Siptex
Swedish Innovation Platform for Textile Sorting

A summary report of the final stage of the project

SYSAV

ivl SVENSKA MILJÖINSTITUTET

Siptex, **Swedish Innovation Platform for Textile Sorting,** is a research project funded by Sweden's Innovation Agency's Challenge-driven innovation initiative and the project partners.

Project coordinator: IVL Swedish Environmental Research Institute
Project partners: Elis, Boer Group, Refashion, Gina Tricot, H&M, Human Bridge, Ica, Ikea, Kappahl, the Swedish Chemicals Agency, Sustainable Waste and Water City of Gothenburg, Malmö City, Myrorna, the Swedish Environmental Protection Agency, Renewcell, Red Cross, Stadium, Stockholm Vatten, and Sysav.

The Siptex project began in 2015 with the third and final stage initiated in 2019. This report focuses on the work carried out during this final stage which aimed to create conditions for high-quality textile recycling on an industrial scale through the establishment of automated textile sorting.

Authors: Maja Nellström, Sophie Grahn Lydig, Gustav Sandin Albertsson and Dämien Johann Bolinius,
IVL Swedish Environmental Research Institute

Photographs: Sysav, Andreas Offesson, Stadium
Graphics: Sysav and Ragnhild Berglund, IVL Swedish Environmental Research Institute
Layout: Ragnhild Berglund, IVL Swedish Environmental Research Institute

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IVL Swedish Environmental Research Institute Ltd, PO Box 210 60, S-100 31 Stockholm, Sweden
Phone +46 (0)10 788 65 00
www.ivl.se

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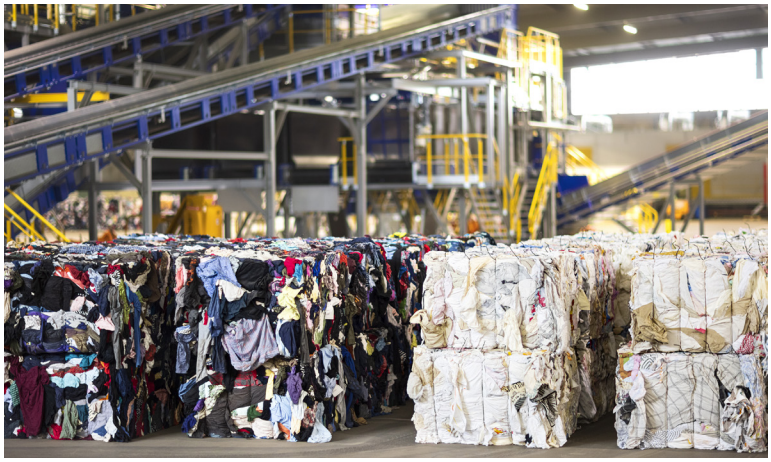

Siptex is both a project and a facility

Siptex, **Swedish Innovation Platform for Textile Sorting**, is a research project funded by Sweden's Innovation Agency's Challenge-driven innovation initiative and the project partners. But it is also a textile sorting facility, situated at Sysav in Malmö.

The Siptex project began in 2015 with the third and final stage initiated in 2019. This report focuses on the work carried out during this last stage which aimed to create conditions for high-quality textile recycling through the establishment of automated textile sorting on an industrial scale.

During the final stage of the project, Siptex, the world's first automated sorting facility for post-consumer textiles on an industrial scale, was built in Malmö. The Siptex plant uses near-infrared and visual spectroscopy (NIR/VIS) to sort mixed pre-sorted textile waste according to market needs in terms of fibre composition and colour. As a new step in the textile value chain, the Siptex plant provides the previously missing link between manual sorting of collected textiles and fiber-to-fiber recycling. (figure 1).

In addition to sorting optimization, quality assurance and environmental assessment, the project focused on defining and creating functioning markets for high-quality Siptex sorted materials. The project included Swedish textile and fashion companies with global value chains and actively collaborated with both Swedish and international companies.

