HSLU Lucerne University of Applied Sciences and Arts

Design Film Art
Research Group Product & Textile

Towards a circular treatment of textile waste

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Research Group Product & Textile

The **Product and Textile research group of the Lucerne School of Design, Film and Art** conducts applied research in the field of textile sustainability. Its research is based on the scientific concept of the circular economy, and it is committed to a systemic and circular approach. The research group is interdisciplinary in its methods and composition and its competencies range from textile and product design to historical research and environmental sciences. Its activities encompass collaborating with practice partners in applied research projects as well as providing advice and guidance to public institutions. Communicating its findings, building networks, and making a valuable contribution to attaining the SDGs are the main objectives of the group's research activities.

Commissioning organisations

The **Office for Waste Management and Recycling of the City of Zurich (ERZ)** is the municipal competence centre of circular economy for the prevention, treatment and recycling of waste and wastewater.

The **Office for Waste, Water, Energy and Air (AWEL)** is committed to a healthy, safe and attractive environment in the Canton of Zurich.

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The problem with textile waste

According to the Federal Office for the Environment FOEN, professional textile collection and recycling organisations collected a combined 59,300 tonnes of used clothes, home textiles and footwear in Switzerland in 2022 (cf. Federal Office for the Environment FOEN, 2023a, p. 1). Textile waste industry leaders report that between 58 % and 64 % of the items collected are declared usable abroad *(reuse abroad)*. While some of the usable clothes are sold in Europe, others are exported to Asia and Africa. Bales of unsorted textile waste are sold to sorting plants in Italy, Belgium and Eastern Europe. 26 to 34 % are recycled and sold as insulation materials, added to other materials or made into cleaning rags. 8 to 10 % are processed in waste-to-energy plants (i.e. incinerated) (Texaid, 2024, p. 25–26; Tell-Tex AG, 2022, p. 6). 36 % of the textile waste produced in Switzerland is not collected separately but discarded as household waste (Federal Office for the Environment FOEN, 2023b, p. 54).

Contemporary marketing of used textiles is rife with social divides and power imbalances between the exporting Global North and the importing Global South. The textile waste collected in Western Europe only contains about 5 % high-quality items, which predominantly remain in the Western European markets (Trzepacz et al., 2023, p. 4). According to Quantis, this share is 39 % in Switzerland, though interviews conducted in the framework of their study suggest that the quality of the textiles collected is in steady decline (Faist et al. 2024, p. 8). Mid-range and poor quality textile waste collected is typically sold to Eastern Europe and the Middle East from where it makes its way to the Global South and processed as part of the global waste flow, causing both social and ecological harm (Trzepacz et al., 2023, p. 4). Due to the enormous volumes of textile waste imported and the lack of professional waste management infrastructure, these waste products end up on illegal landfill sites, get thrown into rivers or the sea, or burned openly (Cobbing et al., 2022, p. 11). Moreover, the “Sorting for Circularity Europe” study predicts that the share of poor-quality textiles will continue to grow in future, thus further aggravating the challenges around textile waste in the EU (cf. Van Duijn et al., 2022).

Switzerland must assume responsibility for the social and environmental impact of unregulated dumping and incineration of textile waste in the Global South. Eager to use textile waste as a valuable local resource In the future, the City of Zurich (Office for Waste Management and Recycling ERZ) and the Canton of Zurich (Office for Waste, Water, Energy and Air AWEL) have commissioned a study to analyse the framework conditions for, and conception of, circular waste collection, sorting and utilisation processes from the HSLU’s Product and Textile research group. In addition to enabling *slow growth* and *aggressive material substitution*, the systemic rethinking of circular processes creates great potential for a textile industry striving to become more sustainable. This report showcases potential, identifies possible areas of intervention and describes a cascading approach to using and recycling waste with a view to replacing linear recycling systems with circular ones.

Cascading utilisation and treatment of waste

The objective of cascading utilisation and recycling according to Reike et al. (2018, p. 255–257) is to replace linear recycling systems with circular frameworks. The circular economy is described as a function of ten value retention options (R-strategies) in three utilisation cascades: smarter product use and manufacture, extend life span of product and its parts, and useful application of materials.

