Circular Textile Innovations

– Sustainable system change in the textile industry

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Circular Textile Innovations – Sustainable system change in the textile industry

The project Circular Textile Innovations (CITEX) was initiated to support the development of a sustainable, circular textile industry in Sweden, focusing on creating a non-toxic and bio-based textile value chain. The project featured three main initiatives. Two focused on advancing textile recycling technologies, while the third explored new fibre blends and innovative yarn-spinning techniques using bio-based raw materials. These efforts contributed to the broader vision of creating a circular bioeconomy for the textile industry.

In addition to the technical work, CITEX included a coordination effort to ensure smooth collaboration between the different initiatives and to share knowledge with other industry stakeholders. This involved organising events, facilitating partnerships, and connecting with related innovation projects to drive progress in sustainable textile solutions.

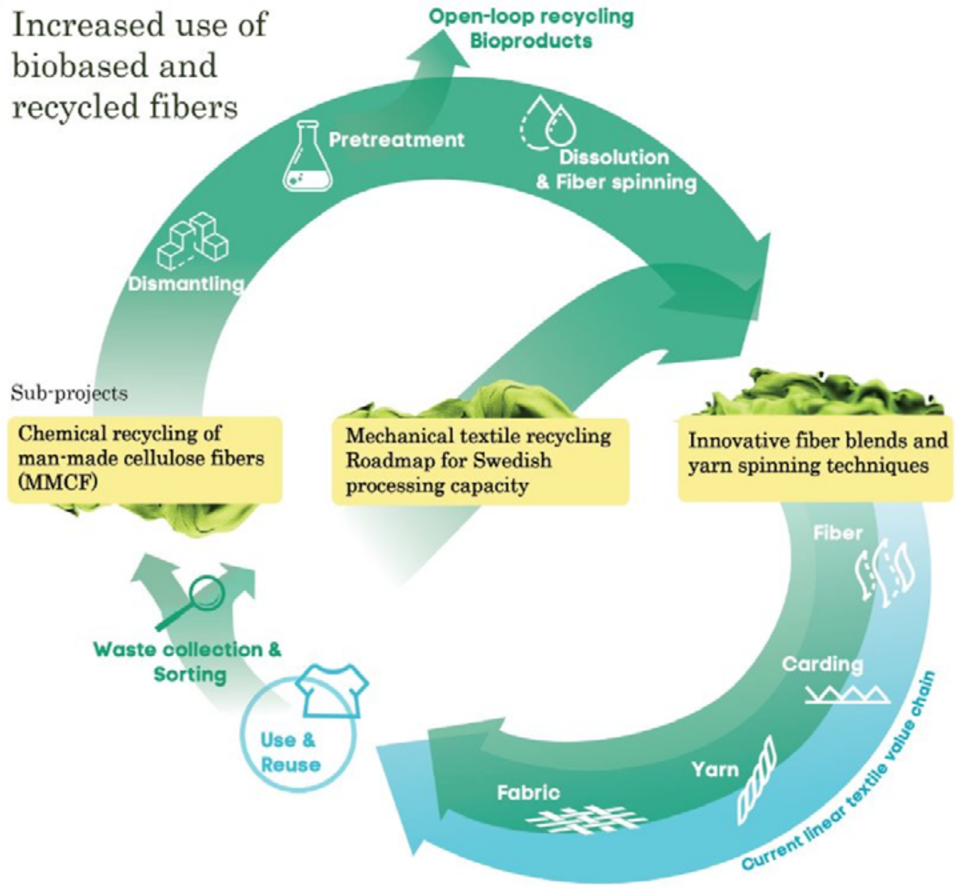

Figure 1. The position of CITEX's three projects in the textile value chain.

CITEX coordination project

Duration: December 2021 until December 2024
Project manager: Heidi Hautajärvi Stenmark, RISE Research Institutes of Sweden AB
Project partners: RISE Research Institutes of Sweden AB, IVL Swedish Environmental Research Institute
Financier: BioInnovation and project partners
Budget: 1 500 000 SEK
Project aim: Communicate and disseminate project results and information between the projects.

