TEXTILES CIRCULARITY

UKRI Interdisciplinary
Textiles Circularity Centre

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Establishing a Culture of Circular Economy in Society

The Textiles Circularity Centre's research has revealed that for people to adopt sustainability practices, the means to enact them must be embedded into our culture. Our research has therefore focused on designing the means for people, be they consumers, businesses, NGOs, local governments, to practice circular economy in place-based settings, such as on the high street. To this end, we have focused on SMEs and start-ups in fashion-apparel brands and designers, manufacturing, materials, repair/upcycle, waste collection, as well as local government and NGOs, as they are already active in local settings.

Our aim was to demonstrate a transformation pathway to establish a culture of circular economy for the UK apparel-textiles industry by adding environmental, economic, social, and technical value to biowaste as it flows from recycling of waste, production of textiles, to consumption and reuse of apparel.

Our approach was vision-directed, design-led, and highly interdisciplinary. We employed visioning to reframe fashion-apparel from the current global linear system of production and fast consumption, to a culture centred on care, prolonged use, community wellbeing and locality.

The book starts with the *story of the now*, which illustrates the volume of clothing that flows through the UK economy.

We then present the main outcomes of our research.

We start with visioning a future UK circular clothing economy. Based on the material flow analysis of UK clothing in the story of the now, we modelled scenarios exploring more sustainable clothing economies. Our work has focused on supporting the ambitions of the high reuse and less consumption scenario by innovating high value circular bio-based textiles that have reduced environmental impacts, and positioning these materials in circular experiences that slow down consumption by satiating human wellbeing needs, which are put into a relationship by the design of a supply chain that brings together these strategies in a localised way through collective behaviours.

We continue with the means developed by our three strands of research through which stakeholders can promote a culture of circular economy in society.

The Materials Circularity research strand developed a 'Materials Library' based on an innovative bio-based process that converts organic waste into circular and recyclable fibres and filaments, and advanced textile fabrication technologies to produce a 'Maintaining Materials Toolkit', and a 'Circular Materials Design Toolkit' for apparel brands to develop their circular design strategies and process flows, whilst enabling them to creatively differentiate themselves, thereby promoting cooperative design of circular materials.

The Consumer Experience research strand developed a 'Wellbeing Framework for Circular Consumer Experiences' to understand the factors that constitute human wellbeing and apply this strategically in consumer experiences for apparel. It provides brands with a platform for the design and evaluation of circular experiences that support consumers to keep apparel in use for longer and consume fewer new items whilst providing long-term wellbeing.

The Supply Chain research strand developed a 'Circular Systems Design Toolkit' to design a 'Social Production Network', a collaborative distributed place-based circular supply chain system of diverse interdependent actors whose collective behaviours emerge into a circular economy fostering cultures of cooperation and community in supply chains. It provides a way to understand how cultural production, rooted in circular practices, can harness the links between sustainability and community wellbeing.

We then present our approach to design-led interdisciplinary research to translate and guide our vision into action.

This is followed by how we immersed stakeholders in our vision to motivate action, for which we developed a stakeholder-engagement platform – the Regenerative Fashion Hub.

At the end of the book we present our research insights on the behavioural actions needed to establish a culture of circular economy in society to promote high reseuse & less consumption, the value and the flows of value that our solutions add to biowaste, and the related environmental impacts. We also indicate what the requirements for change in terms of technology, policy, economy, data and society would be for our circular solutions to be adopted.

The book concludes with our Design Manifesto for a circular economy.

This book marks the end of the Textiles Circularity Centre's journey, and we hope that our research inspires others to address the core challenge of effecting a cultural transformation to grow the reuse sector in order to reduce the environmental impacts of apparel.

The Story of the Now

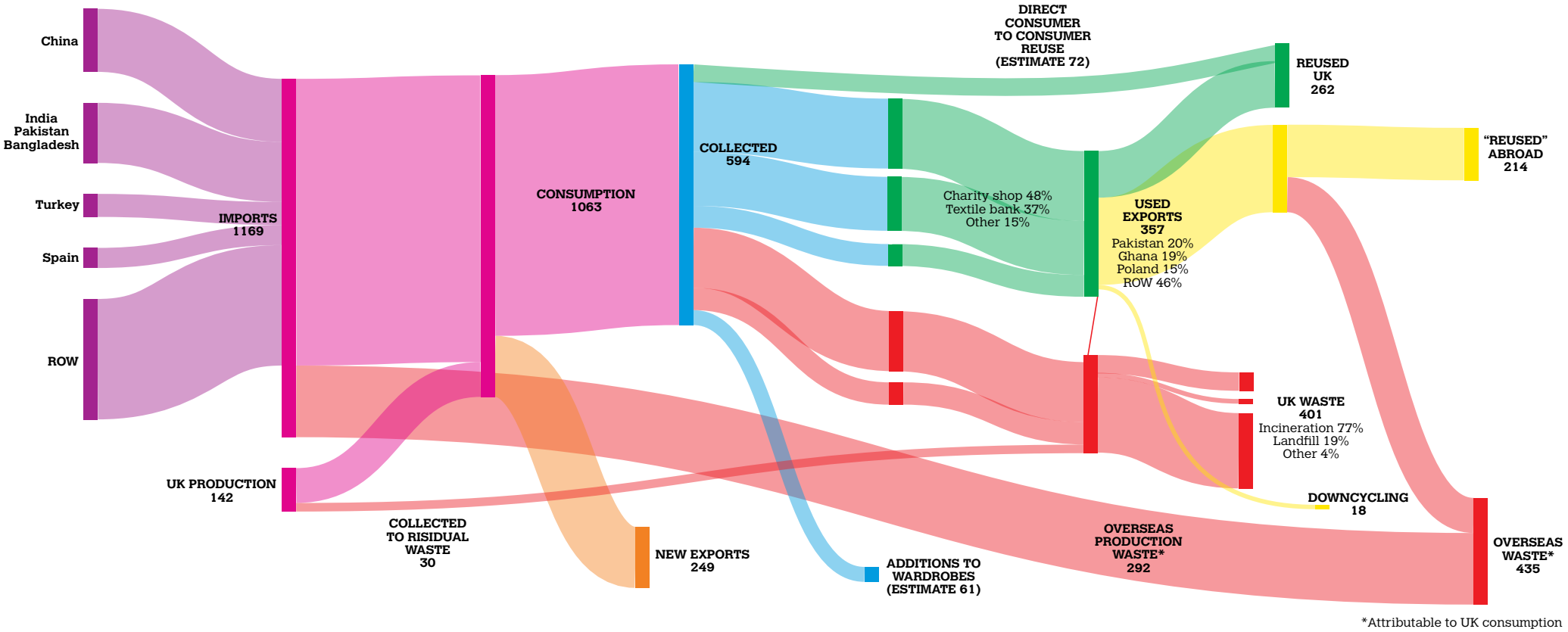
The journeys that clothing takes as they flow through the UK economy