The **shortest cycles** (consumer choices – product remains with user and retains function) includes:

R0 Refuse
Avoiding certain products or components e.g., types of packaging, to minimise waste.

R1 Reduce
Consuming less to reduce waste, handling products with care to extend their lifespan; manufacturers adjusting product specifications to reduce material use.

R2 Resell/Reuse
Resell/Reuse: Keeping products that retain their original use and appearance in a cycle between consumers, textile collectors, traders and producers.

R3 Repair
Repairing products to extend their lifespan.

The **medium cycles** (product upgrade – enhancing the product with the producer's involvement) include:

R4 Refurbish
Components are repaired, replaced or added to enhance the product.

R5 Remanufacture
Remanufacture: Product is disassembled, assessed, cleaned and repaired in an industrial process and/or parts of it are replaced with new or recycled components.

R6 Re-purpose
Waste products or parts thereof are repurposed as new products.

The **long cycles** (Downcycling – product loses its original function) include:

R7 Recycle
Further processing of post-consumer products or waste materials through elaborate technical processes (considered the most widely used R-strategy).

R8 Recover
Energy recovery through incineration of varied types of waste or utilisation of biomass materials.

R9 Re-mine
Recovering various types of material and valuable resources by mining old landfill sites or, more generally, from resource processing structures such as wastewater treatment plants.

Untapped potential

Textile waste as a resource is an area of significant ecological potential. Extending the use of products decreases the need for new products and primary raw materials alike. Global fibre production for the textile industry has been growing significantly, from 8.3 kg per capita in 1975 to 15.5 kg in 2023 (Textile-Exchange, 2024, p. 8). Key elements of textile reuse are the sorting and treatment processes (e.g., sorting for specific reuses, removal of foreign objects, etc.) and novel mechanical and chemical Recycling (R8) processes, some of which are currently in development. Treatment processes are particularly significant in fibre-to-fibre recycling, where material purity is essential to ensure high-quality products. However, the material complexity of waste textiles as a resource can be considerable: yarns and fabrics often contain mixed fibres, some garments have labels, sewing threads and other non-textile components such as buttons and zips, and certain fabrics have a chemical finish or coating. Designing products with future recycling processes in mind can be an important step towards making them more sustainable.

In a recent study, Wiprächtiger et al. (2022, p. 8) conducted a comprehensive investigation into waste avoidance measures in Switzerland. Interestingly, the study concludes that the R-strategy of *Repair* (R3) has a greater positive impact on the environment than *Reuse* (R2), *Refurbish* (R4) and *Remanufacture* (R5): repairing products is an alternative to purchasing new items rather than just a complementary measure (rebound effect). The fast fashion industry is launching new trends in ever shorter intervals, leading to increased production and an industry-wide planned overproduction rate of 20 % (cf. Press, Claire, 2021). Unfettered consumption is harmful for the environment. In their study, Wiprächtiger et al. (2022) identify great potential in awareness campaigns designed to steer consumers towards reducing their carbon footprint by buying only half, but high-quality clothing rather than twice the amount in fast-fashion items. What is more, by reintroducing textiles into the production cycle, consumers assume a new role as materials suppliers. The goal is to make the roughly 36 % of used textiles that currently end up as household waste (Office for the Environment FOEN, 2023b, p. 54) available as a resource.

Technological innovation is key for the digitalisation and automation of sorting plants and the development of new fibre-to-fibre recycling processes. Hedrich et al. (2022, p. 16) argue that, deployed at scale, fibre-to-fibre *(closed-loop)* textile recycling technologies have the potential to address two of the textile industry's main challenges: they could reduce emissions by replacing raw with recycled materials while simultaneously reducing the amount of waste resulting from the consumption of textile products. In the textile sector, only an estimated 1 % of fabrics can be recycled at the same quality (Textile Exchange, 2024, p. 11). In the textile waste industry, sorting is still largely done by hand, and an exhaustive categorisation of the discarded items by type, condition and fashion value impossible to achieve. Pehrsson et al. (2023) point out that future generations of automated and AI-controlled sorting technologies as well as the mechanical and chemical recycling processes currently in development will boost the R-strategies 2–5 (Reduce, Reuse, Repair, Refurbish). They will facilitate a more efficient approach to dealing with growing volumes of textile waste and a more targeted introduction of materials into the medium and long cycles.