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CITEX project: Chemical recycling of man-made cellulose fibres

Duration: December 2021 until June 2024
Project manager: Tahani Kaldéus, The Loop Factory
Project partners: Wargön Innovation, Södra, The Swedish Red Cross, RISE Research Institutes of Sweden AB, MoRe Research, Imogo, Lunds University, TreeToTextile, The Loop Factory, BASF, IVL Swedish Environmental Research Institute, Valmet, TEKO, Albany International, Smart Textiles
Financier: BioInnovation and project partners
Budget: 7 800 000 SEK
Project aim: Investigate how man-made cellulose fibres can be included in a circular and non-toxic value chain.

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CITEX project: Innovative fibre blends and yarn spinning techniques

Duration: December 2021 until June 2024
Project manager: Anna Hammarstedt, IVL Swedish Environmental Research Institute
Project partners: Albany International, FOV Fabrics, Houdini, ICA, IVL Swedish Environmental Research Institute, Pure Waste, Rester, RISE Research Institutes of Sweden AB, Stadium, The Swedish School of Textiles, TreeToTextile, Trikåby, Ullkontoret
Financier: BioInnovation and project partners
Budget: 8 100 000 kr SEK
Project aim: Explore new fibre blending options and new yarn spinning techniques to increase the use of bio-based and recycled fibres in technical and high-performance textiles and for less demanding applications.

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CITEX project: Mechanical textile recycling – a roadmap for Swedish processing capacity

Duration: December 2021 until June 2024
Project manager: Johan Strandberg, IVL Swedish Environmental Research Institute
Project partners: IVL Swedish Environmental Research Institute, RISE Research Institutes of Sweden AB, Elis, Wargön Innovation, The Loop Factory, Sporda Nonwoven, SYSAV, BjörkåFrihet, Houdini, Samhall, ICA, Albany International, Stadium, Trikåby, Human Bridge, The Swedish Red Cross.
Financier: BioInnovation and project partners
Budget: 4 300 000 SEK
Project aim: Investigate the conditions for establishing a mechanical textile recycling facility in Sweden

Picture: RISE

Innovative fibre blends and yarn spinning techniques

The project on innovative fibre blends and yarn spinning techniques aimed to develop bio-based and recycled fibre blends and yarn spinning techniques that contribute to increased sustainability, while also meeting the quality and property requirements of the entire textile industry, including both fashion and technical sectors.

WHAT HAS BEEN DONE IN THE PROJECT?

The project has investigated new fibre blend alternatives and developed new yarn spinning techniques with the aim of phasing out fossil fibres. The main activities conducted within the project are presented in the following text.

Five concepts have been developed

Through collaboration between researchers and industry partners, the project developed new fibre blends, optimised spinning techniques, and tested material performance. This work led to five main concepts (see Figure 2). These concepts, developed within the project, were based on different technical challenges in the textile industry. A short description of each concept (A-E) is presented in the following text.

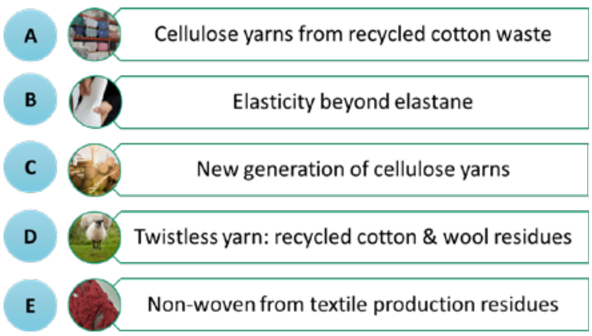

Figure 2. The five concepts developed in the project: innovative fibre blends and yarn spinning techniques.

CONCEPT A: Enhancing spinnability of recycled post-consumer cotton

This concept explored the use of mechanically recycled cotton and new yarn blends with hemp, lyocell, viscose and primary cotton.

CONCEPT B: Elasticity beyond elastane

Elastane is a material that has proven difficult to recycle, and even a small amount of elastane in blends limits the possibility of recycling. This concept, therefore, explored ways to increase the stretchability of bio-based materials without using elastane.

CONCEPT C: Pioneering cellulosic yarns with enhanced potential

This concept investigated blending several types of cellulose fibres with a new type of regenerated cellulose fibre developed by the company TreeToTextile.