In the Middle Ages, a shirt cost a week's wages. Until the 1960s, clothes were too valuable to discard unless they were beyond repair. Now, an hour's work buys a 'fast fashion' item that is often discarded after a few wears. We buy clothes at an ever-increasing rate – 25 kg each per year – and have hundreds of items in our wardrobes. The industrialisation of clothing production, fuelled by low wages and poor working conditions in the global South, comes at a price. The resources consumed have doubled during the 21st Century and could double again in a decade. Clothing is responsible for 5-10% of global carbon emissions and millions of tonnes of waste. It deprives the thirsty of water and diverts land from growing food.

Our Material Flow Analysis illustrates the flows through the UK clothing economy[1].

We import 1169 kt (1,169,000 tonnes), produce 142 kt and export 249 kt of clothing each year, which means we consume just over 1 million tonnes. The nation's wardrobe grows by 60 kt per year. About 600 kt of discarded clothing is collected, of which 360 kt is exported and 190 kt is reused in the UK. 70 kt is reused directly (via e.g. resale platforms such as Vinted, or hand-me-downs). Less than 1% is recycled. 400 kt becomes waste (including the waste from UK production), most of which is incinerated. 300 kt of waste is produced abroad from producing UK-bound clothing, and of 140 kt of the used clothing exported is rejected. Total waste is over 800 kt per year[1,2].

We can estimate the annual carbon emissions associated with these flows. The answer depends heavily on how the analysis is done and the data used for the impact of different fibres. It could be anywhere between 21 and 46 Mt of CO2 (plus about 6 Mt for washing and drying) or 2.5 - 5.2% of the UK's total carbon footprint – comparable to UK household transport emissions. This uncertainty means that green strategies based on substituting one fibre with another might have no effect, or make things worse. The only sure way to reduce emissions is to produce less fibre and reduce demand by keeping clothes in use for as long as possible[3,4]. Increasing the value of used clothes through better durability, upcycling and reuse infrastructure will be essential for sustainable business models.



*Attributable to UK consumption

Material Flow Analysis of current UK clothing economy

The Textiles Circularity Centre

Design-led interdisciplinarity research to transform relationships between science and society

The Textiles Circularity Centre was a UK Research and Innovation funded research programme that aimed to enable the transition to a circular textiles economy through an interdisciplinary approach to research. Building a circular economy requires a whole-systems approach, and so the Textiles Circularity Centre combined three distinct strands of research, Materials Circularity, Consumer Experience and Circular Supply Chain, to envision a circular future for the fashion industry, based on producing high value textiles from biowaste.

Led by the Royal College of Art, the consortium included the universities of Cambridge, Cranfield, Leeds, Manchester, UCL and York, spanning expertise in human-centred design, materials biology, materials design and science, social science, cognitive neuroscience, computer science, sensory interaction design, and advanced manufacture.

Our objectives were to:

- Demonstrate transformation pathways towards a circular model for the UK apparel industry
- Develop circular strategies combining advanced fabrication technologies for bio- based textiles that support designers and consumers to extend the life of materials
- Create consumer experiences that satiate human wellbeing needs to enable brands and consumers to keep products in use
- Devise collaborative circular business models that circulate flows of value, information and materials in a distributed localised supply chain

The Textiles Circularity Centre Principles

Visioning a UK circular clothing economy: Scenarios for reducing the environmental impacts of apparel-textiles

The Textiles Circularity Centre developed scenarios[4] to explore how the UK clothing economy could achieve the necessary reductions in environmental impacts to bring humanity's impact back within planetary boundaries. These scenarios consider the impacts of production- and consumption-focused changes, modelled using material flow analysis to assess energy consumption, carbon emissions, water consumption, and land use.

These scenarios look at combinations of cleaner production of fibres, increasing recycling rates and reuse of clothes, and decreasing consumption. They make one thing very clear - to get anywhere near published ambitions for reducing the environmental impact of the clothing industry (e.g. the Textiles 2030 roadmap) or the country (e.g. the 2035 carbon budget) is to combine all these approaches, and quite aggressively.

This is not just a technical problem. New green textile mills, recycling processes or collection and sorting infrastructure will not solve this on their own. These welcome and necessary technical advances must be combined with new business models that help us retain the value of clothes through their physical lifetime, and changes in social attitudes that return us to being custodians of clothing, not consumers of fast fashion.

Our research aspired to make contributions to knowledge that would advance a scenario that is a combination of two interventions:

High reuse & less consumption, where reuse and repair of clothing is significantly increased and excessive consumption is discouraged, reducing effective consumption by 50%. We proposed materials fabrication strategies and consumer experience strategies combined with a new supply chain model – a social production network – to promote reuse and extend the life of materials and apparel and promote a reduction in consumption.

Cleaner production & high recycling, where reduction in the impacts associated with primary production (through efficiency gains or cleaner processing) is achieved alongside increased recycling, diverting material from waste, downcycling and exports, a path most textiles "roadmaps" focus on. The Textiles Circularity Centre has developed a proposal for new circular fibres produced from bio waste sources, including some waste textiles, that reduce land use to produce new fibres, like cotton and trees, and divert waste from landfill and incineration.

Glossary

Biomaterial: While there are many definitions of a biomaterial, we use the term to reference the biologically grown material, bacterial cellulose.

Cellulose: A biopolymer commonly found in plants. Paper and cotton and viscose fibres are made of cellulose fibres. When produced by bacteria, it is called bacterial cellulose.

Circular behaviour: An action (or a chain of actions) which promotes resource-efficiency. It can be reusing, repairing, refurbishing, remanufacturing, recycling and borrowing or leasing products.

