Mechanical, chemical and biological recycling processes are being investigated in an effort to tackle the titanic task of turning the mountains of textile waste generated each year at all levels of the fashion industry, from manufacturers to retailers and to consumers, into new fibres.

Closing the clothing loop

What a wonderful world it would be if all existing clothing could be chopped up or dissolved and re-used indefinitely to make new clothes. And all the more so as access to raw materials from both renewable and non-renewable sources is becoming increasingly tense.

The heterogeneous nature of the apparel industry – the prodigious diversity of materials and components that make up an item of clothing – pose countless challenges to the many different research programmes seeking to close the loop in clothing manufacturing.

Collectors of used clothing are at the forefront of this mission. These companies have a clear vision of the state of the textile waste they collect. With the rise of fast fashion, their business model is under pressure: how much value can a cheap item of clothing have in its second life when it is already of little value in its first useful life? Reprocessing these items means removing what textile recyclers consider "contaminants" and what consumers call ornaments, prints, decoration, or simply buttons and zippers. Removing these and sorting the items into different streams for future use is a labour-intensive process.

In the Netherlands, Wieland Textile has collaborated with Valvan Bailing Systems, a Belgian manufacturer of equipment for clothing collectors, to develop Fibersort, an automated system for identifying the fibre composition of clothing using near-infrared spectroscopy. It was officially presented a year ago (see *WSA* May/June 2018). It can currently sort used clothing by composition, colour and



At French used clothing collector and social business Le Relais, specialised workers sort 800 kilogrammes of clothing per day by composition.

Le Relais

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fabric structure (knit or woven) in 100 milliseconds, or approximately 1 tonne per hour. This is still deemed too slow and Valvan is working on speeding up the optical reading process. It is also developing a robot to replace the worker that deposits each item of clothing on the conveyor belt.

At the international Conference on Recycling of Textiles and Plastics, organised by Belgian textile research institute Centexbel in Bruges last November, Valvan project engineer Maurits Vandeputte declared that Fibersort's ability to sort knitted garments was now 96% accurate. But he also listed a number of remaining challenges. "Grey coloured clothing is difficult to read, wetness can interfere with the machine's ability to identify composition and elastane is transparent to NIR scanning. It can be 'seen' in a polyester fabric but not in cotton blends," he said.

Other used clothing collectors, such as Texaid in Switzerland, Le Relais in France and Soex in Germany have all joined research programmes to close the loop. Texcycle is a programme launched last year by Texaid, retailer Coop and the Lucerne University of Applied Sciences and Arts to find a solution for the items that cannot be resold as clothing, representing 45% of the 36,000 tonnes Texaid collects annually. Le Relais has several partnerships underway with French research centre CETI and sports retailer Decathlon, backed by funding from Eco-TLC, the French extended producer responsibility (EPR) eco-tax collector. Métisse, a thermal and acoustic insulation for buildings made from used jeans and cotton clothing, was developed by Le Relais in 2007. More recently, last June, Soex and I:Collect inaugurated a recycling facility that mechanically disassembles shoes.

Changing legislation

The European Commission's Circular Economy Action Plan supports many of these research programmes while also implementing regulations to push the industry into action. A revised legislative framework on waste was introduced in July 2018, setting new targets for the reduction of waste and the promotion of recycling schemes. Separate collection obligations have been strengthened and extended to hazardous household waste (by the end of 2022), bio-waste (by the end of 2023) and textiles (by the end of 2025).

One such programme, Retex, funded by the European Union, covers the Hauts-de-France region in the north of France and the Belgian regions of Flanders and Wallonia. It is an evolution of the Valley of Recycling, a circular economy project for textiles created in France and that now extends beyond its initial geographic perimeter. One of Retex's first goals is to identify and find uses for waste materials generated by textile manufacturers located in the three regions, project manager Jeanne Meillier tells *WSA*. This practical approach will help the organisation have a clear picture of what is available and increase the possibility of finding industrial uses for existing waste streams. In exchange for contributing to the project, companies will have access to a Life Cycle Assessment of the recycling process developed.