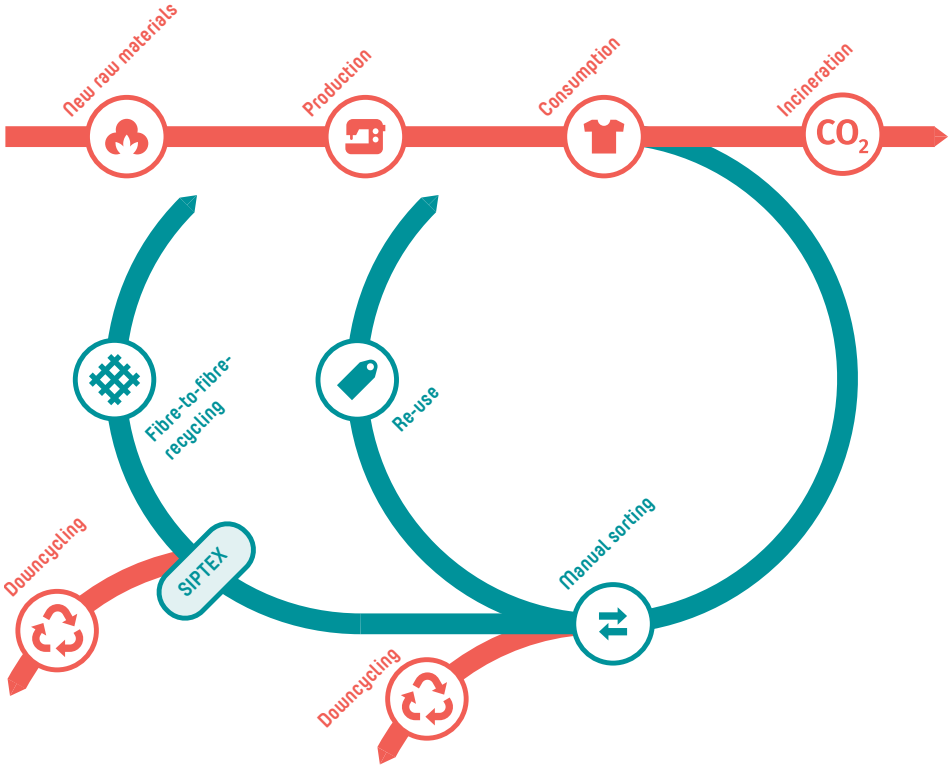

Figure 1. The position of the Siptex plant in the textile value chain.

The Siptex facility uses near-infrared and visual spectroscopy to sort mixed textile waste in terms of fibre composition and colour.

THE SIPTEX PROJECT

- **Project title:** Siptex, Swedish Innovation Platform for Textile Sorting
- **Duration:** From 2019-05-02 until 2022-10-31
- **Project coordinator:** IVL Swedish Environmental Research Institute
- **Financier:** Sweden's Innovation Agency and the partners of the project
- **Budget:** 55 million SEK (of which 22 million SEK from Sweden's Innovation Agency)
- **Project aim:** Create the conditions for high-quality textile recycling by establishing automated textile sorting on an industrial scale as a new step in a circular textile value chain
- **Awards:**
  - The Special Award at the Swedish Recycling gala (Återvinningsgalan), 2020
  - National Energy Globe Award, 2021
  - Stockholm Fashion District Award – Encouragement for Action 2022, category Closing the Loop

THE SIPTEX PROJECT PARTNERS

- **Project coordinator:** IVL Swedish Environmental Research Institute
- **Project consortium,** 19 national and international partners: Elis, Boer Group, Refashion, Gina Tricot, H&M, Human Bridge, Ica, Ikea, Kappahl, the Swedish Chemicals Agency, Sustainable Waste and Water City of Gothenburg, Malmö City, Myrorna, the Swedish Environmental Protection Agency, Renewcell, Red Cross, Stadium, Stockholm Vatten, and Sysav

THE SIPTEX FACILITY

- **Owner:** Sysav
- **Manufacturer:** Stadler/Tomra
- **Location:** Bjurögatan 20, Malmö
- **Capacity:** 4,5 tonnes per hour (24,000 tonnes per year at three shift operation)
- **Technique:** Four NIR/VIS (near-infrared and visual spectroscopy) scanning units
- **Conveyor belt:** 260 metres

What has been done in the Siptex project?

From 2019 to 2022, the Siptex project completed the third and final stage within the Sweden's Innovation Agency's Challenge-driven innovation initiative. In this final stage, the focus was on developing, testing, and introducing solutions on an industrial scale.

A full-scale automatic sorting plant has been established

The industrial-scale Siptex plant was launched in 2020. It consists of a feeding bunker, a dosing drum, four scanning units and a baler, coupled together with 260 metres of conveyer belts (figure 2).

The main objective of the Siptex plant is to sort mixed textile waste into quality assured Siptex sorted materials tailored to suit different fibre-to-fibre recycling processes.

Using near-infrared and visual spectroscopy (NIR/VIS), Siptex sorts textile waste unfit for re-use according to fibre type and colour. The textiles are illuminated by NIR light, which is reflected in different ways depending on the material fibre type. A sensor identifies the fibre type by comparison with reference spectra and compressed air blows the textile into the right container.

