were mirrored, which would need to be corrected to ensure the product could be easily worn by both men and women. This highlighted the need for consistency in unisex sizing and design.

• Pocket design:
The initial pocket design was too simplistic, with four identical pockets. It was suggested to add variety to the design, including a vertical zipper pocket on the left chest and pocket flaps on the lower front pockets for improved functionality and visual appeal.

• Cuff size and movement:
Both the jacket and pants had cuffs that were too tight, limiting movement. Expanding the cuff size would offer greater mobility, particularly for manual labor.

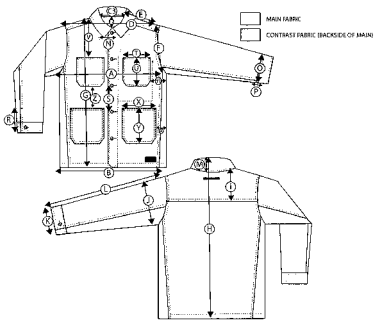
• Unisex sizing range:
The current sizing system needed to be expanded to cater to a broader range, from XS to XXL, ensuring the garment would be truly unisex and inclusive of different body types.

• Missing washing instructions:
Clear washing instructions were absent in the prototype. This is a critical aspect for both user guidance and maintaining the integrity of the recycled textiles.

Figure 20. Prototype 2 development.

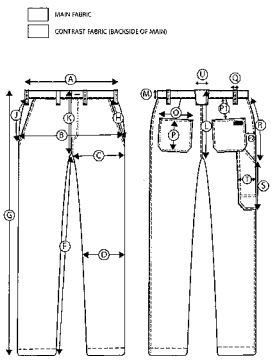
A key insight from this phase was the development of a new unisex sizing system inspired by denim wear, incorporating adjustments for length, width, and fit types. The goal was to create a more flexible sizing system that moves away from generic grading rules and adapts to the specific needs of different body types. For instance, during testing, we found that the size 34 measurements were too small, particularly in the cuff area, which impacted the wearability and comfort of the garment.

JACKET HTM-GUIDE



Description of measurment	Measured
Size on sample: S Camilla	
A. ½ Chest width - at armhole	46 cm
B. ½ Bottom width – Side to side	46 cm
C1. Neck drop center back - form straight line (like on front)	1,5 cm
C2. Neck drop center front - from straight line	2 cm
C3. Neck width (from SP to SP)	18,5 cm
D.Shoulder point to shoulder point	38 cm
E. Shoulder length - neck hole to armhole	12 cm
F. Armhole depth	22,5 cm
G. Front length to edge (from HSP to bottom)	68 cm
H. Center back length W.O. COLLAR	69 cm
I. Back yoke height FROM HSP	13 cm
J. ½ Upper sleeve width - 90 ° angle	17 cm
K. ½ Bottom sleeve/ cuff width	8 cm
L. Sleeve length sleeve head to bottom edge incl. Cuff	57 cm
M. Collar height CB	9 cm
N. Distance between Collar points	9 cm
O. ½ Cuff width closed	8 cm
P. Total Cuff height	9,5 cm
R. Sleeve slit height	13 cm
S. Distance between buttons	15 cm
T. Top Pocket width	12,5 cm
U. Top Pocket height	14 cm
V. Top Pocket placement from HSP	23 cm
V1. Top pocket placement from side	7,5 cm
X Lower Pocket with	16 cm
Y. Lower Pocket High	19 cm
Z Lower pocket placement from top pocket bottom	10 cm
Æ. Lower pocket placement from side	4 cm

PANTS HTM-GUIDE



Description of measurment	Measured
Sample size: C34 Camilla	
A. 1/2 waist with measured at top	38 cm
B. ½ Hip width	47 cm
C. ½ Thigh width	29 cm
D. ½ Knee width	20 cm
E. ½ Bottom leg width	16 cm
F. Inside seam length	80 cm
G. Outside length incl. Waistband	105 cm
X Fly Zipper length	12 cm
H. Pocket opening front - along waistline	16 cm
J. Pocket opening front - along sideseam	15 cm
K. Front rise incl. Waistband	25 cm
L. Back rise incl. Waistband	39 cm
M. Waistband height	4,5 cm
O. Back pocket opening top	13,5 cm
P. Back pocket high	15 cm
P1. Back pocket placement form top	6 cm
P2. Back pocket placement from side	3,5 cm
Q. Belt loop with	1,5 cm
R. Back side pocket placement	29 cm
S. Back side pocket high	16 cm
T. Back side pocket with	9 cm
U. Big belt look with TOP	8 cm

Figure 21. Prototype 2 measurements.

Figure 22. Prototype 2

Recommendations for scaling circular workwear production

1. Refine unisex sizing system:
A well-developed unisex sizing system will address the anatomical differences between men and women while offering flexibility in fit. This requires a deeper understanding of how workwear is used by different genders in practical settings, and adjustments should be made accordingly.

2. Standardize button placement for unisex garments:
Ensure that all unisex garments have a standardized button and buttonhole placement. This consistency is key to achieving a truly unisex design that works seamlessly for all users.

3. Enhance functional features:
Workwear needs to balance aesthetic appeal with functionality. Including diverse pocket designs, such as zipper pockets and flap pockets, not only adds to the garment's visual appeal but also increases its practicality, offering storage solutions for various work tools and accessories.

4. Adjust fit for greater mobility:
For workwear, particularly pants, it's important to ensure the design allows for ease of movement. Wider cuts in high-movement areas, like the legs and cuffs, will improve comfort and functionality for the wearer.

5. Include clear washing instructions:
Clear and durable washing instructions must be included with every garment, especially when dealing with recycled textiles. Proper care is essential for maintaining the quality of the material and extending the garment's lifecycle.

6. Production pricing and comparison:
As circular workwear moves toward scalability; it is important to compare production costs with conventional alternatives. This will help assess the economic feasibility of circular workwear in the broader market knowing that initially there will be a not insignificant difference between the two economic setups in the short term.

Contributors: Marie Budtz (Bacher Work Wear), Maria Frey (COOR), Tina Winberg (City of Copenhagen), Rasmus Trøst Simonsen (Design School of Kolding), and Penille Dalmose Bruun Christensen (KEA Copenhagen School of Design and Technology).

Design experiment #6: User test study with City of Copenhagen & COOR

What we wanted to explore

In this experiment, we aimed to understand how the circular workwear design performed in real-world conditions, specifically in the daily routines of facility managers at COOR and employees at ByOasen from the City of Copenhagen. The primary goals were to explore how the design worked across different genders and body types, how it functioned in various work situations, and whether there were any necessary adjustments to improve fit, comfort, and functionality. We also aimed to compare the performance of workwear made from mechanically recycled textiles with those made from standard fabrics. This allowed us to assess the durability and wearability of recycled materials under everyday working conditions. The results from these tests would not only help refine the design but also inform recommendations for scaling the production of circular workwear.

Delimitation

It is important to acknowledge certain limitations in the user test study, particularly regarding the planned inclusion of an additional user group within the City of Copenhagen's Technical and Environmental Administration (TMF). This group, primarily engaged in supervisory tasks such as inspecting small businesses and office buildings, did not participate in the testing phase. Their feedback could have provided complementary insights, as their work requires less physical exertion and mobility compared to the gardener roles. Such input might have offered perspectives on aspects like professional appearance and general usability rather than durability or movement-focused functionality.