Belgian spinner and weaver Utexbel seeks to develop fabrics recycled from used garments and is a member of the EU-funded programme Retex. Initial near-industrial scale tests have shown positive results, according to the company.

Utexbel

Belgian spinner and weaver Utexbel is a part of the Retex programme as the family-owned company based in Ronse-Renaix seeks to expand its offering of recycled materials. In partnership with Belgian textile research centre Centexbel and French recycling machine maker Laroche, it recently recycled several hundred kilogrammes of used polycotton hospital worker uniforms. "These clothes would ordinarily have been downcycled into low value products," says Utexbel's sustainability manager Jean-Luc Derycke.

After processing on Laroche equipment, the resulting material was spun into yarn and woven into fabric, ready for re use in the apparel industry. But, the original 65% polyester/35% cotton fabric clothes produced a recycled yarn composed of 90% polyester and only 10% cotton. "The synthetic fibre appears to resist mechanical recycling processes better than cotton," says Mr Derycke. Utexbel also added a measure of its own industrial waste fibres to the mix to offset the dryness of the used clothing fibres that make them prone to static electricity. These first, near industrial scale tests will be followed by others that the company plans to present at the Techtextil exhibition in Frankfurt later this year.

The Hong Kong Research Institute of Textiles and Apparel (HKRITA) has also made progress on mechanical textile-to-textile recycling, just one of three different circular economy projects

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A garment-to-garment recycling micro-factory has been installed in a former textile mill that has been converted into a shopping mall and maker space in Hong Kong, a collaboration between HKRITA, the H&M Foundation and Novetex Textiles Limited. Housed in a glass-walled shipping container, it allows consumers to bring in their used items of knit clothing and see in real time how they can be turned into new ones.
HKRITA

it is working on (along with a chemical and a biological technology). The system has been in operation since last September at a new spinning mill opened in the city in collaboration with Novetex Textiles. Three production lines are up and running, each producing 1 tonne of yarn a day for a total of 3 tonnes daily. "Current output is being sold at 70% of the cost of virgin material and, though cheaper, these yarns have performance characteristics similar to that of virgin yarns," HKRITA CEO Edwin Keh told *WSA*. After an ozone-based sanitisation process, the used garments are sorted by colour (optical reading) and by composition by six trained workers. Mr Keh believes trained workers are faster and more precise than machines. "They generate fewer false positives," he says.

A polyester chemical recycling plant may see the light of day in France in 2021, the result of a partnership between research cluster Techtera and Japanese company Jeplan, whose method depolymerises textile polyester into BHET (the monomer), removes impurities and re-polymerises it anew to obtain a polyester resin. Jeplan says its major breakthrough is the purification process, though blended materials, buttons and zippers need to be removed from clothing before recycling. To launch the programme, Techtera has teamed up with French eco-responsible outdoor clothing brand Picture Organic Clothing to launch a garment-collecting campaign.

Hydrothermal processes

The companies that are working on mechanical recycling processes have often chosen to do so to avoid additional chemical use. But mechanical methods cannot separate the blended textiles that make up a large portion of everyday clothing. HKRITA switched from a chemical to a hydrothermal recycling method to avoid "creating a new waste stream," says Mr Keh. As its name implies, this method uses a mix of water, heat and pressure to separate cotton from polyester. The polyester comes out as a staple fibre that can be twisted back into yarn while the cotton comes out in the form of a powder. Mr Keh sees it as "an interesting cellulose material" that could be used as a moisture management coating for textiles or in agriculture. The technology developed by HKRITA is currently at pre-industrial scale, with two 500 litre vats recycling 100 kilogrammes of used clothing per day at the Novetex factory in Tai Po.