CONCEPT D: Twistless yarn with Swedish wool residues and recycled cotton

The concept explored blending fibres from a residual stream of Swedish wool production with recycled cotton with some elastane content to create a new kind of ribbon-like yarn.

CONCEPT E: Transforming textile residues into resources

The reuse of waste streams from the weaving and production of nonwoven materials into new textiles was investigated within this concept. By developing the carding process and mechanically recycling waste pieces, new circular textiles could be produced.

A life cycle assessment of two concepts has been conducted

Environmental impact has been assessed through the execution of a life cycle assessment (LCA) of the two concepts that showed the most promising results: Concept A and D. The analysis showed that electricity consumption during production had the greatest climate impact, while transportation had less significance. Additionally, environmental burdens such as water and land use decrease when recycled materials are used instead of primary materials.

WHAT ARE THE MAIN CONCLUSIONS?

All the concepts that the project has worked with are contributing to solving major sustainability challenges in the textile value chain, including textile recycling and the processes involved in producing yarn from fibre. They all play an important role in a circular bio-based textile industry, in some cases as single concepts and in other cases in combination to achieve a greater impact. Particularly worth mentioning are the innovative way of making yarn without twist and the fibre blends with TreeToTextiles' fibre technology, both of which have great potential from both a commercial and sustainability perspective.

Exhibition about the project Innovative fibre blends and yarn spinning techniques. Picture: RISE

Chemical recycling of man-made cellulose fibres

The aim of this project was to explore how man-made cellulose fibres (MMCFs) can be recycled and reused in various products, including new textiles, packaging materials, and chemical components, all while maintaining a non-toxic value chain.

WHAT HAS BEEN DONE IN THE PROJECT?

This project has focused on integrating MMCFs, such as viscose and lyocell, into a sustainable, circular system. The following text provides a description of the main activities undertaken in the project.

Three recycling routes have been studied

This project studied three main recycling routes, including essential processes such as dismantling, sorting techniques, and dye removal. The three pathways explored involve recycling MMCFs into new textile fibres, packaging, and production of known chemical building blocks (see Figure 3).

Several technology and process improvements have been showcased, and the insights gained have heightened the awareness of additional improvement areas and opportunities to achieve more sustainable production processes.

The project has demonstrated that viscose fibres can be used as a raw material to produce new viscose fibres. Using viscose fibres as a raw material also enabled a more efficient process with lower chemical consumption. The scientific results from the study on viscose recycling are available in the following publication: *Towards sustainable viscose-to-viscose production: Strategies for recycling of viscose fibres.*[1]