Another key limitation relates to the choice of fabric color for the tested garments. The selected color, while suitable for prototyping, was not optimal for workwear, given the nature of tasks that cause daily soiling and necessitate frequent washing. This choice was influenced by the material availability at the time of production. However, it is worth noting that the fabric can be produced in darker colors better suited for practical workwear applications, which could offer flexibility in functionality and maintenance of workwear items.

Testing phase

The user testing phase involved employees from COOR and the City of Copenhagen, with participants from various job roles, including gardeners and facility managers. They tested workwear prototypes over a period, logging their experiences and providing feedback through interviews and logbooks.

Figure 23. Morthen and Morthen's equipment.

Figure 24. Fit for Josefine, Solbjørg, & Camilla.

Initial observations and feedback

Several key observations were made early on during the handover of workwear:

• Pockets:
Many users felt the pockets were insufficient or poorly designed. Nicolaj mentioned, *"My phone kept falling out of the chest pocket because there's no closure,"* highlighting the need for secure pockets. Another common request was for larger side pockets with additional functionality, including compartments for kneepads and tools.

• Fit and movement:
Some participants found the pants too narrow, especially around the ankles and calves, which restricted movement and allowed dirt and gravel into their shoes. Nicolaj remarked: *"When I'm standing, the pants fit perfectly, but as soon as I bend down or sit in my car, they become tight around the knees and crotch."* This caused discomfort during more physically demanding tasks, underscoring the need for improved fit in these areas.

• Weather suitability:
Several users working outdoors expressed concerns about the garments' inability to protect against wind and cold. Solbjørg shared: *"I had five layers on, but it was still cold. A thermal layer would have been nice."* This highlighted the insufficiency of the fabric in colder weather and raised the need for better insulation in the design.

• Logo and identification:
A common theme was the lack of visible branding, which made it difficult for participants to be recognized in public-facing roles. Nicolaj stated, *"People looked at me like, 'Who is this guy and why is he messing with my garden?' We need some sort of logo to make it clear who we are."* This reflected the need for clear visual markers to identify the wearer as an employee.

• Sustainability perception:
Despite the functional issues, the fact that the workwear was made from recycled materials was appreciated. Solbjørg expressed her enthusiasm, stating, *"It's really cool that it's made from recycled material! That's something I always prefer."* This suggests that while sustainability was a positive feature, it was not prioritized over practicality.

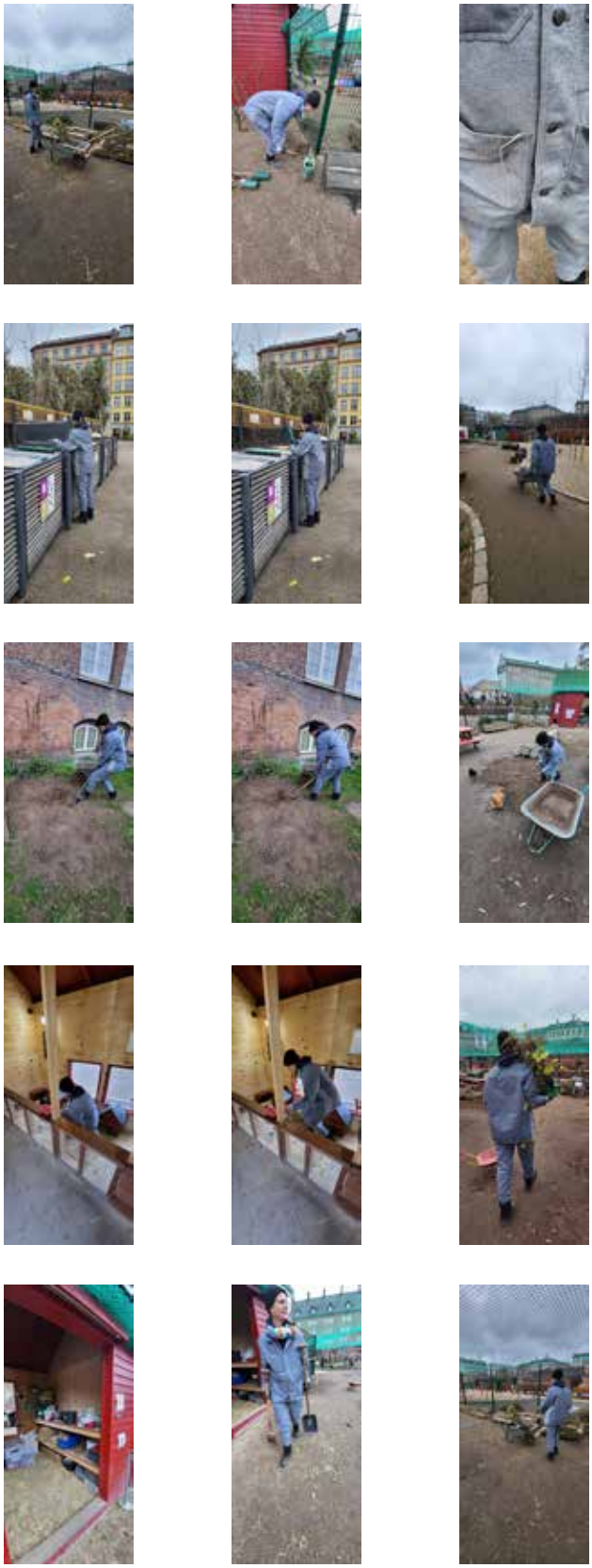


Figure 25. Solbjørg at work.

Test phase results (See Appendix 1).

The feedback from users was categorized for analysis:

• Materials:
Although the recycled fabric was soft and comfortable, it did not provide adequate weather protection. Nicolaj noted that the jacket *"wasn't windproof,"* and others mentioned pilling and fiber shedding. Solbjørg added that the fabric could feel too cold, particularly during winter, stating, *"It's just not enough for the colder months."*

• Fit:
Fit issues were prevalent, especially in the pants. Nicolaj explained that his pants were too tight in the calves and waist, while Solbjørg found hers to be slightly too short for her height, commenting, *"The pants are fine, but maybe a little too short when I bend down."* Jackets, on the other hand, generally fit well in the body, although sleeve lengths were an issue for some users.

• Functionality:
Participants identified a need for more functional features, such as additional and secure pockets, zippers instead of buttons, and reinforced knees.

Nicolaj suggested, *"Kneepad pockets would make a big difference,"* while Morten proposed, *"Flexible accessories for hanging pockets that can be zipped on and off would be great."* This feedback emphasized the need for greater versatility and adaptability in workwear.

• Design and aesthetics:
The visual design was seen as overly formal by some users, who compared the look to *"a prison suit"*, as mentioned by Nicolaj. While a modern appearance was appreciated, participants stressed that workwear should balance style with practicality. Solbjørg commented that *"It looks good, but I miss something that's more unique to our daily work with the public."* The light-colored garments were also impractical for outdoor work, as they quickly became dirty.

What we learned

The user study revealed several insights that will inform future design improvements for circular workwear:

• Functionality is paramount:
Practical elements such as secure, well-placed pockets and reinforced knees are essential for workwear. Nicolaj's comment about the need for functional pockets, like *"pockets in the jacket should be angled, with a zipper,"* underscores the importance of easily accessible storage for tools and personal items.