US-based Tyton Biosciences is also working on a hydrothermal recycling process for used garments. In development for the past 14 months, and building on previous research into the extraction of high value molecules from biomass, its technology can separate polyester from cellulose using water (and a catalyst). "The polyester is broken down into PTA and glycol in a single step and the cotton reduced to cellulose pulp," says company president and co-founder Peter Majeranowski, adding that "80 to 90% of the original material is recovered." Currently in operation at lab-scale, Tyton Biosciences is now reaching out to universities and research institutes to see how the output substances can be used to make new textiles. It expects to validate the process on an industrial scale in the next 12 to 18 months, and will then start to develop partnerships and joint ventures or license the technology to others.

Mixed streams

Cotton and polyester blends are the focus of many chemical recycling programmes in development, including Evrnu in the United States, Worn Again in the UK, and Far Eastern New Century (FENC) in Taiwan. "Our TopGreen rTex chemical recycling process breaks polyester

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Installed in Tai Po, the pre-industrial hydrothermal recycling system in development at HKRITA currently operates at a scale of 500 litres per vat. It separates and recycles cotton and polyester blends using heat, water and less than 5% biodegradable green chemicals.

HKRITA

down to its original building blocks, PTA and glycol, which are turned into PET chips, ready for repolymerisation in an infinite closed loop cycle," says FENC research and development manager Jeffrey Hsu. The cotton portion is compacted into fuel rods for incineration. The company plans to scale up its pilot plant to treat 400 tonnes per month by 2020/2021.

The "dual polymer recycling technology" in development at Worn Again Technologies is also designed to separate, decontaminate and extract polyester polymers and cellulose from non-reusable textiles, plastic bottles and packaging, the company claims. It recently raised £5 million and expects to launch a demonstration plant in 2021. Its partners include chemical engineering company Sulzer Chemtech, Mexican garment manufacturer Himes Corporation, textile maker Directex and fashion retailer H&M.

Resyntex is an even more ambitious programme that seeks to transform non-wearable textile waste into fibres and chemicals. The multi-partner biotech effort uses enzymes and chemistry to break down textile waste. A pilot plant opened at the beginning of the year in Maribor, Slovenia and is said to be able to process 100 tonnes annually. Speaking at the Centexbel conference on textile recycling, Resyntex co-coordinator and technical manager Professor Aleksandra Lobnik stressed the importance of sorting and decolourising textiles to obtain high added value chemicals and secondary raw materials. Resyntex partner Soex is said to be working on an automated optical-reading separation technology to improve the quality of the input material.

Regenerating cellulose

Other research programmes and recycling schemes are working on processes that dissolve used cotton clothing into cellulose that can be turned into a lyocell-like fibre. With Refibra, Austrian man-made cellulosic fibre producer Lenzing offers a lyocell yarn made from pre-consumer cotton scraps. Others, such as Saxion (Saxcell) in the Netherlands, Re:newcell in Sweden and Ioncell in Finland are working on similar processes for post-consumer textiles. "When recycling pure cotton waste, the lyocell production method yields longer fibres that have a higher market value and is thus superior to mechanical recycling," Saxion engineer Dr Jens Oelerich declared at the Centexbel conference. The high cellulose content of cotton-based textiles gives the resulting lyocell fibre a higher tenacity, but the technology in development for the past six years at Saxion University needs 147 kilogrammes of used clothes or raw materials to make 100 kilogrammes of lyocell, generating nearly 30% waste.

"Fibre to fibre recycling: An economic & financial sustainability assessment," a report released by the UK-based Waste and Resource Action Plan (WRAP) in January this year, presents possible business models based on current projects and market conditions. It focuses specifically on post-consumer textile waste and even presents detailed financial models, which will help stakeholders have a clearer view of the market for closed loop clothing recycling in the UK. Fibre-to-fibre recycling "is a challenge for science and for business, and has to be made cheaper. It is also a logistics problem," says Edwin Keh. Since China banned the import of textile waste, the rising stocks of unwanted clothing need to be treated in the countries where they are generated. It makes no sense, as Mr Keh points out "to move bundles of used clothes around the world". As seen in the number of projects underway around the globe, multiple solutions to this problem may soon be in operation.

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