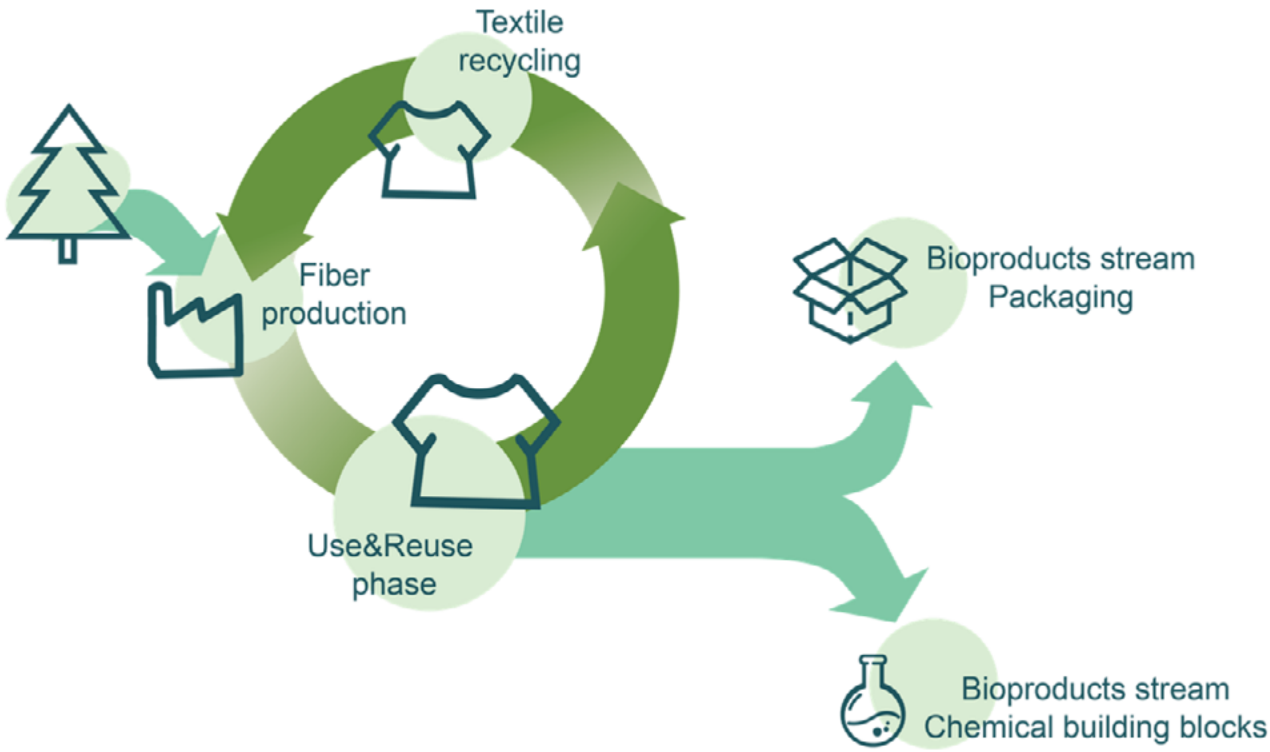

Figure 3. The scope of the project Chemical recycling of man-made cellulose fibres (MMCFs).

[1] Forsberg, D.C.R., Bengtsson, J., Hollinger,N., Kaldéus, T. (2024). Towards sustainable viscose-to-viscose production: Strategies for recycling of viscose fibres. Sustainability, 16(10), 4127. Retrieved from: https://doi.org/10.3390/su16104127

For the other recycling routes, it was demonstrated how MMCFs can be used to produce packaging and biobased chemical building blocks. The activities on recycling viscose into chemicals showed that MMCFs can be chemically recycled and depolymerised into smaller building blocks, which can serve as platforms for chemical manufacturing.

Glucose appears to be the most promising intermediate from viscose, though further research and optimisation could reveal the potential of other intermediates as well. Moreover, the circularity aspect has been further explored by demonstrating that residues from the chemical building block process can be repurposed as a raw material for packaging manufacturing.

A sustainability assessment has been conducted

A sustainability assessment was carried out to evaluate the environmental impact of recycling of textiles into new textiles, packaging/storage solutions, and chemicals. All three options are available at laboratory scale. The results indicate a lower environmental impact for textile-to-textile and textile-to-packaging recycling compared to production using primary raw materials.

The assessment also revealed the need for improvement that should be considered when scaling up to industrial production.

A dye study was performed

The sustainability assessment identified bleaching of used textiles as one of the main contributors to the environmental impact. Therefore, efforts were made to explore how the bleaching process could be optimised and to question the overall necessity of extensive bleaching. Most textiles are dyed into darker shades, like black or navy, and such colours could most likely be obtained by using non-white starting material. A dye study was conducted within the project to highlight this potential, see Figure 4. The dye study investigated the impact of varying brightness levels of the starting material, from white to light grey, on the final colour after dyeing. As shown in Figure 4, when the fabric was dyed blue, the initial colour did not affect the final colour, even for lighter shades. However, when dyed pink or light yellow, a non-white starting material did influence the final colour, as indicated by an asterisk in Figure 4.