• Aesthetics and cultural fit:
Workwear should reflect the cultural identity and practical needs of the job. As Nicolaj put it, "*We don't want to look like we're going to a fashion show. People should know we're working.*" The overly formal, uniform-like design did not resonate with participants, particularly in trades like gardening, where darker colors and more functional designs are preferred.

• Fit and sizing:
Unisex designs posed challenges for many participants. As Solbjørg noted, *"I ordered a bigger size because I know I need the extra room for movement,"* pointing out that more attention needs to be paid to fitting different body types. Jackets were often found to have sleeves that were too long.

• Weather resistance is crucial:
Workers emphasized the importance of weather protection, particularly in colder, windier conditions. Solbjørg's feedback—*"It would have been nice to have a thermal layer"*—emphasizes the need for better insulation or more weather-resistant materials.

• Sustainability matters, but functionality is essential:
While users appreciated the recycled textiles, practicality and comfort were their main concerns. Nicolaj summed it up by saying, *"It's great that it's sustainable, but if it doesn't work, it's just not worth it."*

Recommendations for future development

1. Enhance functional features:
The workwear design would benefit from integrating more practical elements, such as additional pockets with zippers, removable tool pockets, and better knee protection. These changes will increase the versatility and usability of the garments in various work environments.

2. Improve fit and sizing:
Develop a more comprehensive sizing system that addresses the anatomical differences between men and women. Unisex designs need careful adjustments to ensure they fit comfortably across a wide range of body types, offering both mobility and comfort.

3.Design for weather conditions:
For outdoor workers, consider adding layers or using fabrics that provide better protection against cold, wind, and rain. This could include incorporating more weather-resistant materials or offering options for different seasons, by layering garment according to the need.

4.Adjust aesthetics to suit the industry:
Workwear reflect the cultural and practical needs of the society. Avoid overly formal designs and opt for colors and styles that are practical for the work being performed. For instance, darker colors may be more suitable for outdoor work to hide dirt and wear.

5. Logo and identification:
Offer workwear that includes visible identification, such as logos or badges, to clearly indicate the wearer's role and workplace. This is particularly important for public-facing roles where identification is crucial.

6. Explore further sustainability innovations:
While sustainability is appreciated, future designs should focus on maintaining practicality without compromising on functionality. Continue exploring recycled materials that can meet higher durability and weather resistance standards and ensure that repair and care options are clearly communicated to users.

M.I.S	COOR	CITY OF COPENHAGEN	RECOMMENDATIONS (Regarding sustainability)
MATERIALS	• Itching • Fibers sticking out • Not windproof or waterproof • Soft	• Soft and comfortable • Lacks stretch if it sits tight • Too cold for winter use • The jacket is not windproof or waterproof	• Other weaving options?→ What is the strongest possible? • Use the back of the material → Especially on the stressed areas • (Stretch for a tighter fit → Loose fit = no stretch)
FIT	• Too narrow in the legs / Too wide in the waist • Morten ordered two sizes bigger • Nicolaj's is tight around his calves, ankles, and crotch • The jacket fits great	• Slightly too long in the sleeves → proportions • Good fit in the body, but sleeves are too long • Slightly tight in the legs → No freedom of movement • A: Preferably wider legs at the bottom (more freedom of movement) • A little too short in leg length (she is tall)	• Slightly oversized, as larger sizes fit best • Remove unisex (for the men's side) • A: Wider leg width at the bottom (from slightly above the knee down) • Gradation needs to be checked, as KK Camilla (size 34) could not fit the jacket → Cuff too small • Can be made higher + lower in size (It seems that both women's and men's basic patterns have been used) • L: Slightly too narrow cuffs + too long sleeves
DESIGN	• Too smart/modern → It doesn't look like work clothes • "Sticks out" • Suit → Prison suit (too different) • "A great topic of conversation" • "It must be practical" (about work clothes) • Not suitable for outside workers → more indoor/office work perhaps?	• Prisoner (due to the twill weaving) • Good with a more modern look (workwear) • A little too suit-like	• Preferably color difference on top and bottom • Function over form • Investigate an alternative target group/ job description • Not being sold as a set?

M.I.S	COOR	CITY OF COPENHAGEN	RECOMMENDATIONS (Regarding sustainability)
FUNCTIONALITY	• Missing pockets / knee pockets • I: The buttons in the jacket goes up → It must be a zipper • The jacket's pockets must be angled • F: Belt loops must be 5mm longer to fit the belt • You could have a small fabric piece over the trouser button. • O: Flexible accessories for hanging pockets that can be zipped on/ off • G: Location of trouser side pocket needs change • Too open in the neck	• Missing zippers in pockets • The buttons go up • G: Pocket on the side of the trousers (must be moved here) • A few more pockets for tools	• Missing pockets in general • J: Pockets in the jacket must be angled + zip • K: Chest pocket (1) → Vertical with zipper • E: Trouser button must have a small protective piece of fabric • C: Trouser pockets are fine → Slightly smaller opening + slightly deeper pocket • Missing pockets for tools • Zips in the pockets on the jacket • G: Missing a large side pocket on the trousers • D: The buttonholes in the jacket are too big • B: Knee pockets for knee pads
COLOR	• Too light in color for dirty work (pants) • Must be green, as it signals a gardener (job)	• The trousers must be darker due to wear and tear and dirt stains • And so that it doesn't look too suit-like. • Too bright colored trousers	• M: Use color code → Indicates field of work (green for gardener). Wolkat has color charts • M: Could the R-PET fiber be darker? (Currently white) → It would prevent it from looking dirty
LOGO	• Missing logo → Can't be recognized	• Missing logo that can make them more visible • Important to be recognizable to people → Place-specific	• H: Preferably an embroidery / print on the chest or back (+ back of the trousers) • N: Shop on back removed
WASH/CARE	• Haven't washed it (Morten and Nicolaj) • Washing at 30 degrees is not suitable for workwear • No repair-service	• Haven't washed it • (Haven't washed it, but will do it at home)	• Test whether the textile can be washed at 60 degrees • Which repairs are worth doing? • Does the material release microplastic? And is central washing a necessity?

M.I.S	COOR	CITY OF COPENHAGEN	RECOMMENDATIONS (Regarding sustainability)
UNISEX	• Wears men's clothing only • Comment: Doubt how men/women will fit the same design	• It will be good, as the fit will also be looser and the expression more practical	• Prefers unisex look / fit • No experience
WEAR & TEAR	• Knees, calves (+ dirty) • Ankles	• Knees • Pants	• How long is a satisfying period of use expected to be? • Where to repair? • Reinforcement on knees • A little thread extraction at the pockets • Sewing sequence → in relation to being able to easily replace worn out areas + trim (for the next loop)
REGULAR WORKWEAR	• Nicolaj: Pants last 6-9 months • Morten: Pants last 1-(2) years. Probably 1 year at the most • Neck warmers to keep warm • 3-4 layers • Mascot, Snickers, COOR company clothing, Helly Hansen, knitted textiles on the upper body + long underpants	• Many layers • Fristad (label) • Lasts for 6-9 months, maybe more	• Room for several layers' underneath in winter • Maybe a removable thermos lining • Maybe a sweatshirt for the summer • Can Wolkat knit for the inner layers?