Using three NIR/VIS scanning units, the plant can be programmed to sort three different fractions as the same time. A fourth NIR/VIS scanning unit is used as a purification step where the material is sorted a second time to achieve a higher sorting quality. Currently, the sensor in each scanning unit

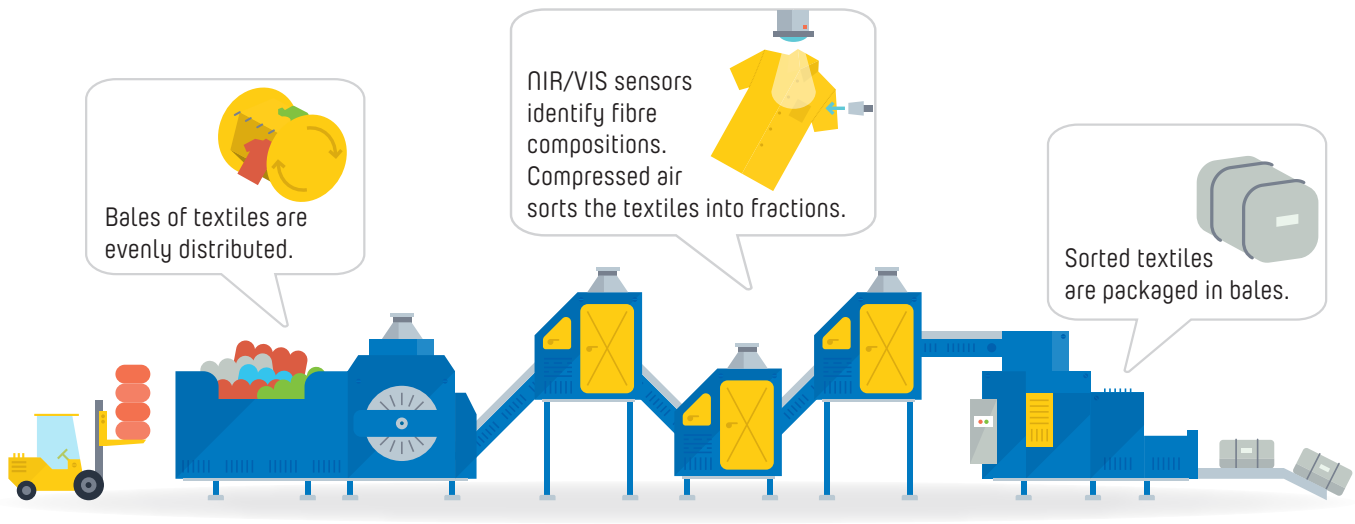

Figure 2. Principle sketch of the Siptex facility.

can distinguish between 16 different fibre types.

At full operation, the plant can sort up to 24,000 tonnes of textiles each year, which corresponds to approximately 30 percent of the textiles thrown away in Sweden during the same period. At present, the plant is operating during one working shift with the capacity of sorting 6,500 tonnes of textile waste per year.

Sysav accepts different categories of textile waste for sorting at the Siptex facility, for example:

- pre-sorted post-consumer material, such as non-reusable garments;
- pre-consumer material from industry, such as waste from production;
- post-consumer material from industry, such as worn-out working clothes or textile material from laundries.

The textile waste sorted at the Siptex facility needs to fulfil certain specifications, for example, the material cannot contain any of the following:

- textiles that are damp, dirty, contaminated e.g. by paint, oil, or other impurities;
- products of several layers and textile materials, e.g. lined garments, down jackets, and pillows;
- textile material with any dimension larger than 2 metres or smaller than 0.2 metres.

A complete list of specifications and delivery requirements can be found at Sysavs webpage.[1]

A product range of Siptex sorted materials has been developed

Five different outbound products of specific fibre content have been developed based on market demand. The products are referred to as ReFab® by Sysav, which stands for ”Renewable Fabulous Fabric”.

The ReFab products consists of the following fibre materials (by weight):

- 95 percent cotton
- 70 percent cotton
- 95 percent polyester
- 60 percent polyester
- 95 percent acrylic

In addition to the ReFab products, specific fibre mixtures can be sorted upon agreement with Sysav.

The Siptex textile sorting also generates some residual textile fractions without a specified fibre content. These residual fractions are currently stored at Sysav for the purpose of finding downcycling solutions, such as rags or insulation material, rather than sending these fractions for incineration.