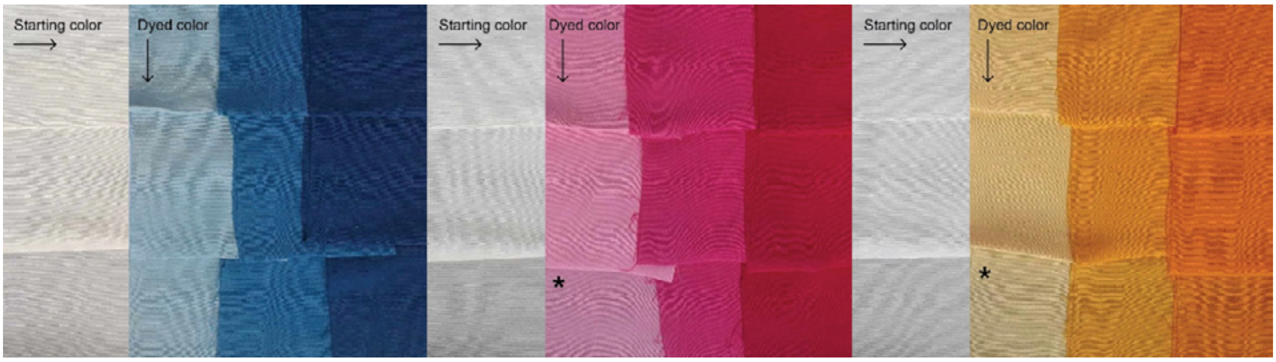

Figure 4. Overview of the dye study. The colour of the starting material was varied from white (ready to dye) to a brightness of about 90%. The dyed colour was varied in intensity to see the impact on the final colour. * indicates a difference in the colour compared to the same colour dyed on a bright starting material. Ref: RISE

Market and techno-economical aspects have been analysed

The project has also addressed market aspects and conducted techno-economic analyses. Interviews with organisations working with biobased fibres revealed that the challenges of integrating recycled raw materials into the value chain are complex. A collective effort from all sectors of society is required to drive the transition toward greater use of recycled and biobased materials.

The technical challenges associated with incorporating waste textile raw materials into the textile fibre industry are illustrated in Figure 5. These identified areas limit and complicate the sourcing of recycled materials and must be addressed to increase the proportion of recycled raw materials used. Many of these challenges relate to the lack of established infrastructure and technologies for collecting and sorting recycled materials in sufficient volumes.

WHAT ARE THE MAIN CONCLUSIONS?

Overall, the project has demonstrated the potential of using recycled MMCFs within a circular textile value chain. More importantly, it has provided valuable insights and a deeper understanding of the complexities involved in recycling discarded textiles in general, and MMCFs in particular. Several technology and process improvements have been identified, and the insights gained have increased the awareness of further improvement areas and strategies for enhancing the sustainability of production processes. Additionally, understanding the differences in material properties and their impact on processing and the selection of recycling streams has yielded important results that will facilitate the integration of recycled MMCFs into a circular textile value chain.

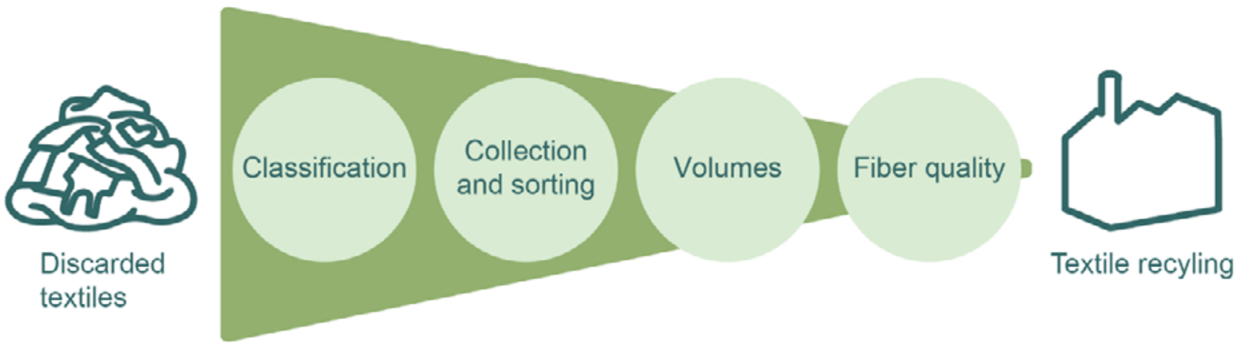

Figure 5. Technical challenges associated with using waste textiles as raw materials in fibre production.

Picture: Kerstin Jonsson, Swedish Forest Industries

Mechanical textile recycling – A roadmap for Swedish processing capacity

This project aimed to develop a roadmap for mechanical textile recycling process capacity in Sweden, contributing to a circular ecosystem for textile waste, promoting resource-efficient material utilisation, and reducing reliance on fossil raw materials.