Recycling technologies

(cf. Hedrich et al., 2022, p. 21)

In the **mechanical recycling process**, cotton, wool, polyacrylic etc. fabrics are cut and shredded to recover fibres. Processing in conventional shredding mills produces considerably shorter and therefore lower-quality fibres. This loss in quality can be addressed by adding fresh fibres to the mix.

Less damaging shredding methods to maximise fibre length are currently being developed, as are a number of new **chemical recycling technologies**. Thermoplastic textiles such as polyester are shredded and dissolved into polymers and monomers through a chemical process, allowing for new fibres to be spun of a quality that almost matches that of fresh fibres.

In the case of thermosetting plastics such as cellulose-based fibres, chemical bonding methods are used to dissolve them and create new, viscose-like fibres. Many of the chemical recycling methods on the market are used for fabrics made of cotton, polyester and blends of the two where a high degree of purity is required due to narrow specifications.

Policy and research

The European Commission's *Circular Economy Action Plan* (2020), itself a building block of the European Green Deal, sets out concrete regulatory measures to promote circular economy practices across Europe.

Waste regulation
In future waste management processes, used textiles must be processed at the highest possible level of the recycling hierarchy, with the smallest possible decrease in value according to their value and suitability. To this end, used textiles must be collected separately and recycled in cascades organised along the waste hierarchy (cf. European Commission, 2023a, p. 6). In addition, the revised Waste Shipment Regulation[1] aims to stop the illegal shipment of textile waste to non-EU countries and to strengthen circular economy practices within the EU, especially in the field of textile recycling (R7–R9). At the same time, the Extended Producer Responsibility (EPR)[2] legislation will introduce an advance recycling fee for manufacturers and brands. This would be one pillar of the financial framework to fund textile recycling in Europe.

Product design
The objective of the Ecodesign for Sustainable Products Regulation (ESPR)[3] is to ensure that products are high-quality, functional, safe and affordable. These requirements will be documented in a compulsory Digital Product Passport[4]. In addition, products must be durable and suitable for reuse, repair and high-quality recycling. This will be regulated in the EU Directive on Common Rules Promoting the Repair Of Goods[5] which aims to promote affordable repair options and the repair industry overall. A ban on the destruction of unsold durable goods[6] is also scheduled to come into force.

These regulations will likely cause higher volumes of low-quality textile waste to flow into all use cycles until the ESPR has achieved its desired long-term effect of steering the flow of high-quality used textiles towards the appropriate levels within the recycling hierarchy. The Waste Shipment Regulation will cause a steady materials flow to be processed by the recycling sector in Europe. Its quality is expected to be diminished for an initial period, but high-quality in the long term (through the purposeful design of textiles as mandated in the ESPR).

1 The WSR (Waste Shipment Regulation) is scheduled to **come into force between 2026 and 2027**, after the EU Commission has passed secondary legislation.
2 According to the Commission's current schedule, the revised EPR (Extended Producer Responsibility) rules **will not come into force before 2027**.
3 The development of the requirements for textiles will likely conclude **in September 2025**.
4 The first Digital Product Passes for textiles should be **available in 2027/28**.
5 Right-to-repair legislation was passed by the European Commission in March 2024 and scheduled to be implemented between **late 2026 and early 2027**.
6 In their first report following the ban on the destruction of unsold goods (likely **in 2026, based on the 2025 figures**), large corporations will be required to list all products disposed of in the first full business year since the introduction of the ESPR. The ban on the destruction of unsold textiles and footwear is also expected to come into force that year.