ReFab® by Sysav, which stands for ”Renewable Fabulous Fabric”.

Quality assurance has been performed

To be of value to textile recyclers, the fibre content of the Siptex sorted materials needs to be of a reliable and consistent quality. Within this context, the Siptex project has focused on developing and testing a sampling method to take representative samples from bales of Siptex sorted materials. The method consists of taking 15 drill samples per bale which are shredded and homogenised before being sent to a certified lab where the samples are analysed.

This method, in combination with regular manual inspection in which labels are checked against expected results, ensures that products fulfil the quality requirements. Mismatches between garment labels and actual fibre content were also investigated. In the future, the visual examination of labels could potentially be replaced by a handheld NIR/VIS instrument. Feedback collected during trials with project partners has also resulted in further optimisation of the sorting process.

It took Sysav a year and a rebuild of the facility to achieve a fibre quality of the Siptex sorted materials which could be delivered to customers. Sysav and Tomra (supplier of the NIR/VIS sensors) worked throughout 2021 to optimise the sorting. Textile batches that do not fulfil the requirements regarding fibre content are sent back for sorting.

Sorting by colour has proven to be more difficult

1) www.sysav.se/foretag/Sorteringsguiden-for-foretag/fraktion/textil/#inneh%C3%A5ll

than expected and is still under development. Therefore, the focus of the quality assurance process has been on fibre content quality and identification and quantification of hazardous chemical content.

Knowledge of chemical content has increased

For the Siptex sorted materials it is not only important to ensure a specific fibre content but also to comply with chemical regulations such as REACH and specific chemical requirements set up by customers (e.g. compliance with AFIRM or Oeko-Tex® criteria).

Due to uncertainty of composition of inbound material the Siptex sorted materials cannot be certified with regards to hazardous chemicals. To gain certification, samples from every bale of Siptex sorted material would need testing to ensure compliance.

To deal with this issue, the Siptex project investigated existing data on hazardous chemicals in post consumer textiles[2] and supplementary data from testing on Siptex sorted materials consisting of cotton, polyester, and acrylics. Analysis revealed that the presence of hazardous chemicals, in compliance with REACH and Oeko-Tex criteria, was not an issue for these post-consumer textiles. Many of these additives are likely washed out or evaporated from the materials during the use phase. At the time of writing, all samples taken during the Siptex project have complied with REACH. Many of them also comply with Oeko-Tex criteria for Oeko-Tex Standard 100 class 2, for articles that come into direct contact with the skin.

In the future, Siptex sorted materials consisting of other fibre types should undergo these same testing procedures, as different fibre compositions can contain different additives. The substances that were detected at low levels or that breached the Oeko-Tex criteria should also be monitored more frequently to ensure that their concentrations comply with regulations.

Environmental impact assessment has been done

Better sorting, that enables more recycling, can reduce reliance on primary resources and mitigate the associated environmental impacts. But sorting and recycling do not automatically lead to environmental gains – these rely on resource-efficient sorting and recycling, and the impact of the materials that are being replaced.