Circular Consumer Behaviour: Underlying attitudes, motivations, and decision-making processes that lead consumers to adopt circular practices.

Circular Consumer Practices: Actions consumers take to engage with the circular economy, such as repairing products, buying second-hand, recycling, upcycling, and renting or sharing.

Circular materials: Materials derived from waste instead of virgin resources, such as trees or cotton. They are produced in a way that their life can be extended through reuse, repair, reinforcement and customisation before being recycled into high value textiles using the same biological recycling process.

Circular supply chain: A sequence of processes involved in the sourcing, producing and distributing of products in a circular economy system.

Co-design: Design process in which multiple stakeholders, including consumers and designers, work together to create products, services, and systems.

Collaborative circular business models: Networks of many organisations which achieve circular economy goals through working in cooperation.

Consumer experience: Interactions between consumers and products throughout their lifecycle.

Creative technologies: Tools and processes that combine art, design and technology to innovate forms of expression and interaction.

Cultural production: A concept in the sociology of art that refers to the potential of cultural objects to mediate and change culture across temporalities.

Customisation: Tailoring a product or experience to meet individuals' preferences, needs, and desires.

Distributed circular supply chain: A network of localised supply chains that exchange resources, information and value across regions in a way that is aligned with the circular economy.

Healthy Consumption Habits: Behaviours driven by mindful purchasing decisions that consider the human wellbeing, lifecycle of products, reduced material consumption, and engagement in practices such as reuse, repair, and recycling.

Holistic human-centred approach: Designing out problems to address a person's needs and wellbeing.

Hyper-local economy: The economy of a town centre within a locality that has multiple town centres. A level of specificity which compares to local, regional, national and international levels.

Human wellbeing: Holistic concept balancing hedonic (pleasure-oriented) and eudaimonic (purpose-driven) aspects of life. It is linked to how individuals engage with their environment, materials, and products, where meaningful effort and emotional attachment foster circular behaviours, satisfaction, and community connections.

Lifecycle of clothes: Stages that a garment goes through, from initial design and production to consumption and end-of-life.

Machine Learning: A technique that enables systems to automatically learn and improve from experience by identifying patterns and making predictions based on data.

Process flow: The mapping of the steps and stages of a product or material from start to end of life.

Product-service system: Products and services combined into a single offering to facilitate a resource-efficient use.

Socio-technical system: A system in which human and technical elements are interdependent.

System actor: A person or a thing that performs or takes part in an activity; an agent, a doer, a stakeholder; a human or non-human element.

Social production function: A framework for understanding how social systems can produce well-being through various means, including economic activities, social relationships, and cultural practices.

Solvent: A solution that can dissolve other substances, such as cellulose.

Upcycling: A process of repurposing or upgrading products to add value, such as a new shirt can be made from multiple old shirts.

Use phase: The stage during which a garment or material is worn.

Viscose and lyocell: Textile fibres typically made from tree pulp and solvents in a wet spinning fibre production process.

Materials Circularity

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Advanced technologies to extend the life of materials and improve access to circular economy practices through tools for businesses, designers, and consumers

Introduction to Materials Circularity

Advanced technologies to extend the life of materials and improve access to circular economy practices through tools for businesses, designers, and consumers

In the Materials Circularity research strand, circular design is embedded into advanced scientific and technical processes. Our research provides a holistic view on new practices that could keep textiles in use for longer.

Our research draws on circular design engineering to provide a systemic view of the entire lifecycle of materials. It weaves together processes including fibre regeneration, biotechnology to transform bio-waste into circular materials, and robotics and advanced manufacturing, particularly nonwovens and 3D printing. These are combined with lifecycle analysis to evaluate the sustainability of our processes.

This research strand sought to address two main challenges. The first was to nourish the resilience of the planet by designing and creating circular bio-based textiles from waste, thus reducing environmental impacts. The second was to maintain materials within reuse contexts, as well as support businesses, designers, and consumers to do so.

We addressed these challenges in a variety of ways, such as recycling biowaste to regenerate and fabricate textiles and redesigning the application of advanced technologies.

We developed an innovative biobased process that enables the transformation of waste, such as end of life textiles, wheat straw or even used pizza boxes, into bio-based fibres and dyes that seek to replace current fibres for circular textiles.

We advanced new technologies that reduce waste and extend the life of materials to empower small and medium businesses in a circular economy to compete with large brands through creativity and innovation. The circular material properties and processes were facilitated by a Circular Materials Design Toolkit that enables designers to operationalise our innovations in their process flows and to inform business models that lead to a circular economy. These innovations were demonstrated in a Materials Library and Materials Showcase. A Maintaining Materials Toolkit facilitates apparel brands to adopt strategies, practices, and contexts that extend the life of materials and to creatively differentiate themselves through cooperative design. We used 3D printing as a means of depositing biomaterials onto textiles for reinforcement. Together this work aims to inform and empower the next generation of advanced circular material practices.

Biobased Recyling

A biological process that converts waste into a biomaterials for use in circular textile and apparel production

The University of York developed and scaled a biological recycling process that uses enzymes and bacteria to convert waste, such as post-consumer clothes, straw or standard municipal waste, into a biomaterial that could replace wood pulp for the manufacture of viscose or lyocell[5].

These waste sources are abundant and all contain cellulose, a biopolymer that is commonly found in plants. Viscose fibres, paper and cardboard are made of cellulose that is derived from wood pulp; cotton fibres are made of pure cellulose fibres that are derived from the cotton plant. Some bacteria can produce cellulose through fermentation, which is known as bacterial cellulose. Our research innovation uses enzymes to efficiently digest cellulose, that has come from waste, into sugars. The sugars can then be fed to bacteria to produce bacterial cellulose, thus recycling the cellulose from waste into new pure cellulose. The cellulose can then be regenerated into fibres such as viscose or lyocell[6].

By transforming waste materials into high value textiles, we can link the end of the lifecycle of one material with the start of a new one and propose a circular solution for materials. This closed circular loop can reduce waste as well as reduce the need for land resources to grow cotton or trees for fibres. Our innovation helps support the development of local biorefineries, similar to microbreweries, across the UK, which will enable local circular manufacturing. Bacterial cellulose has the potential to be used for a broad range of material applications. We envision a future in which this biological recycling process will link with a range of material industries, such as paper, packaging, and composites.