Design experiment #7: Functionality in workwear

What we wanted to explore

In this design experiment, we aimed to explore the specific job functions and tasks of facility managers to understand how these roles influence the design and functionality of workwear. This included investigating both the general job description and the specific demands of workers in the test group. The goal was to determine how well the workwear in this experiment met the practical needs of the user group, focusing on comfort, mobility, and performance in different work environments. Additionally, we wanted to assess how the workwear's functions relate to the demands of light versus heavy physical labor and indoor versus outdoor tasks.

What we did

We conducted research into the role of facility managers and the diverse range of tasks they perform. Facility management is a multidisciplinary profession encompassing a variety of services, including building maintenance, energy optimization, waste management, and outdoor upkeep. Facility managers must often transition between indoor and outdoor environments, requiring versatile workwear that can handle a wide range of physical activities and environmental conditions.

Job descriptions / COOR

Key job functions

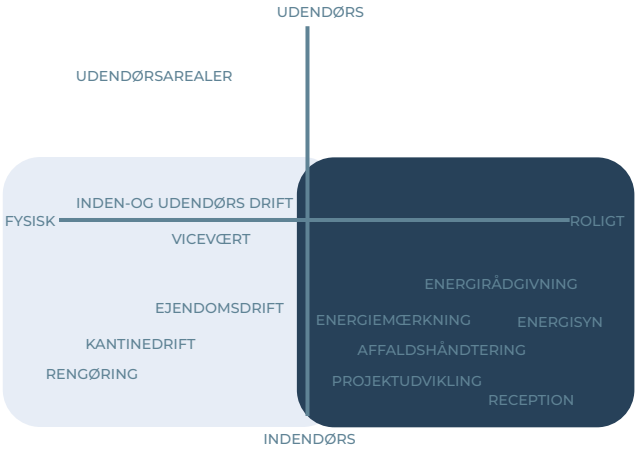
Facility managers perform tasks such as:

- Building maintenance: Regular upkeep of technical installations, HVAC systems, electrical work, and small to large renovations.

- Outdoor upkeep: Including tasks like gardening, snow clearing, waste disposal, and maintaining outdoor structures.

- Logistics and operations: Managing day-to-day operational tasks in buildings, overseeing energy consumption, and ensuring regulatory compliance with waste management practices.

This range of responsibilities meant that the workwear needed to be highly functional, adaptable to different environments, and durable enough to withstand both indoor and outdoor conditions.



Positioning of job describtions / Illustration by Rasmus Trøst

Textile performance and suitability

- Weather resistance:
The current recycled textiles tested did not provide adequate protection against outdoor elements. To meet the needs of facility managers, future iterations of workwear should include outer layers made from materials that offer better resistance to wind, rain, and cold.

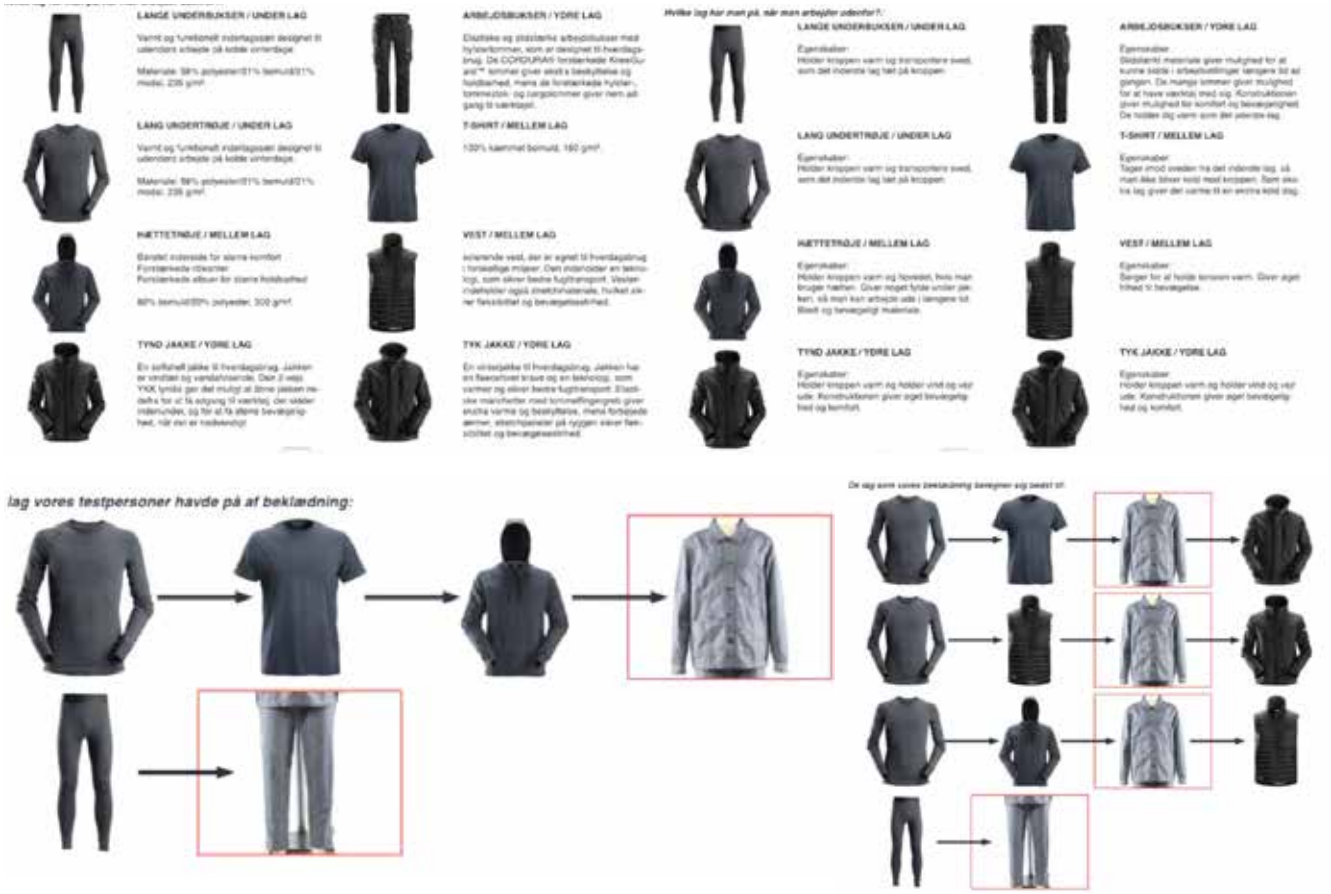


Figure 26. Layers from user studies. Visualisation by Rasmus Trøst

• Flexibility and movement:
The workwear must allow freedom of movement, particularly in high-motion tasks such as kneeling or lifting. While the layering system helps maintain comfort and warmth, the outermost layers need to be more flexible, allowing for ease of movement without restricting the worker.

• Sustainability and practicality:
Facility managers were generally open to the use of recycled materials, but the primary concern was practicality. They emphasized that while sustainability is important, the workwear must first and foremost meet the functional needs of the job. Future designs should balance environmental goals with practical performance.

Recommendations for future workwear design

1. Develop workwear with stronger outer layer properties:
The recycled textiles used in this experiment are well-suited as mid-layers but should be supplemented with outer layers that provide protection against wind, rain, and cold. Consider incorporating materials that have strong weather-resistant properties while maintaining the circularity goals of the project.

2. Refine the layering system:
To accommodate the diverse tasks performed by facility managers, future designs should offer a comprehensive layering system that allows workers to adjust their clothing based on the environment and activity. Mid-layers should provide warmth without adding bulk, while outer layers need to offer protection without compromising mobility.