To explore the potential environmental benefits

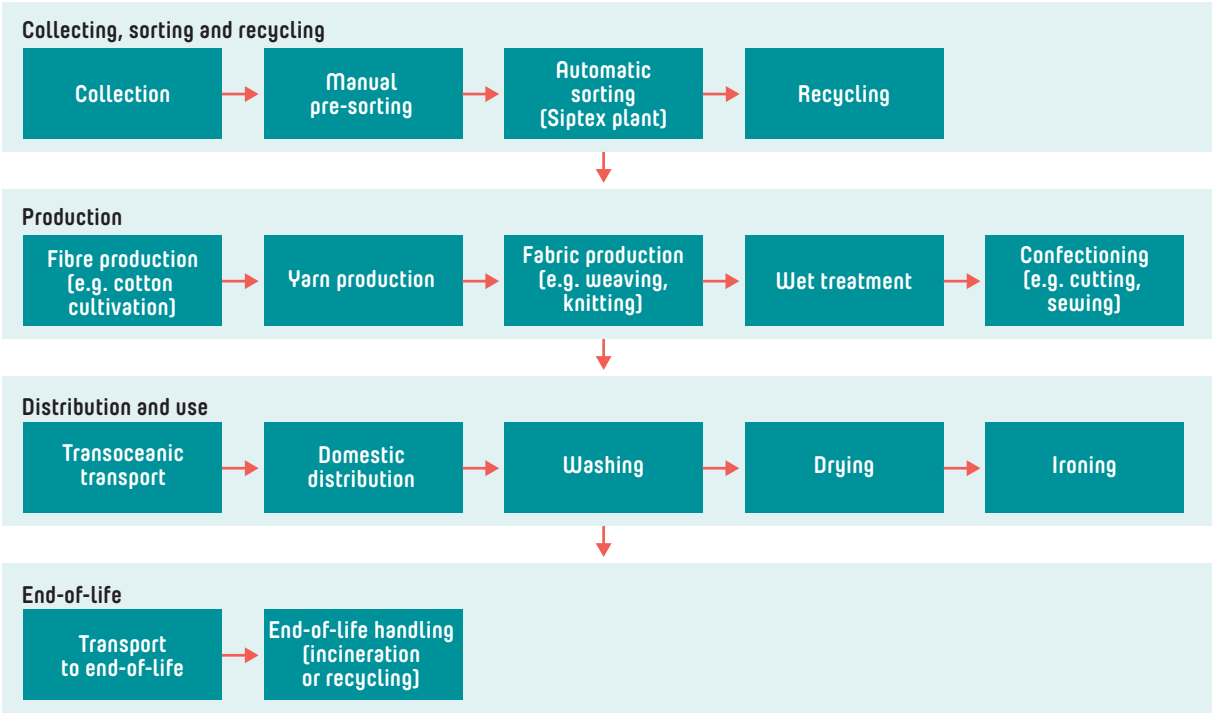

Figure 3. Overview of the life-cycle stages and processes of the four LCA case studies.

2) www.ri.se/en/what-we-do/projects/classification-and-risk-assessment-of-textile-for-material-recycling

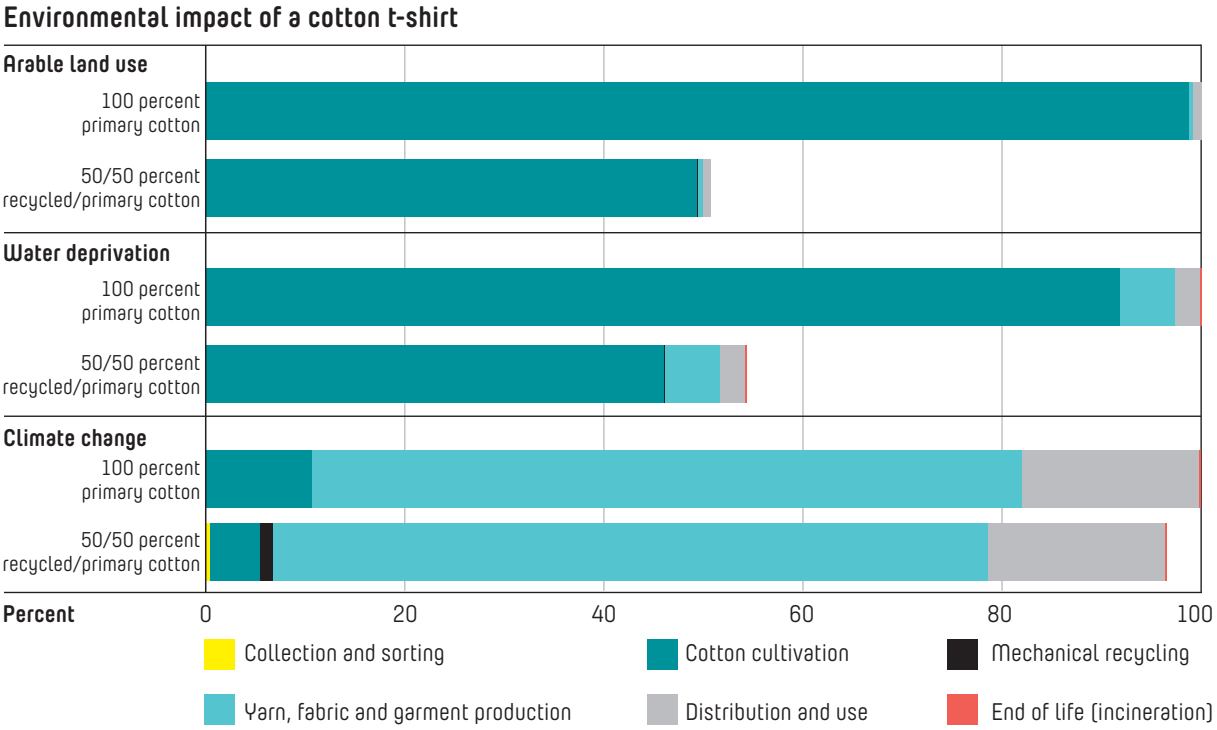

Figure 4. Examples of results from one of the four LCA case studies. This is a comparison between two t-shirts, one made of 50 percent primary cotton and 50 percent mechanically recycled cotton, and one made of 100 percent primary cotton (benchmark). Results are shown for three of the studied impact categories and have been normalised to the results of the benchmark.