Catalyst

Widening access to complex circular economy science using experimental design

Catalyst tested an interdisciplinary model for learning with students in the MA Information Experience Design at the RCA with the Textiles Circularity Centre. Students visualised and materialised a highly complex scientific process— biobased textile recycling—using experimental design to metabolise and translate this complex process for laypeople at the cross-section of design and science: macro-, human- and micro-scale.

Catalyst is a multimedia and multi-sensory installation wherein the audience becomes the catalyst in the transformation of textile waste into materials in biotech processes. It includes a tactile sculpture (a rotating drum to be operated by visitors), a visual display illustrating the production of cellulose by bacteria, and an evolving soundscape linked to these to elicit both a cognitive and emotional experience. Together, the three elements form a narrative which facilitates understanding of complex processes to the wider public, wherein the visitor is invited to play the role of the 'catalyst' in biological textile recycling creating a more sustainable textile industry. The designers were able to build new knowledge and actively fuel discovery by making visible the invisible in design and science collaborations through mediating scientific biotechnological processes at different scales for laypeople to experience and actively participate in these.

The imperative of creating for an audience, where the endpoint of the learning process is not with the designer, but with someone one step removed who will encounter the design without the same scientific context the designers were immersed in. Interdisciplinary experimental design is a highly effective way of teaching and learning complexity using diverse sensorial modes and diverse experience inputs. The student learner took on the role of creative mediator in a productive and transformative mode of interdisciplinary mediation-as-learning for the field of future transdisciplinary design education.

Fibre Spinning Process

A production method that turns our circular biomaterial from solid sheet into fibres

The process we use to transform bacterial cellulose into fibres for textile and apparel is called ‘wet spinning.’ The process starts with a sheet of bacterial cellulose, which we add to low toxicity solvents to transform it into a thick solution called a spinning dope. The liquid dope is then shaped into a solid fibre by pushing the solution in small holes using a process called fibre extrusion. The extruded fibres are then passed through a water bath to remove the solvent and to coagulate and regenerate the cellulose fibres. This process transforms the solution into a continuous fibre. The fibre can then be processed into yarns and then textiles for apparel.

Naturally, the fibres that are produced by this process are white in colour, but we can directly integrate natural dyes, such as curcumin using a process called dope dyeing or solution dyeing into the fibre spinning process. The solution or dope dyeing process eliminates the need for dyeing of the fibres after they are manufactured. For the solution dyed fibres, there is no need to dye this material after it is made into a textile. The elimination of the post fibre production dyeing process can result in reducing the water consumption by 50% and energy consumption by up to 30%. Further, the dyes are prevented from entering into freshwater bodies. The synthetic dye pollution from the textiles industry is the second largest cause of freshwater pollution. Our novel solution dyeing process using natural dyes has the potential to significantly reduce the freshwater pollution from textiles industries.

Industry collaboration: Natural dyes from food waste

In collaboration with Sages London, we developed avocado waste based natural dyes for modified cellulose fibres. Sages London developed dyes derived from avocado food waste. We then developed a solution dyeing process for these dyes. The Sages food waste dyes are natural, and they eliminate the need for agricultural land for dye manufacturing, while simultaneously reducing food waste.

Bacterial cellulose fibre

Bacterial cellulose fibre dyed with Brazilwood

Materials Library

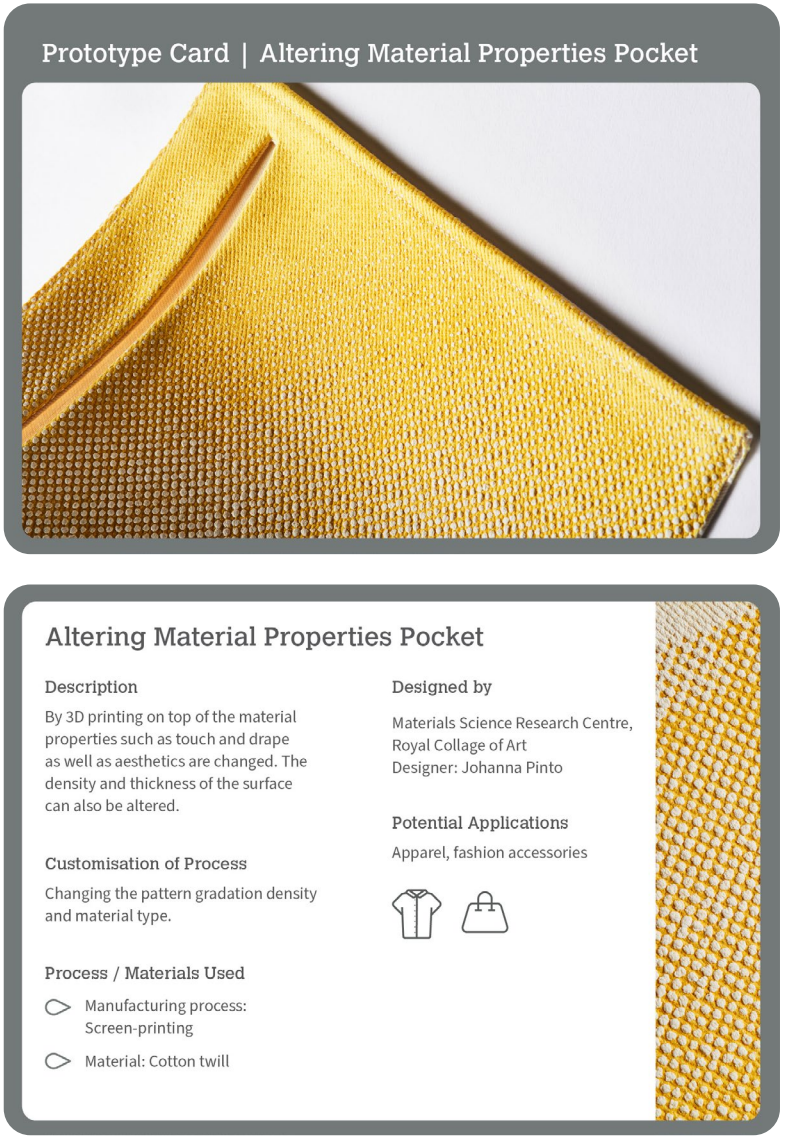
Translating complex interdisciplinary circular materials research into a visual card-based toolkit for designers

We developed a Materials Library to help designers understand and use our circular materials and advanced manufacturing technologies to transform their business and practice. The library consists of cards that show the range of materials and manufacturing processes we have developed. They include fibres, yarns, textiles and finishes that can be used to add value to waste.