Source timeline: Ohana (2024)

Responsible for 10 % of the global carbon footprint (European Parliament, 2024), the textile industry plays an important role in attaining the UN's sustainability goals. The recycling of textile waste is a globally recognised and widely pursued area of research within this industry. The three research projects described below are part of a growing body of research in the field.

The **Rewear Project** (Fashion for Good, 2024) builds on the **Sorting for Circularity Europe** framework and investigates the potential of automated sorting for the R-strategy Reuse. The goal is to roll out automated and AI-supported sorting technologies such as near-infrared spectroscopy (NIRS) to assess the composition and quality of the fibres and, in future applications, to sort the textiles by resale value and demand on the relevant used textiles markets.

Zero Waste Europe is a trans- and interdisciplinary network dedicated to the topic of waste. The network's report *How to collect, sort, and reuse textile waste locally?* provides an overview of proven processes and experiences with textile waste in Europe. Its findings are supported by case studies from Finland, Spain and Belgium (Mörsen, 2023). The chapter *Recommendations for Municipalities* gives communities easy access to the topic and provides a list of activities and ready-to-use best practices (Mörsen, 2023, p. 4).

The HSLU's transdisciplinary Innosuisse-funded project **Texcircle** shows that compared with conventional semi-finished products (Garne/Vliese), the carbon footprint of design-driven materials and process interventions in the field of textile recycling and secondary raw materials with a recycling rate of 50–85 % can be reduced by up to two thirds (cf. Tomovic et al., 2022).

Area of intervention: use cascades

Potential areas of intervention can be identified based on the untapped potential within the sector, the EU's new political framework conditions and existing research into the topic. The different areas of intervention are organised along the different levels that constitute the use cascades and designed to show a path towards circular, local value creation through textile waste recycling. The infographic represents material flows along use cascades. The material flows' proportions roughly represent the amounts of materials collected in Switzerland as well as the changes that can be achieved through increased circularity (hatched sections).

There are certain gaps in the data collected on three areas in particular: composition of collected textiles, reuse and recycling rates, and intended destination (Faist et al., 2024, p. 22). In the future, systematic data gathering along the material flows may facilitate decisions that accelerate the economy's transformation towards successful circularity (cf. Van Duijn et al., 2022).