and impacts of recycling enabled via the Siptex plant, the project conducted life cycle assessments (LCAs) of four cases reflecting value chains that can utilise Siptex sorted materials:

A. Cotton t-shirt made of 50 percent mechanically recycled cotton and 50 percent primary cotton.
B. Viscose t-shirt made of chemically recycled cotton.
C. Sports jersey made of chemically recycled polyester.
D. Sweater made of mechanically recycled wool.

All garment life-cycle stages were mapped, and several environmental and resource concerns, i.e. impact categories, were studied: climate change, water deprivation, eutrophication, land use, fossil-resource use, energy use (figure 4). Scenarios were set up to evaluate the influence of collection distances and end-of-life practices (incineration vs. another recycling loop). All garments were compared to identical clothing made of primary resources.

Figure 4 shows some of the results for the cotton t-shirt. There are clear benefits if recycling reduces the needs for extracting virgin resources, in this case the cultivation of cotton, which is a thirsty crop and often grown in arid regions where arable land is a limited resource. However, there are not necessarily benefits in all impact categories. For example, concerning climate change: the 4 percent difference between the recycling and benchmark scenarios is within the uncertainty range, as cotton cultivation is generally not an important climate-impact contributor.

The collection and sorting, including the electricity used to run the Siptex facility, cause negligible environmental impact from a life-cycle perspective. However, if the collection system relies on people driving their car to dispose of their textiles, this may influence the climate-competitiveness of recycling.

Several collaborations have been established

During the Siptex project, several ongoing collaborations were established between Sysav and different actors within the textile value chain.

Some of these collaborations are described in the adjacent boxes.

PARTNERSHIP WITH STADIUM

Polyester garments are produced from Siptex sorted materials

The Swedish sports fashion brand Stadium started a collaboration with Sysav in 2021 with the aim of recycling post-consumer polyester into new fabric for polyester garments.

Through their collaboration, Sysav has supplied Stadium with Siptex sorted polyester material sent to recycling to produce polyester fibre. This recycled polyester fibre is used to spin yarn for knitting fabric which is used by Stadium's product development team to produce new garments. Initially, Sysav supplied five tonnes of Siptex sorted polyester for production testing with the hope of scaling up in the future.

On the next page, Titti Larsén, Quality & Sustainability manager at Stadium, provides some more insight into the testing of polyester recycling within the project.

PARTNERSHIP WITH RENEWCELL

Siptex sorted materials become Circulose®

Founded in 2012 by researchers at KTH (Royal Institute of Technology) in Stockholm, Renewcell is a Swedish based textile recycling company that produce Circulose®, a dissolving pulp made from textile waste such as cotton clothing. Circulose is used for production of MMCF (man-made cellulosic fibres), such as viscose and lyocell, which are used to manufacture fabric for new clothing.

In 2021, a collaboration was initiated between Sysav and Renewcell where Sysav deliver their Siptex sorted materials (Refab®) to Renewcell who recycle the textile waste into Circulose.

PARTNERSHIP WITH RECOVER

Siptex sorted materials become new cotton fibres

Building on their 2020 collaboration, in 2022 Sysav signed a new partnership agreement with Recover, a global producer of recycled cotton fibre and cotton fibre blends, to supply them with post-consumer waste (PCW) of ReFab 95 percent cotton. The agreement with Sysav is part of Recover's strategy to sign long-term contracts to secure textile waste supply and increase its recycling of post-consumer textiles.

"This technique will be essential in the future of the industry"

Stadium has been one of the industry partners in the Siptex project. We asked Titti Larsén, Quality & Sustainability Manager at Stadium, about her thoughts on the project.

Why has Stadium been involved in the Siptex project?
We believe in this technique and the transition to more circular processes. It will be essential in the future of the industry, considering the lack of raw materials, legislation, depletion of natural resources, speed to market etc.

Titti Larsén, Stadium.

Has Stadium delivered any textile materials to the sorting facility?
We haven't delivered any materials directly to the facility but through our partnership with the textile collector Human Bridge.

Have you ordered any Siptex sorted material?
Yes, we have received polyester of mixed colour. Half will be used for mechanical recycling and half for chemical recycling.