WHAT HAS BEEN DONE IN THIS PROJECT?

The project has delivered a roadmap to the mechanical recycling of textiles in Sweden, and several benefits of the concept were identified. The main activities performed within the project are summarised in the following text.

A business case for a mechanical recycling plant in Sweden has been developed

Globally, less than one percent of textile waste is currently recycled into similar applications, with most collected textiles being downcycled into lower-value products. In some cases, textile production waste (pre-consumer waste) is upcycled by blending it with new fibres to create yarns with recycled content. Both processes primarily rely on mechanical recycling. Mechanical textile recycling is a well-established technology, with several European plants already processing textiles into fibres used in new products. However, Sweden currently lacks large-scale mechanical recycling facilities. This project collected the necessary data to explore whether establishing a mechanical recycling plant in Sweden could be economically viable.

The business case presents a strong case for establishing a mechanical textile recycling plant in Sweden, showing promising economic profitability. The two most critical factors driving this success are the price of the outbound fibres and the plant's processing capacity. Energy prices, transport costs and staffing were never critical. A key assumption in the analysis is that there will be sufficient demand for recycled fibres and that suitable textiles are available for processing in adequate amounts. Interviews with downstream market actors provided valuable insights into fibre prices, differentiated by type and length and they appear to be well within reach for a mechanical recycling plant.

One of the primary challenges in running a mechanical textile recycling plant lies in sourcing homogeneous material streams. Inconsistent material inputs can result in lost production time due to the need for machinery adjustments, reducing overall efficiency. Optimising the output is another crucial aspect, which requires specialised knowledge or advanced process control to maximise fibre length and reduce downtime. Moreover, the role of a broker becomes essential in this context. Significant effort may be needed to match the materials for tearing with customer specifications downstream. This is expected to require determination and persistence, as this is a well-recognised challenge within the textile industry.

A life cycle assessment of a mechanical recycling plant in Sweden has been conducted

A screening life cycle assessment (LCA) of a potential future mechanical textile recycling plant located in Sweden has been conducted within the project. The assessment is based on rough assumptions, data estimates and scenarios exploring the influence of uncertainties regarding, for example, the location of the recycling plant (influencing the transport distances), the need for constructing new infrastructure for the recycling plant, the need to sort the incoming feedstock, the electricity mix used at the recycling plant, and fuel type used in transports. The LCA shows that the climate impact of mechanically recycled cotton fibre in Sweden ranges from 70 to 300 kg of CO_2 equivalents per ton of fibre, compared to 500 to 4,000 kg of CO_2 equivalents for primary cotton fibre.

It is worth mentioning that the LCA is based on likely circumstances and technologies available today. Potential future changes are not accounted for. Furthermore, the impact categories selected for this study relate to energy-related issues, which are expected to be the main issues of mechanical textile recycling. There are other substantial impacts, especially when discussing the environmental impact of mechanically recycled fibres compared to primary biobased fibres, such as water deprivation and impacts on land use. A more detailed description of the LCA and the results from the study are presented in the following publication: *Life cycle assessment of mechanical textile recycling in Sweden* .[2]

WHAT ARE THE MAIN CONCLUSIONS?

The business case demonstrates significant potential for establishing a profitable mechanical textile recycling plant in Sweden. With competitive fibre prices and sufficient processing capacity, the plant could meet market demand effectively. However, the success of the venture hinges on verifying two key assumptions: the availability of a consistent supply of suitable textiles for recycling and sustained demand for recycled fibres in the market. Addressing these uncertainties, along with overcoming challenges related to material homogeneity and process optimisation, will be crucial for ensuring the plant's long-term viability.

One of the main conclusions from the LCA is that the results, in terms of climate impact, energy demand, and fossil resource use, for mechanically recycled fibres, are in the lower range, or about an order of magnitude lower, compared to the results of production of primary fibres. Another important conclusion from the LCA is that the relatively low climate impact of Sweden's electricity grid mix considerably reduces the climate impact of mechanical recycling. In contrast, a location relying on a higher-impact grid mix, like the current European mix, would increase the climate impact of recycled fibres by approximately 200 kg CO_2 equivalents per ton fibre. Even so, these fibres would still have a lower climate impact than most primary fibres.