3. Ensure practical features:
Workwear for facility managers must include practical features like ample pockets, adjustable cuffs, and reinforced knees for durability. These features help workers carry out their tasks more efficiently and comfortably, particularly in physically demanding roles.

4. Balance sustainability with functionality:
While sustainability is a priority, the functionality of the workwear must come first. Future designs should continue to explore the use of recycled materials but must ensure that these materials meet the practical needs of workers in challenging environments.

Contributors: Berit Konstante Nissen & Simone Olivia Bakke (KEA Copenhagen School of Design and Technology), and Martha Von Gunther (Design School of Kolding).

Design experiment #8: 3D development

What we wanted to explore

In this design experiment, we aimed to explore how unisex or gender-neutral garments, in both fit and sizing, could be developed and optimized for workwear. The primary focus was on creating a flexible sizing system that accommodates different body shapes, preferences, and inclusive sizing requirements, with the added potential benefit of reducing SKU count.
For this project, we used two different sizing systems. The pants were based on a numeric system ranging from C34 to C54, while the jackets used an alpha sizing system, from XS to L. The objective was to develop a more gender-inclusive approach to workwear sizing, allowing for a better fit across a diverse user base and providing practical insights for further production scaling.

What we did

Base shape and unisex sizing

We explored how to translate the insights from user studies and research into design solutions for unisex workwear. Key considerations included:

• Regular and shaped fit:
The garments were designed to accommodate the most critical measurements for both genders—chest, shoulder, waist, hip, and buttocks for pants.

• Multiple length options:
We introduced the concept of offering at least two length options for pant legs and sleeves, with the potential for easy disassembly and replacement to enhance circularity.

• Inclusive sizing range:
Recognizing the importance of inclusivity, we proposed a broad range of sizes, from XXS to XXXL, with incremental steps of approximately 6 cm between sizes.

• Inspiration from stocking size systems:
We drew inspiration from stocking size charts (e.g., Wolford) that provide visual guidance for users to choose the correct size, making it easier for individuals to find the right fit.

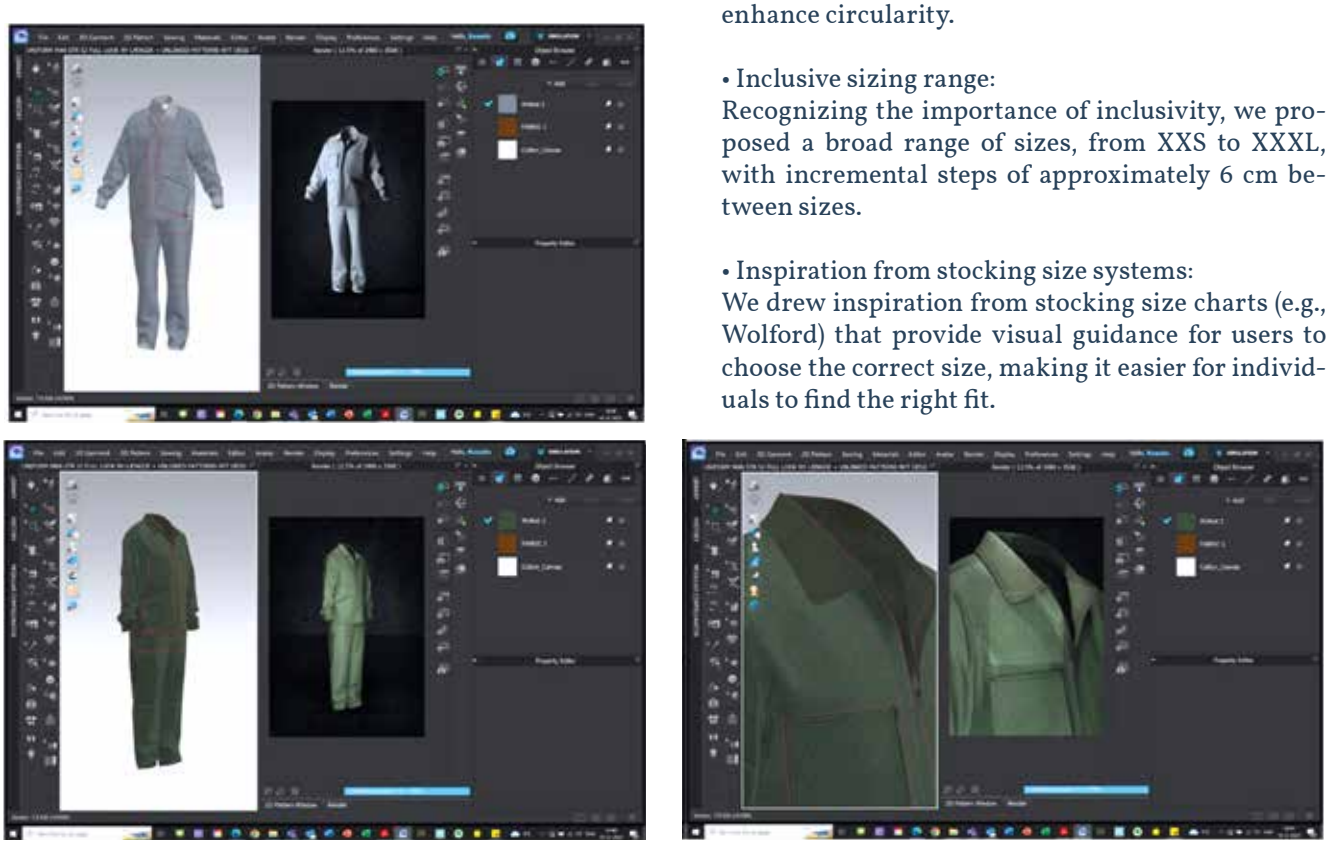


Figure 27. New design suggestion. CLO 3D by Berit Konstante Nissen & Simone Bakke.

Functionality in design elements

Several functional design changes were made to optimize the workwear for practicality and ease of use:

- Pockets and closures:
  Adjustments were made to pocket designs, including the addition of zippers and the modification of their placement to enhance usability. Zippers were also added to replace button closures for greater ease and durability.

- Color adjustments:
  The color of the garments was changed to darker shades, particularly for the pants, to make them more practical for dirty work environments and less uniform-like. Green was chosen for gardening roles.

- Circular design:
  The design emphasized easy disassembly for circularity, with components such as pockets, closures, and logos sewn on last to allow for easy replacement and repair. The assembly order was adjusted to facilitate easier repairs in high-stress areas, such as the knees and sleeves.

3D development in CLO

We digitally rendered the original design using CLO 3D software, starting with a size L on a male avatar. Based on the findings from the user tests, we made several key adjustments to both the design and product assembly, which were then visualized in 3D for further refinement:

- Design adjustments:
  Front button closures were replaced with zippers, and additional zippers were added to pockets. The back yoke was adjusted, and cuts were made at the sleeves and pant legs to allow for length adjustments.