The library includes:

- Orange coloured cards that show feedstocks of the waste we use to make bacterial cellulose-based materials
- Green coloured cards showcasing prototypes of materials with illustrations of design possibilities
- Blue coloured cards illustrating the manufacturing processes of the materials detailed on the green cards, as well as materials that do not exist yet at scale
- Grey coloured cards with prototypes showing the possibilities of how the materials created could be applied in the design of circular products

The Materials Library cards offer a new knowledge base to enable brands both to creatively differentiate themselves, as well as to establish processes that enable material longevity in circular material practices. The colour coding system simplifies the process of navigating the library allowing for easy and efficient resource selection.



Example Materials Library card

Circular Materials Design Toolkit

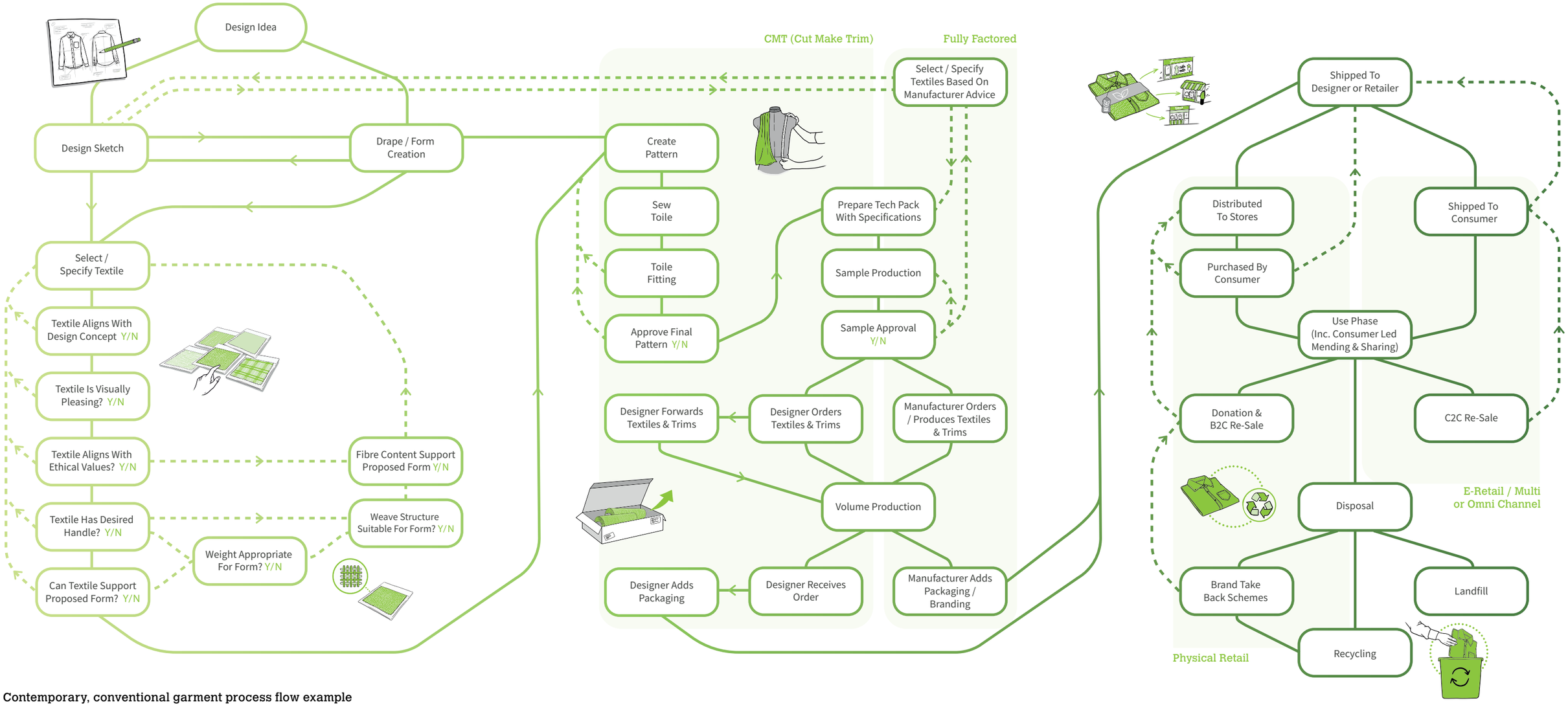
Creating alternative circular process flows in reuse contexts

There is not one standard process when it comes to designing a textile or a garment. Some apparel brands or designers might start with a concept or idea, while others will start with a material. All the steps taken in the process of producing a product will be unique.

We have designed a Circular Materials Design Toolkit to help guide designers and brands map their own personal process flows from concept to final product towards the integration of circularity. The Toolkit includes cards that map the key stages in the development of an apparel product, including design, material selection and manufacturing. It includes the Materials Library and worksheets to help apparel brands, designers, and material start-ups understand, develop and apply circular materials.

The Toolkit encourages reflection on what happens to the product after use, or if systems are in place for it to be repaired or taken back for recycling. Brands used the Toolkit to map circular process flows that could be achieved by introducing elements from our Materials Library. They also understood how our Materials Library could enable them to creatively differentiate themselves by designing circular materials that are unique to their brand, as well as the opportunities to extend the life of materials and to design them for reuse.

The insights of the Toolkit revealed the current process flows in existing brands. Visualising alternative process flows can be achieved with help from the Toolkit to introduce circular materials and manufacturing processes into these existing systems. The Toolkit enabled brands to develop customised material processes as well as personalised material properties that will support increased longevity of materials. These contributions differ from current toolkits that focus solely on replacing materials with circular and sustainable alternatives in existing production and consumption models. This Toolkit fosters creativity and differentiation in material properties and processes by applying advanced textile manufacturing technologies to inform reuse possibilities of materials and products.