Has Stadium done chemical testing of the Siptex sorted material?
We have done a chemical screening of the bales. Going forward we will test in each stage, i.e shredded material, yarn, and fabric, to track chemicals down the textile value chain.

Is Stadium planning to manufacture any products from recycled material?
Yes, we are planning to use the chemically recycled polyester just as virgin polyester in a collection together with the mechanically recycled material. Depending on what yarn quality we will receive from the spinner we will see what our team can create.

Does Stadium have its own targets for increasing the use of recycled material?
Our goal for 2025 is to have 100 percent sustainable materials for textile products from our own brands. As we produce a broad variety of products, we have not found recycled materials for the whole product range. Our portfolio also includes for example various sport equipment, personal protective equipment, ice skates, bikes, tents and food contact products where we might have some parts in recycled material but not the whole product yet.

What do you see as obstacles to increased recycling?
Price, lead-time and availability as for any other raw material. But for now, the biggest obstacle I see is the uncertain chemical content of the input material. This needs more and broader testing. As a garment producer we also need to plan for new raw materials streams which will be new for us.

What opportunities do you see in the future in using Siptex sorted material for recycling?
To meet the UN's Sustainable development goals, Stadium's emission goals and coming legislation this is a must. It is something we need to prepare for to be able to cut fossil dependency. In a near future, it is possible that the food industry will use recycled PET bottle material within their own packaging and not provide this material stream to the textile industry. Then, we will need a new material source of recycled polyester for our products. China is today world leading on raw materials so to move part of the fibre production closer to our customers is a fantastic opportunity to spread the risk and be more flexible.

What challenges remain?

The Siptex project ends on October 31, 2022, after which Sysav will continue with plant operation and commercialisation of their ReFab products. However, the work towards increased textile sorting and recycling is far from complete. There are remaining challenges to address and more innovative solutions are needed.

The competition for inbound material is increasing

The competition for inbound material has increased due to an increased demand for outbound material of certain fibre types, e.g. cotton-rich textiles. Cotton-rich textile fractions are in high demand since the most developed textile recycling techniques at the largest operational scale are based on the recovery of cotton fibres.

The Siptex plant competes for inbound material with existing textile recyclers regarding the purchase of manually sorted textile fractions for low-value recycling processes, i.e. downcycling. In addition, many textile recyclers have long-term supply agreements with manual sorting facilities, which means that not all sorted material is available today on the market.

Pre-sorting is resource intensive

The Siptex plant cannot handle products such as multi-layer garments, shoes, and upholstered products (pillows, quilts, etc.), which means that these types of products must be removed in a manual pre-sorting step. Pre-sorting is also needed to sort textiles suitable for reuse, since reuse is known to provide significantly higher environmental benefits than recycling. The manual pre-sorting is resource-intensive and requires experienced and trained employees. In addition, there is no large-scale manual sorting in Sweden today, and therefore most textiles collected in Sweden are sorted at facilities abroad. This means that textiles usually need to be transported abroad for pre-sorting before they reach the Siptex facility for automatic sorting.

A possible alternative to manual pre-sorting could be to use a more automated pre-sorting step. For example, Artificial Intelligence (AI) could be used to identify and sort garments that cannot be handled by Siptex NIR/VIS sensors. Research has already begun on using AI technology in the textile field to facilitate the valuation of textile products for the second-hand market.[3]

Optimisation of the sorting process is needed

A challenge with the Siptex sorting process is that some textile material fractions must be sorted several times to obtain the desired purity. Adding further sorting steps, e.g. additional scanning units, would likely improve the sorting efficiency.

Colour sorting is a feature that the VIS technology can perform. However, the colour sorting proved to be challenging due to difficulties in categorising different colour shades and the lack of standards for

3) wargoninnovation.se/ai-for-cirkulart-mode/

Several challenges remain in textile sorting, for example the need for manual pre-sorting as the Siptex facility cannot handle products such as multi-layer garments and upholstered products.

how much impurity that can be accepted. Sorting trials were performed on a light and dark colour basis, but even this simplification produced variable results with some inconsistency, mainly due to how multi-coloured garments were categorised by the sensors. In addition, trials showed that colour sorting requires different calibrations for different fibre types (e.g. cotton or polyester), making the sorting process more challenging.

Even though colour sorting is challenging, there are incentives for sorting the textile waste based on colour. For example, an advantage of colour sorting in combination with fibre sorting is the potential avoidance of subsequent processes such as dyeing of the fibres obtained from mechanical recycling.