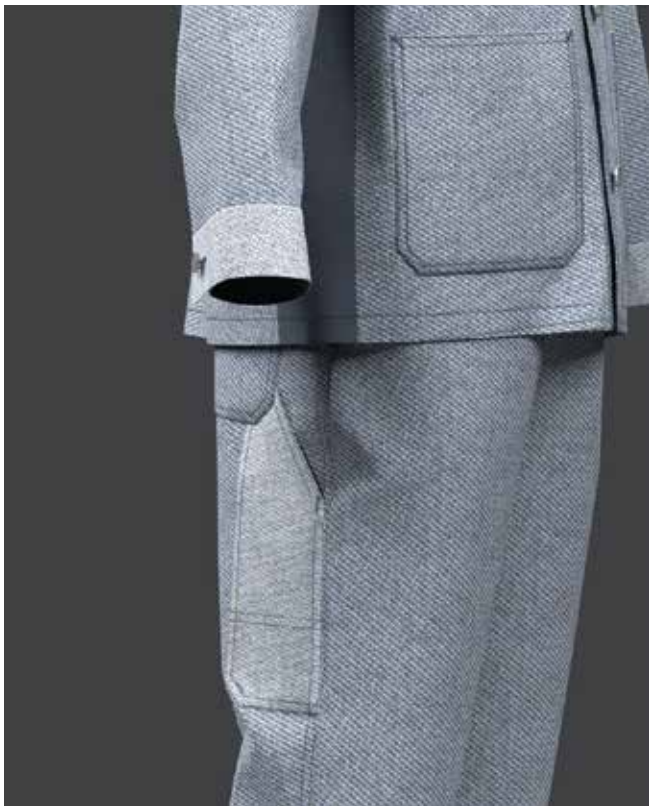
- Fit adjustments:
  The sleeve and cuff widths were modified, and the inside seam length and bottom hem width were adapted to provide a better fit across a wider range of body types.

- Product assembly adjustments:
  The garments were designed for easier disassembly, with changeable knee patch pockets and straps for easy logo removal, supporting circular design principles.

FIRST DESIGN

Renderung: Uniform old FRONT

Renderung: Uniform old RIGHT BACK



Renderung: Uniform old RIGHT

Figure 28. Design evolution.

LAST DESIGN

Renderung: Uniform new FRONT

Renderung: Uniform new LEFT

Renderung: Uniform new RIGHT

What we learned

Challenges in creating gender-inclusive workwear

One of the main challenges in designing gender-inclusive workwear is that traditional workwear sizing is often based on a standard male body form, which doesn't account for the differences in female body shapes. Historically, workwear manufacturers have catered to male-dominated industries, where women account for less than 10% of the workforce in sectors like construction. This results in workwear that does not always meet the comfort and fit needs of women.
Unisex sizing, while well-intentioned, often leads to compromises, as it is difficult to create a single size system that fits a wide range of body types equally well. Physical differences such as bust size, waist curvature, shoulder width, and leg length must be carefully considered when developing unisex garments. Research into uniform design for the U.S. Army and medical staff has shown that while unisex sizing can reduce manufacturing costs, it often fails to provide a satisfactory fit for all body types.

Design for longevity and circular repair solutions

To address challenges of circularity and longevity in this project, we explored how workwear could be designed with repairability in mind. While traditional repairs are often linked to craftsmanship, where time and aesthetic value are invested into prolonging a garment's life, this approach does not resonate with functional workwear. Instead, the focus here is on circular repair systems that integrate with the production process from the outset.

One approach is to design workwear with an assembly order that accounts for which parts of the garment are most prone to stress and wear. By constructing garments in a way that makes high-wear areas easy to replace—such as detachable pockets or panels on knees and elbows—repairs could be simplified, reducing the need for full garment replacement. This would require a deep analysis of discarded workwear to understand where these high-wear areas are and how assembly patterns could be adjusted to facilitate easier repairs.

Additionally, adjusting construction techniques to allow for modular repairs—where individual components of the garment can be replaced without affecting the overall structure—would help extend the life of the workwear. This system would prioritize functionality and practicality, ensuring that repairs are cost-effective and accessible to users.

Recommendations for circular systems in workwear:

1. Implement modular design for repairability: Workwear should be designed with easily replaceable components in high-wear areas (e.g., detachable pockets or knee panels). This approach would reduce the need for full garment replacement and support circular practices.
2. Prioritize functionality over aesthetics in repairs: While traditional repair work often focuses on craftsmanship and aesthetics, workwear repairs should prioritize functionality. Developing repair systems that integrate with the assembly process will ensure practical, cost-effective solutions.

Exploring new technologies

One potential solution is the use of emerging technologies like 3D body scanning and body shape analysis tools. These technologies offer more accurate data on body shapes and dimensions, allowing designers to develop garments that better accommodate a wider range of users. Companies like Avalution and Alvanon are already exploring how to combine gender-neutral sizing systems with advanced body scanning data to create more inclusive clothing solutions.

Recommendations for future workwear development

1. Flexible and functional fit:
A flexible two-part fit system should be developed for unisex workwear garments. This system should accommodate different body shapes by using key ID measurements such as chest, hip, and waist, and should offer options for length adjustments in pant legs and sleeves. The fit should allow ease of movement, comfort during physical activity, and room for layering additional clothing when necessary.

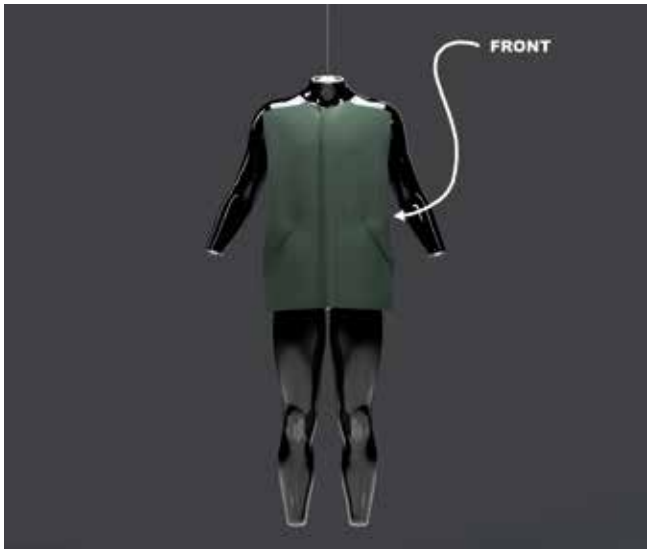
2. Offer multiple fit options:
For tops, offer both a regular fit and a more shaped or adjustable fit to cater to different body types. For pants, a regular fit with a medium rise should be paired with options for waist adjustments and straight-leg designs that allow for easy modification of length.

3. Inclusive size and height range:
A gender-neutral size system must account for differences in body shape, stature, and girth across genders. Offering a wide size range with several breaks and uneven grading intervals, based on body scan data, can help ensure a better fit. Providing different length options for pant legs and sleeves will address the height differences between men and women, particularly in regions like Denmark where the average height difference is significant.

4. Use of 3D body scanning and digital tools:
Incorporating body scanning technologies and 3D development tools can enhance the design process by visualizing fit and sizing strategies before production. This approach can help designers refine garment fit across a range of body types and sizes more efficiently.