Contemporary, conventional garment process flow example

Materials Showcase

A tangible display of circular materials for designers to understand the properties of bio-derived materials that can be made using waste

To understand a new material, it is important for designers to interact with its physical, sensory and aesthetic characteristics beyond its purely technical specification. The Materials Showcase allows for that interaction.

The Materials Showcase is a collection of the technical processes we developed in order to demonstrate the results of our advanced textile fabrication processes. It demonstrates the different processes and materials that can be made from waste and mirrors the materials in our Materials Library. It includes prototypes of repair concepts, demonstrated on apparel components such as collars, pockets and cuffs, and prototypes of materials that integrate circular design, such as textiles that have been reinforced with 3D printing to extend their life within product reuse contexts.

Maintaining Materials (M^2) Toolkit

Redesigning the application of advanced textile fabrication technologies for maintaining materials in use

The Maintaining Materials (M^2) Toolkit demonstrates how advanced fabrication technologies can be redesigned so that they can be used to extend the life of materials already in use. We propose using our circular textile fabrication technologies beyond simply the production of textiles, but also throughout the use phase to extend their lifespan.

These fabrication technologies include:

3D printer and 3D robotic arm: 3D printing is a versatile technique for depositing bio-based materials onto specific locations. We use this technique for repair by printing bio-based materials directly onto garments and production of textile composites.

Bespoke needle-punching machine: fine-gauge barb needles developed to integrate bacterial cellulose with short recycled fibres that are otherwise unable to be spun into yarns. We use this technique to reinforce products through a recycled textile substrate suitable for garment use.

3D weaving loom: a digital manufacturing technology to seamlessly produce bespoke garments with significantly reduced process wastage, production lead-time and touch-time. Unlike traditional methods that involve cutting and stitching flat fabrics, we use this technique to create functional elements, reduce fabric waste, simplify production, and enhance the durability and comfort of garments.

The M^2 Toolkit has been used in research workshops with small and medium apparel brands, material start-ups and repairers to transform current circular economy practices for repair and longevity that either only focus on the product or production phases, or use standard craft techniques. Through the studies we revealed how advanced fabrication technologies facilitate maintaining materials as a new strategy for circular product reuse to result in new circular economy practices such as repair using a 3D printer to achieve multi-faceted material properties, as well as new places and contexts for maintaining materials in new advanced technology hubs on the high street.

Biomaterial Deposition for Reinforcement

Demonstrating the use of 3D printing and robotic arm technologies for the deposition of bacterial cellulose to reinforce textiles and extend their lifecycle

3D printing technology conventionally uses synthetic, petroleum-based materials to create products or product parts. Recently, 3D printing has also been used for aesthetic embellishments and finishes. Within our research, we advanced the use of 3D printing to deposit bacterial cellulose directly onto textiles in order to alter their properties for unique customisation and repair possibilities. We designed different patterns that could be 3D printed, enabling reinforcement of a fabric. We created a physical swatch book to demonstrate how 3D printing can be used as a new circular economy practice for the repair and reinforcement of textiles.

The print design of the bacterial cellulose can be customised according to how the material will be used. For example, we printed the biomaterial onto collars that needed reinforcement. We developed this work further by adding a 3D printing head to a robotic arm to give a range of design possibilities for printing directly onto a three-dimensional apparel product, enabling further possibilities for product reuse. 3D printing technologies can be accessible for both designers and consumers, and could create opportunities for brands to offer in-store customisation and repair services in new repair hubs using advanced fabrication technologies. These new repair experiences using advanced fabrication technologies would then enable people to keep materials and products in use for longer.

This approach demonstrates several opportunities in using bacterial cellulose that is derived from waste for 3D printing, extending the life of the material through the deposition of this bacterial cellulose, as well as enabling this material to be recycled as all materials are cellulosic. In addition, the work demonstrated that the design of the pattern was directly correlated to the strength of the material reinforcement, fortifying the value of design within science and engineering research[7].

Consumer Experience

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Design of experiences that resonate positively with human wellbeing, empowering consumers and apparel businesses in the transition to a circular textiles economy

Introduction to Consumer Experience

Design of experiences that resonate positively with human wellbeing, empowering consumers and apparel businesses in the transition to a circular textile economy.

Our Consumer Experience research strand brings together experts from social sciences, neuroscience, psychology, human-computer interaction, textiles, and design from the Royal College of Art and University College London. We use a holistic human-centred approach to consider the connections between individuals, society, and the environment. Our work addresses two main challenges:

Transforming waste into wonder: we investigate ways to position new textiles made from waste as valued and desirable and to support their adoption by fashion designers and brands.

Promoting circular practices: we identify strategies to enable consumers to become active co-creators in a sustainable product cycle, reduce consumption through design, and encourage care, repair and repurposing.

These strategies involve designing experiences that meet human wellbeing needs and foster circular consumer behaviour. We have developed The Wellbeing Framework for Consumer Experiences in the Circular Economy of the Textile Industry and the Circular Experience Toolkit to guide this process. These tools help to design experiences that encourage circular consumer behaviour and extend the life of apparel and materials, leading to healthier consumption boundaries.

Through our innovative Configurator conceptual space, we offer tools and methods to create tailored circular experiences that cater to different types of consumers. Whether you are a consumer or part of the apparel industry, we hope these resources will empower you to extend the life of your products and make a positive impact on the world.

The Wellbeing Framework for Consumer Experiences in the Circular Economy of the Textile Industry

Putting human wellbeing at the heart of circular experience design

The Wellbeing Framework for Consumer Experiences in the Circular Economy of the Textile Industry[8] explores how human wellbeing is connected to the lifecycle of clothes. By linking human wellbeing with the different stages of a garment's life, the Framework offers strategies to reduce textile consumption and support circularity. It is responsive to the complexity of the circular economy for fashion and textiles that is shaped by economic, social, and political challenges and beyond the power of an individual to solve alone.