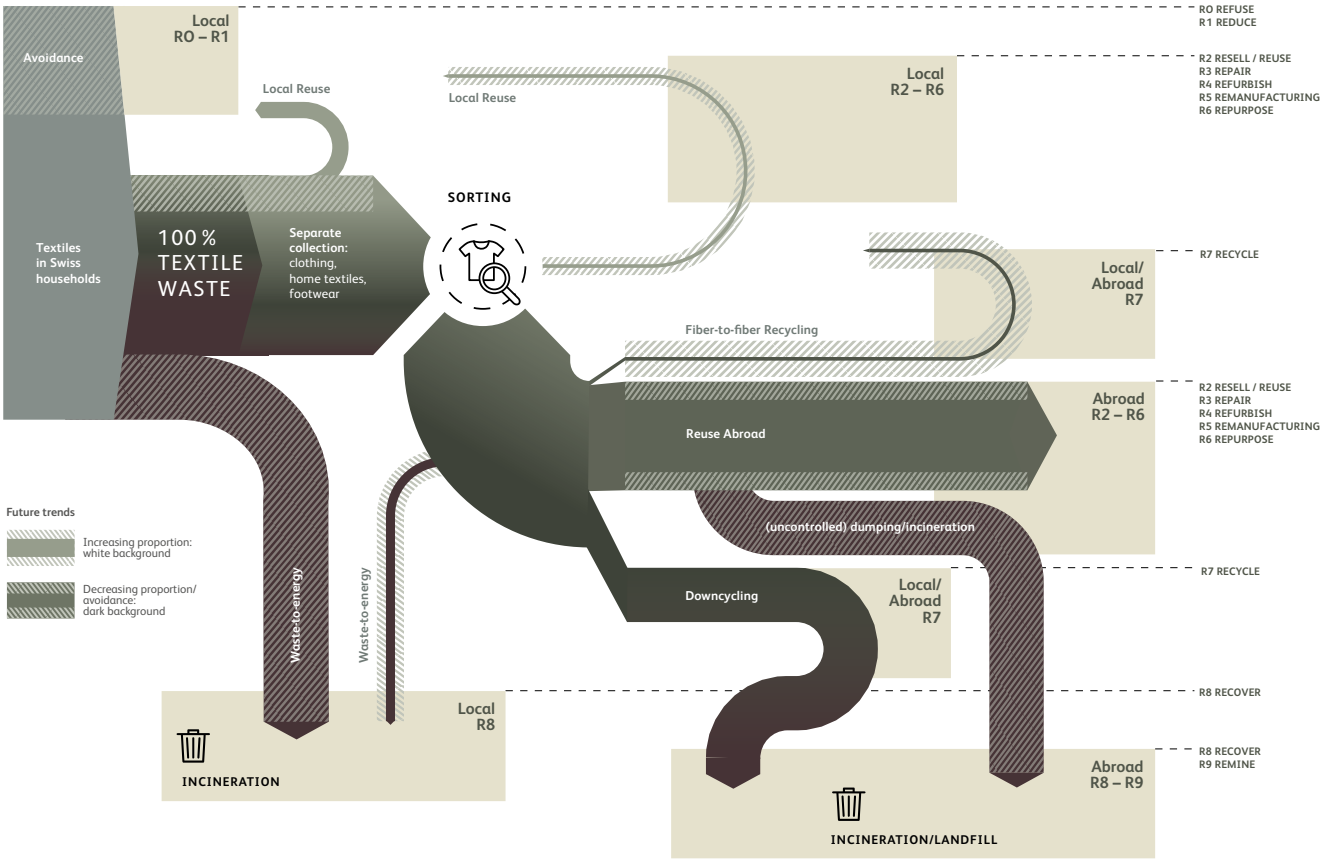


Figure 1: Use cascades of a local, circular value chain for textile waste. The dimensions of the material flows reflect the proportions of the actual volumes collected in Switzerland (solid arrows). The expected changes achieved through the areas of intervention below (hatched sections) represent an estimate of the Product and Textile research group.

Promoting short cycles

Reducing textile consumption (R0, R1), purchasing high-quality textiles and extending the lifespan of textiles through *Repair* (R3), care or clothes *Sharing* are areas of intervention associated with the short cascades with direct relevance to the consumer (cf. Wiprächtiger et al., 2022, p. 1395). In 2024, HSLU researchers conducted focus groups with stakeholders from the textile waste sector—they emphasise that a change in attitude towards waste is essential to be able to deal with the ever-growing amounts of waste produced.

Strengthening local reuse

The aim is to strengthen the local *Reuse* sector (R2) as a key player among processors of collected textile waste. Van Duijn et al. (2022) report that, on average, the share of local reuse is 10 % in Europe. It seems expedient for Switzerland to set this as a minimum target for its own local reuse[7]. In a series of interviews with stakeholders from the textile waste industry, researchers at the HSLU learned that more in-depth research is necessary to identify the *Reuse* sector's market requirements, namely their sorting criteria. According to the vision set out in the EU Strategy for Sustainable and Circular Textiles, business models such as *Repair* and *Share* services are on the rise (cf. European Commission, 2022). The *Refurbish* (R4), *Remanufacture* (R5) and *Repurpose* (R6) strategies must be incorporated in these business models and applied by the actors in the local *Reuse* market. Expert interviews suggest that to successfully pursue these models, sorting criteria for tolerable forms and degrees of textile damage must be defined with current and future actors in the field.

Boosting fibre-to-fibre recycling

Contingent on the industrial roll-out of fibre-to-fibre *Recycling* processes (R7), this material flow is set to become an integral part of the value chain and deliver high-quality secondary raw materials. This will also decrease instances of downcycling. The figures published by Van Duijn et al. (2022) and Hedrich et al. (2022) suggest that the share of *F2F Recycling* can be increased from 1 % to 18 % or more per year by 2030.