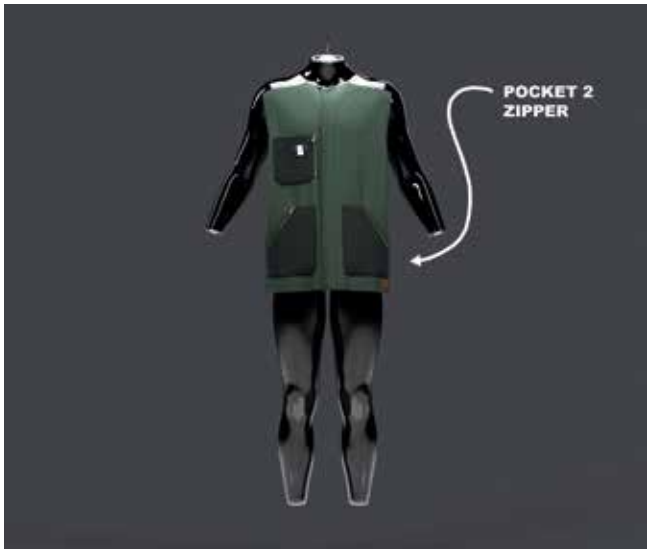
5. Clear and inclusive labelling:
Labelling must be intuitive, easy to understand, and inclusive. An alpha size system (e.g., XS-XL) can be used as it is already familiar to both men and women. Visual size guides should be developed to assist users in identifying the right size quickly and accurately.

STILLS FROM THE SEWING ORDER AS AN ANIMATION



Animation still #1

Animation still #2



Animation still #3

Animation still #4

Animation still #5

Animation still #6

Animation still #7

Animation still #8

Animation still #9

Animation still #10

Animation still #11

Animation still #12

Renderung: Uniform FRONT

Renderung: Uniform BACK

Renderung: Uniform FRONT

Renderung: Uniform BACK

IV: Conclusions: Potentials and challenges for establishing a circular value chain

Contributors: Tina Winberg (City of Copenhagen), Rasmus Trøst Simonsen (Design School of Kolding), Kerli Kant Hvas & Nikola Kiørboe (Revaluate), Penille Dalmose Bruun Christensen (KEA Copenhagen School of Design and Technology).

Transitioning from a linear to a circular value chain presents both significant potentials and challenges. The insights gathered from the project partners offer potentials for how such a system can be developed, but they also highlight the complexities involved in making this shift.

Potentials for a circular value chain

A circular value chain aims to retain resources within the system for as long as possible, reducing waste and maximizing the value of materials through reuse, recycling, and responsible design. In contrast to a linear value chain, which follows a "take-make-dispose" model, a circular approach focuses on closing the loop, ensuring that materials are cycled back into production and use phases. For this to succeed, all actors in the value chain must align on the vision of circularity and be willing to critically evaluate their current practices.

Key potentials include:

1. Collaboration across the value chain:
For a circular system to thrive, all stakeholders—from material suppliers to designers, manufacturers, and users—must collaborate. Partners like *Re-Valuate, Wolkat, Fristads Kansas and Bacher Work Wear A/S* can contribute to developing circular business models by rethinking material sourcing, manufacturing practices, and user engagement.

2. Designing for circularity:
Circular workwear must be designed with longevity and repairability in mind. Partners like *Design School Kolding and KEA Copenhagen School of Design and Technology* have explored ways to design garments that are easy to disassemble, repair, and recycle, which is key for reducing waste and extending the product life cycle.

3. Incorporating users as partners:
Users play a critical role in the success of circular workwear. By engaging facility managers and workers from *COOR and ByOasen in City of Copenhagen* in the testing and feedback process, the project has shown that user insights can guide product development. This ensures that the garments meet real-world needs while also supporting circular practices like repair and reuse.

4. Potential for reuse and recycling:
The value chain explored in this study highlights significant opportunities for reuse within professional sectors. Workwear that is no longer suitable for its original user may still be repurposed in different roles or settings through refurbishment. Additionally, the fiber-to-fiber recycling processes examined in this project, particularly those explored by *VIA University College*, demonstrate promising pathways for extending the lifecycle of materials and reducing waste.

Challenges for a circular value chain

Despite the clear benefits, several challenges must be addressed to fully establish a circular value chain:

1. Alignment across stakeholders:
One of the main challenges is ensuring that all partners in the value chain share a common vision of circularity. This involves rethinking current business models and practices, which can be difficult for companies accustomed to the traditional linear approach.

2. Technological limitations:
While fiber-to-fiber recycling offers a promising avenue for material reuse, the technology is still developing. Challenges such as ensuring the strength and durability of recycled fibers, as well as managing contamination and fiber degradation, need to be addressed.

3. Reuse within professional sectors:
The study primarily highlighted private reuse rather than reuse in the professional workwear sector. There is a need to explore new avenues for extending the life of workwear through professional reuse channels, such as refurbishing and redistributing garments within different industries.

4. Cost and scalability:
Transitioning to a circular system may involve higher upfront costs and logistical challenges in scaling recycling and repair systems. Partners need to assess whether the costs associated with circularity, such as repair services or higher production costs for recycled materials, can be absorbed or offset by long-term savings and environmental benefits.