The Framework highlights the critical role of consumer behaviour and awareness in creating healthier consumption habits. It identifies 16 dimensions of wellbeing in three categories, being well, feeling well, and doing well. Each of these categories encompasses subjective, psychological, bodily, and economic elements that reflect our interdependence with social and natural worlds. We point to how these wellbeing elements, such as feeling attached to our clothes, finding joy in them, and feeling competent in maintaining them, can be articulated through consumer experiences that enable circular consumption. The Framework suggests that by being more active in designing, modifying, and caring for our clothes, we can develop a stronger connection to them, which may lead us to value and use our clothes — and the planet's resources — for longer.

Wellbeing dimensions in a circular economy: these have been identified as useful for integrating and balancing the hedonic and eudaimonic dimensions of wellbeing within the context of the circular economy.

Affordability: refers to the cost-effectiveness of products, often a key concern for consumers that can be offset by perceived long-term value and quality.

Agentive: Active, autonomous, and proficient engagement in interactions, participation, or collaborative creation—often emerges from sharing skills and resources and challenging traditional consumption practices.

Effort: Subjective escalation in mental or physical activity to achieve a specific goal, characterised as a voluntary and purposeful process.

Engagement: Direct involvement of consumers in circular practices, which is amplified and facilitated through interactions with stakeholders towards a common goal.

Competence: Consumer's skill and confidence in making informed choices about product use and acquisition and their ability to engage in specific circular practices like repurposing and repair.

Learning: Active engagement in acquiring skills and knowledge.

Self-expression and creativity: is about aligning style choices with personal values. This often involves "anti-consumption" strategies like buying fewer, high-quality or second-hand items.

Playfulness: Inclination toward engaging in fun, spontaneous and creative activities. However, its manifestation varies across individuals and is often more accessible in social interactions with familiar individuals.

Optimism: Forward-looking emotional state focused on achieving favourable outcomes, especially relevant in climate change and Circular Economy contexts. However, it is one aspect of a complex emotional landscape that includes pessimism and fear and should be balanced with these other responses for a nuanced perspective.

Future thinking: One's ability to envision future results and take proactive steps to bring about change before it occurs.

Enjoyment and pleasure: Related to emotional states influenced by a garment's functional fit, emotional resonance, and aesthetic appeal. While enjoyment refers to the overall emotional satisfaction derived from these factors, pleasure arises from specific positive experiences that can foster an emotional connection with the clothing item.

Bodily and sensory: Perception of physical aspects of textile materials that significantly impact the wearer's embodied experience.

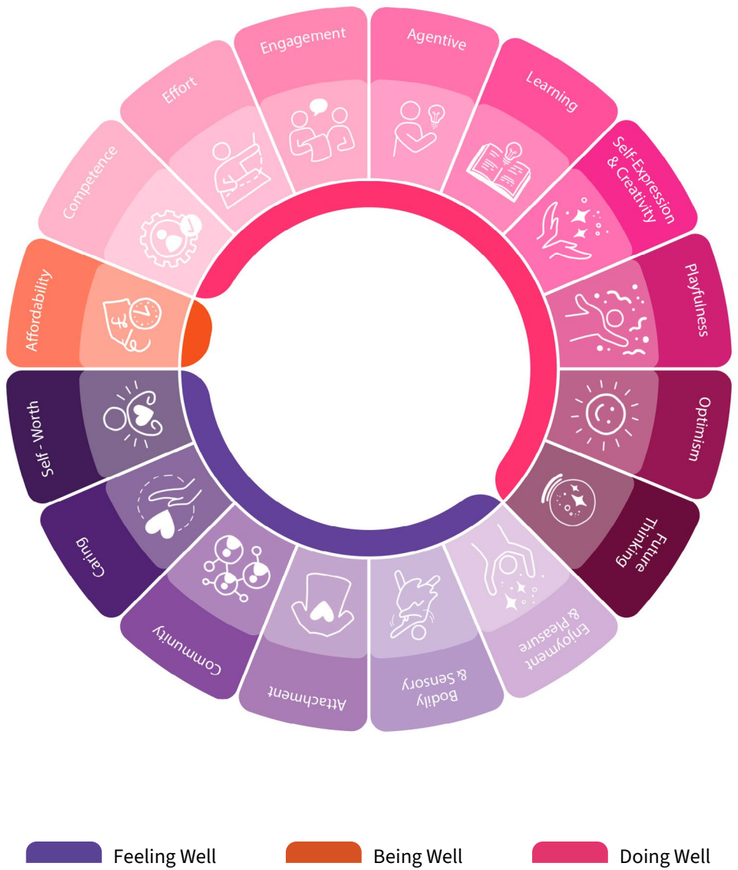
Attachment: Emotional bond formed through a sense of connection and affection, influenced by key factors such as meeting expectations, functional utility, and aesthetic appeal, and further strengthened by the investment of effort and positive experiences.

Community: Groups with shared interests and a commitment to respecting individual differences and supporting each other's well-being and group integrity.

Caring: Practical action directed towards taking care of garments, people, and the environment.

Self-worth: Fashion consumption traditionally relies on social acceptance and external validation. However, for sustainable fashion consumers, it is more internally driven, rooted in material comfort and the expression of non-conformist values, emphasising autonomy and self-esteem.

Circular Experience Toolkit



Redesigning consumer experiences for textiles circularity

The Circular Experience Toolkit is a card-based resource that helps fashion professionals create consumer journey scenarios that stimulate meaningful experiences across the product's lifecycle. By enhancing human wellbeing, the toolkit builds on research that demonstrates the critical role consumers play in creating and sustaining the value of products in circulation.

For example, several cards were used to shape the experience of designing the Biofibre Explorer (see page 52). The Wellbeing cards highlighted dimensions like Enjoyment & Pleasure, Bodily & Sensory, Playfulness, Learning, and Future-thinking, which informed an experience that was fun, educational, and connected to the future of circular practices. The Sensory signature cards focused on sight and feel, encouraging users to physically connect with and visually appreciate the materials. The Technology card brought Augmented Reality into the design of the Biofibre Explorer, allowing for an immersive exploration of regenerated cellulose, as featured in the Material Card (see Materials Circularity strand page 14–15). Finally, the Persona card defined George, a branding professional interested in sustainability and city life, grounding the design in relatable consumer needs. Altogether, the cards enabled a holistic, wellbeing-focused experience that supports doing well through active learning and playfulness and feeling well through sensory engagement.