Reducing and regulating reuse abroad

The practice of supplying used textiles to the international second-hand market can continue if clear guidelines are put in place. However, the decision on whether to export must be based on the market requirements of local actors pursuing the *Reuse* strategy (R2) and on whether *F2F Recycling* (R7) is an option for the textiles collected. The relevant guidelines must be developed with due diligence and export licences should only be issued to address a proven market need in the importing country[8]. Over a transitional period, local waste-to-energy treatment (incineration) (R8) of certain product categories should remain an alternative where processing them in higher cascades is no longer possible. This measure will minimise the risk of uncontrolled incineration and dumping as landfill abroad.

7 Expert interviews suggest that a small number of big actors in the second-hand market are already processing a volume of around 10 % of the used textiles collected in the city of Zurich. This makes 10 % look like a realistic target.

8 According to Cobbing et al. (2022) there are currently no figures available on the share of textiles exported to the Global South that are no longer usable. However, according to estimates, some 40 % of the used textiles arriving at Kamanto Market in Ghana are directly disposed of for their poor quality or lack of market need.

Recommendations for circular textile waste management

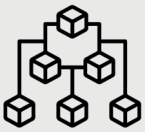
The overarching goal of the recommendations is to promote the local entrenchment of a circular textile waste recycling practice along the 10R hierarchy. Textile waste should be reused at the highest possible level within the hierarchy, with minimal loss of value. Local reuse models and future fibre-to-fibre recycling practices are key to producing high-quality secondary raw materials. Based on these considerations and on the study results submitted to the City of Zurich and the Canton of Zurich, the researchers at HSLU recommend the following:

Ensure the system's compatibility with new technologies and actors

The circular textile waste strategy is creating opportunities for new actors including sorting firms and technology providers. It is essential to secure the necessary volumes of material at the required quality to process: without it, it will be impossible to implement a value-adding business model (cf. Pal et al., 2018). In the future, automated technologies will improve the sorting process, especially in high-quality reuse and recycling contexts. This increases material efficiency and reduces costs.

Introduce data gathering and establish transparent structures

Method-based data gathering about the used textiles collected allows for transparent decision-making and the establishment of transparent structures. The textile waste's volume, composition, condition, product typologies and other features should be continually monitored and visualised.[9]



Build new structures and material flows along different use cascades

Sorted by specifically developed criteria, textile waste is directed to the matching material flows along the hierarchy of use cascades. The criteria should be developed in collaboration with actors in the textile recycling industry. Benchmarks are set for the different material flows and revised periodically. The infographic in the previous chapter can be used as a guideline.

9 Eine Harmonisierung mit der EU Waste Framework Directive ist sinnvoll. Diese verlangt ein jährliches Reporting bezüglich des Volumens mit unterschiedlichen Spezifikationen, einer Begründung der Entsorgung, Informationen zur Art der Wiederverwendung resp. Entsorgung sowie eine Beschreibung ergriffener Massnahmen zur Verhinderung der Zerstörung nicht verkaufter Ware (Ohana Public Affairs, 2023).

Promote collaboration across networks within the system

Separate entities acting in isolation are linked to form networks of actors that are allocated to the different use cascades. This collaboration allows the participants in the value chain to create, and benefit from, synergies that can help to reach the targets set by the community.

Create the conditions for a value-adding system

It is imperative that funding is secured for a value-adding textile waste system. The merits of introducing an advance recycling fee in Switzerland[10] must be evaluated. Introducing a taxed textile waste bag is an alternative approach. It is advisable to consider pilot projects with government funding to investigate the design and application of novel textile waste recycling strategies.

Encourage citizen participation in the new system

Public awareness campaigns can help to increase the volume and quality of the used textiles collected. Sorting-at-source strategies can help to steer the goods towards the suitable use cascades in a more targeted fashion. However, it must be evaluated whether this is useful to streamline the subsequent sorting processes. People are already selling their used textiles to local markets today; it is important to use awareness campaigns to support and strengthen existing C2C and C2B channels and, with them, local and circular businesses.

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10 entspricht der eco-modulated Extended Producer Responsibility der EU (Ohana Public Affairs, 2023)

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