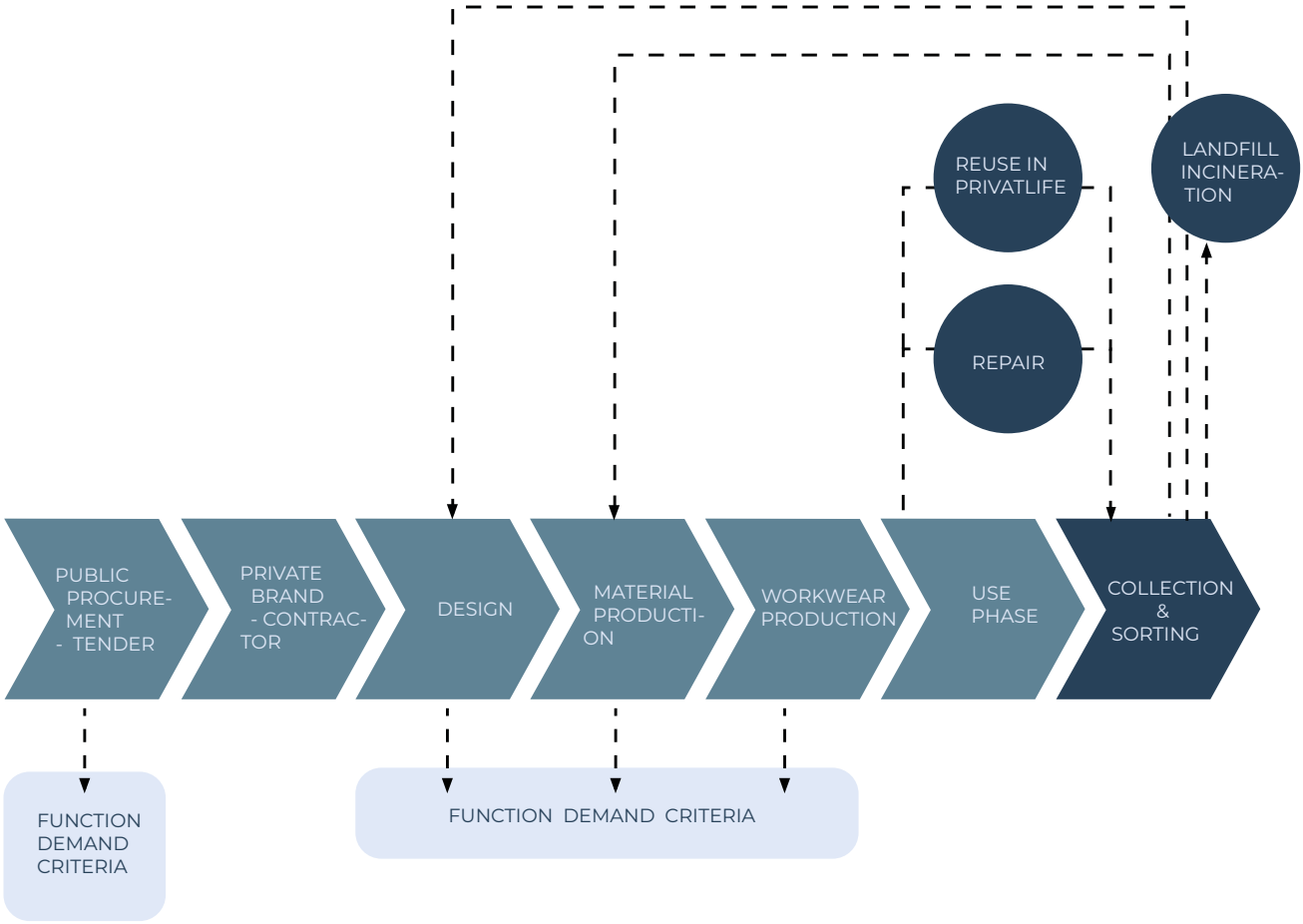


Figure 30. Illustration of the circular value system in the clothing industry.

Recommendations for moving forward

1. Strengthen collaboration:
Establish formal partnerships across the value chain to ensure that all actors are aligned on circular goals. This includes open communication between designers, manufacturers, recyclers, and users.

2. Invest in recycling technologies:
Continue to invest in developing fiber-to-fiber recycling technologies and explore ways to improve the quality and scalability of recycled fibers for workwear production.

3. Expand professional reuse:
Investigate how professional reuse can be better integrated into the value chain, ensuring that workwear is reused or repurposed before being recycled. This could involve refurbishing garments or setting up take-back programs.

4. User-centered design:
Continue to incorporate user feedback in the design process to ensure that circular workwear meets the practical needs of workers while supporting circularity through repairability and reuse.

V: CONCLUSION

The Uniform Project has highlighted throughout the report both the potential, and the challenges involved in transitioning from a linear to a circular economy within the workwear and textiles industry. Through collaboration with key stakeholders - including public institutions, designers, manufacturers, users, and recyclers - this initiative has provided a multifaceted exploration of circular practices. By integrating design experiments, policy analysis, and user engagement, the project suggests practical solutions and recommendations for scaling circularity both within and beyond this industry. Key findings emphasize that achieving circularity rely on aligning stakeholder priorities, reforming procurement systems, and fostering collaborative innovation across the value chain. Principles like modularity, repairability, inclusive design, and recycling been explored to reduce resource consumption and waste. However, systemic barriers, such as cost constraints, technological limitations, and challenges in scalability, persist. While the transition to a circular textile industry is complex, it remains a vital undertaking that demands commitment to sustained innovation, targeted policy reform, and collective action.

Insights across the value chain

Public institutions, exemplified by the City of Copenhagen, have a critical role in driving systemic change through green public procurement. By incorporating sustainability into procurement frameworks, these institutions can stimulate demand for circular solutions and set industry standards. However, current tender processes often allocate insufficient priority to sustainability - typically 10–20% compared to 40–50% for price, which is insufficient to promote circular solutions. Revising procurement frameworks to prioritize sustainable practices, lifecycle costs, durability, and repairability is essential for incentivizing circular practices and can help bridge economic and environmental priorities. While the project reached its intended goals, there remain opportunities for improvement A broader inclusion of stakeholders, such as third-party repair services and waste management experts, could deepen insights into scalability and optimization strategies. Engaging policymakers at the national and EU levels would facilitate standardized circular procurement policies and provide a unified framework for systemic change.

Private suppliers and manufacturers, such as Kansas Fristads and Bacher Work Wear, face the dual challenge of meeting sustainability goals and requirements while navigating cost-driven tendering processes. Innovations in textile development, product design and services are crucial for aligning supplier efforts with circular objectives. Collaborative partnerships with public institutions and investments in circular strategies can help bridge these gaps and align economic and environmental priorities.

Design has played a crucial role in embedding circular principles into workwear creation and advancing a sustainable circular value chain. Iterative and user-driven design processes led to garment proposals that enhanced durability, functionality, and ease of repair. Features like modular components and unisex sizing systems addressed both practical and cultural needs while promoting sustainability. For instance, multiple length options and regular or shaped fits fostered inclusivity for diverse body types and work environments. The project highlighted the importance of thoughtful, context-based design approaches. Decisions about closures and weave constructions significantly influenced garment functionality and comfort. Working with recycled materials revealed both opportunities and limitations for workwear applications. Modular components effectively addressed functional needs, while unisex sizing systems underscored challenges in achieving inclusivity. However, recycled textiles still require substantial improvements in durability and weather resistance. Enhancing fiber blending, spinning processes, and weaving structures remains critical, reinforcing the need for innovative design to advance the transition to circularity.

Engaging test users, such as employees from the City of Copenhagen and COOR, provided actionable insights into practical challenges like comfort, repairability, and the importance of emotional connection to workwear. Feedback showed the need for accessible repair services and interchangeable features such as detachable layers and parts, emerged as solutions to improve functionality and inclusivity. Raising awareness about repair practices and fostering a sense of responsibility among users can extend garment lifespans and promote sustainability. Further expanding design experiments to encompass professions, such as healthcare or inspection workers, could uncover unique requirements for functionality and cultural relevance in other workwear related areas, and with a longer testing period would provide additional insights into garment wear, maintenance, and user satisfaction.

Figure 31. Poster for the Copenhagen Kommune

Efforts like the ReYarn partnership demonstrate the potential of integrating closed-loop systems into production cycles. While recycled materials showed promise, challenges such as material quality, durability, and scalability remain. Continued investment in advanced recycling technologies is essential for overcoming these obstacles and supporting circular production at scale.

Concluding reflections

Looking ahead, global collaboration will be essential for scaling circularity, as harmonizing policies, recycling technologies, and repair infrastructures across regions can create a unified framework for circular practices. Initiatives like the European Union's Green Deal and Circular Economy Action Plan can provide a foundation, with international partnerships helping to bridge inequalities in resource access and waste management systems. Technological advancements can play a key role in this transition as innovations in materials science, resource recovery, and textile recycling address challenges in durability and affordability. Digital tools such as lifecycle assessment systems and blockchain technologies enhance supply chain transparency, driving systemic transformation. Furthermore, engaging workers and communities in this transition can promote fairness and inclusivity, ensuring that everyone benefits equitably from the opportunities and advantages of circularity.

The Uniform Project demonstrates that transitioning from a linear to a circular economy is essential and feasible, however in the beginning of its transformation. Stakeholders must now turn insights into action by adopting innovative procurement practices, investing in sustainable materials and recycling technologies, and fostering inclusive collaboration across sectors and regions. Governments, businesses, and individuals alike have a role to play in advancing this vision. By scaling these principles globally and addressing systemic challenges, we can create a sustainable future where circularity forms the foundation for economic resilience and environmental stewardship. The challenge is clear, and the opportunity is now.

I hope that this project can serve as a reference and an inspiration to collectively build a thriving, circular future.

Thank you for reading,

Kind regards
Mette Julie Bundgaard-Nielsen

Figure 32. Loop 2023 presentation poster

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