Processing of the Siptex sorted materials might be needed

Another development possibility for the Siptex facility is to install an additional processing step of the Siptex sorted materials. This additional step would entail removing of accessories such as buttons, zippers, etc. For example, Renewcell has invested in this type of post-processing to streamline processes at its new facility in Ortviken near Sundsvall.[4]

With extra refinement and cleaning of the Siptex sorted materials, it is likely that the value of the materials would increase. Sampling for chemical analyses would also be easier to perform if the sorted textile fractions were cleaned. Some customers have also expressed preferences of receiving shredded Siptex sorted materials, which would require yet another process step.

Finding customers for all outbound material is challenging

The market for Siptex sorted materials, i.e. sorted post-consumer textile waste for high quality fibre-to-fibre recycling, is a new and unestablished market. To create and define markets for Siptex sorted materials is therefore one of the main challenges in the Siptex project.

The sorting at the Siptex plant has been adapted to the needs of textile recyclers and textile companies

4) www.andritz.com/newsroom-en/recycling/2021-07-27-renewcell-group

but there is still a challenge to find customers for all outbound material, particularly for the fractions with low fibre purity. However, technologies for chemical recycling of textile fibres are under development, and recycling processes converting cotton fibres into MMCF are currently the most developed technologies in terms of fibre-to-fibre recycling. There are also emerging recycling technologies for other cellulose based textiles as well as synthetics, and the market for post-consumer textile fractions prepared for recycling is expected to increase in the coming years. Additionally, the interest in using recycled materials in the fashion industry is extensive and many textile brands have formulated strategic goals for increasing the use of recycled textile fibres.

Regarding low value outbound materials (sorting residues) from the Siptex sorting, there is competition with manual textile sorters that can deliver material for downcycling purposes.

Policy instruments are required to tackle some of the challenges

Different policy instruments are likely needed to remove obstacles that prevent increased collection, sorting and recycling of textile. The implementation of Extended Producer Responsibility (EPR) on textiles in Sweden has already been investigated. This has also been explored within the EU. ”Several EU Member States already have or are considering the introduction of EPR requirements for textiles, given the obligation under EU waste legislation to establish separate collection of textile waste by 1 January 2025,” states the EU Strategy for Sustainable and Circular Textiles.[5]

EPR for textiles requires producers to take responsibility for waste management and recycling of textiles in accordance with the polluters pay principle. Introducing EPR for textiles in Sweden would most likely mean increased volumes of separately collected textile waste and an increased need for textile sorting (both manual and automatic) for reuse and recycling.

More standards are needed within the textile recycling industry

It became clear within the project that there is a lack of standards which can be used for the quality assurance of the Siptex sorted materials. For example, there is no established way of taking representative samples from bales of sorted material to test for fibre content and the presence of hazardous chemicals. Nor is it possible to certify the outgoing materials with reference to hazardous chemicals as chemical certification programs such as Oeko-Tex can only be used to certify yarn and products further downstream. Standards are also lacking when it comes to defining different colour fractions of Siptex sorted materials.

Reliability and consistency are of great importance for Siptex sorted materials to be able to compete with primary textile materials. It is therefore necessary to develop quality assurance standards for the above-mentioned aspects, i.e. fibre purity, colour, and chemical content.

5) environment.ec.europa.eu/publications/textiles-strategy_en

Contact and more information

IVL Swedish Environmental Research Institute

IVL's webpage in English about the Siptex project: www.ivl.se/english/ivl/our-offer/research-projects/circular-flows/automated-sorting-will-increase-textile-recycling
IVL's webpage in Swedish about the Siptex project: www.ivl.se/vart-erbjudande/forskning/cirkulara-floden/automatiserad-sortering-ska-oka-textilatervinningen
Here you will find appendices and other reports, such as needs analysis for policy instruments, sustainability assessment and quality assurance.
Personal contact: Maja Nellström, email maja.nellstrom@ivl.se, phone +46 (0) 10 788 66 88

Sysav

Sysav's webpage about the Siptex project (in Swedish): www.sysav.se/om-oss/forskning-och-projekt/siptex/

- If you are interested in delivering textile waste to Sysav, fill in the contact form at Sysavs webpage www.sysav.se/foretag/tjanster/textilsortering/
- If you are interested in obtaining Siptex sorted materials from Sysav you can visit www.sysav.se/siptex

Personal contact: Lars Persson, lars.persson@sysav.se, phone +46 (0) 40 635 22 77

IVL Swedish Environmental Research Institute Ltd, PO Box 210 60, S-100 31 Stockholm, Sweden | Phone +46 (0)10 788 65 00 | www.ivl.se