[2] Sandin, G., Lidfeldt, M., Nellström, M., Strandberg, J., Billstein, T., Hammar, T., & Larsson, M. (2024). Life cycle assessment of mechanical textile recycling in Sweden. Retrieved from IVL Swedish Environmental Research Institute's website: https://urn.kb.se/resolve?urn=urn:nbn:se:ivl:diva-4312

What challenges remain?

The CITEX project is finalised in December 2024, but the journey towards creating a non-toxic and bio-based textile value chain continues. While progress has been made, ongoing challenges remain, and further research and innovation will be essential to achieve this vision.

The work conducted across these three projects has revealed several important findings, improvements in the textile recycling value chain, and advancements in innovative fibre blends and yarn spinning techniques. However, it has also highlighted challenges and societal concerns that require careful consideration for effectively integrating recycled raw materials and bio-based fibres into a circular value chain. By proactively addressing these social and political dimensions, we can ensure that incorporating recycled and biobased materials is economically feasible and also socially and politically sustainable.

Improved collection, sorting and dismantling processes are essential

Two key factors for a successful transformation to a more circular textile and fashion industry are the collection and sorting of textile waste. These factors are essential to ensuring that there is sufficient feedstock available as well as securing that various fibre qualities and sufficient quantities are available for recycling. Dismantling is a crucial step in ensuring a feedstock suitable for recycling. Currently, this process is performed to a very limited extent in Sweden. However, establishing textile hubs capable of semi- or fully automated garment dismantling could change this situation.

Sufficient volumes and stable feedstock for textile recycling are difficult to achieve

One of the biggest challenges in transforming to a circular textile industry lie in scaling the various recycling methods and securing sufficient volumes of recycled feedstock with consistent and suitable fibre properties tailored to diverse recycling technologies. Achieving this relies heavily on a well-functioning infrastructure and advanced technologies for collection and sorting. This further emphasises the importance of long-term partnerships between sorting facilities and recyclers to ensure a stable and reliable supply.

Political action is needed

At the societal level, political action is needed through legislation and economic incentives. Public authorities and municipalities should take the lead by revising procurement and funding policies to prioritise recycled products. Long-term environmental policies are essential to foster confidence in investors and stakeholders throughout the textile value chain. While demonstration facilities are crucial for scaling textile recycling techniques, they require significant funding, which may come from investors or subsidies.

Established standards and classification systems for recycled fibres are lacking today

Maximising the potential of raw materials in post-consumer textiles is challenging. A key challenge is the diverse mixtures of materials present in post-consumer textiles. To address this, we need established standards and a classification system that identifies the fibres present in the post-consumer materials.

The CITEX end conference

On the 29th of May, 2024, CITEX held its end conference at RISE Research Institutes of Sweden AB in Stockholm. The theme for the day was ”Sustainable System Change in the Textile Industry” and the results from the CITEX projects were presented to almost 100 participants. In addition to the project results, two panel discussions were held that addressed barriers and challenges. They focused on what actions the industry needs to take and what developments are needed in Sweden to strengthen the textile industry when it comes to recycling and increasing the use of biobased and recycled fibres.

Speakers of the day included, among others: Cecilia Tall (moderator for the day) and Lisa Schwarz Bour from RISE Research Institutes of Sweden AB, Sverker Danielsson from BioInnovation, Ulrika Simonsson from TEKO, Helena Claesson from Once More, Marcus Hartmann from H&M, Tahani Kaldéus from The Loop Factory, Anna Hammarstedt, Johan Strandberg, Gustav Sandin and Matilda Lidfeldt from IVL Swedish Environmental Research Institute.

Some pictures from the conference, as well as some of the presentations, can be found at BioInnovation's webpage.[3]

Contact details and more information

Webpage about the CITEX project in English:
https://www.bioinnovation.se/en/projekt/circular-textile-innovations-sweden-sustainable-system-change-in-the-textile-industry/

Webpage about the CITEX project in Swedish:
https://www.bioinnovation.se/projekt/circular-textile-innovations-sweden-sustainable-system-change-in-the-textile-industry/

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[3] https://www.bioinnovation.se/presentations-and-pictures-from-the-citex-end-conference/

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