The Configurator

Circular experiences that reconfigure consumer engagement with apparel and brands

The Configurator is a conceptual space designed to create experiences that are tailored to diverse consumer audiences. In the Configurator, consumers use creative technologies to engage in immersive, multisensory activities that connect them with the circular flow of textiles, making these practices accessible, meaningful, and enjoyable.

Through the Configurator and informed by the Wellbeing Framework, we investigated how to address specific wellbeing dimensions to incorporate consumer perceptions into textile development, engage consumers in product co-creation with brands, and support consumer participation across the lifecycle of clothing in ways that positively impact their own wellbeing, while also contributing to the wellbeing of the planet.

Materials Gym

Work out the textile properties to discover your preferences

The Materials Gym is an interactive experience designed to help consumers realise what they know about textiles and learn how to express and use this knowledge. Since textiles are the materials closest to our bodies throughout our lives, we inherently know a lot about them, even if we don't always realise it. The Materials Gym brings this knowledge to the fore by engaging participants in a guided hands-on exploration of different fabrics.

By engaging multiple senses, the Materials Gym addresses key wellbeing dimensions. It enhances Feeling Well by bringing enjoyment and pleasure through tactile exploration, promotes Doing Well by encouraging engagement and participation, and fosters a sense of competence and mastery. It also contributes to Being Well by helping consumers understand the quality and value of different materials.

Our research found that when consumers consciously use touch skills to evaluate and differentiate material qualities, they can slow the decision-making process, reflect on their needs, and identify their preferences. By touching and engaging in attentive touch, consumers build a better understanding of the material and reflect on other aspects, such as the care that the material will need and how it may feel on their bodies. This demonstrates how the interaction with textiles goes beyond discrete gestures and triggers deeper meaning-making, such as considering how the fabric feels on the body, how it should be cared for, and how it aligns with personal values.

The Materials Gym can be accompanied by an electromyographic gesture sensor (a technique used to measure and record the electrical activity muscles produce during contraction and at rest) and tactile experience recognition machine learning system to understand a consumer's sensory experience and preferences and support them in real-time in making careful clothing purchase decisions.

Step 1: Feel the Texture

Let your sense of touch guide you in identifying the texture of each fabric.

Do: Rub each fabric between your thumb and forefinger or use your whole hand.

Observe: Notice which fabrics feel the roughest and which feel the smoothest.

Step 2: Test the Weight

Feel the weight differences to understand how each fabric might drape or wear.

Do: Lift or gently bounce each fabric in your hands.

Observe: Determine which fabrics are the lightest and the heaviest.

Step 3: Test the Creasing

Assess which fabrics offer the most comfort and how they might behave during use.

Do: Squeeze each fabric into your palm, scrunching and then relaxing it a few times.

Observe: Rank the fabrics from the softest to the hardest based on how they respond.

Step 4: Discover Your Preferences

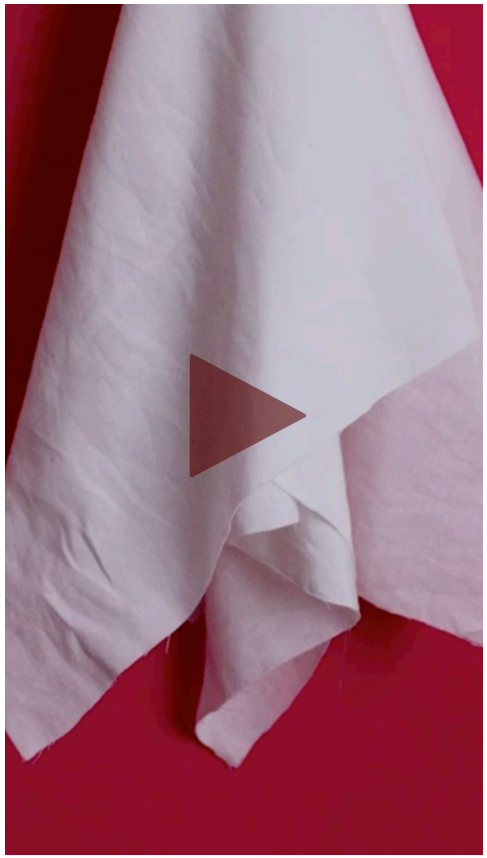
Identify which materials you prefer based on your tactile experience.

Do: Gently stroke or caress each fabric, giving them a soothing massage.

Observe: Rate the fabrics from your favourite to your least favourite.

Join us for a textile workout! Discover the unique properties of each fabric and find your favourites.

By completing these steps, you'll engage your senses to uncover the qualities of each textile. This exploration helps you better understand and appreciate the materials you interact with every day, empowering you to make more informed choices in the future.



The Materials Gym in action

Circular Shirt Builder

Co-design as a tool to rethink our relationship with clothes.

The rise of inexpensive, low-quality fashion has resulted in excessive clothing consumption, shorter garment lifespans, and significant waste, which is neither repurposed nor recycled and ultimately ends up in landfills or incineration. To tackle this problem, we developed the Circular Shirt Builder.

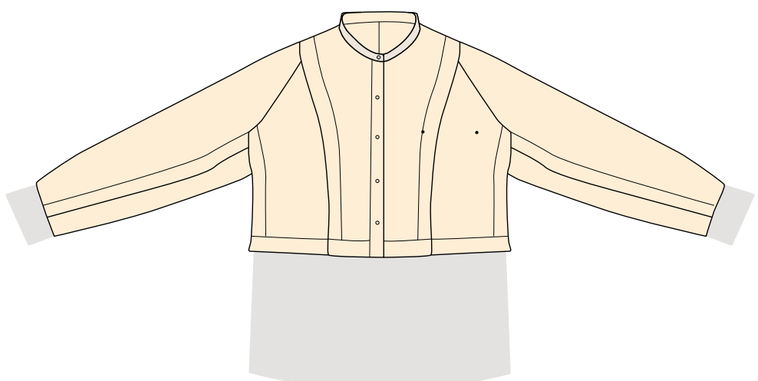
The Circular Shirt Builder is a physical configurator where consumers can customise and assemble a modular shirt featuring interchangeable components such as collar styles, sleeves, and front and back panels. It is a research platform to investigate co-design as a strategy to embed circular principles in consumer behaviour, encouraging them to view garments as long-term, adaptable investments rather than disposable items.

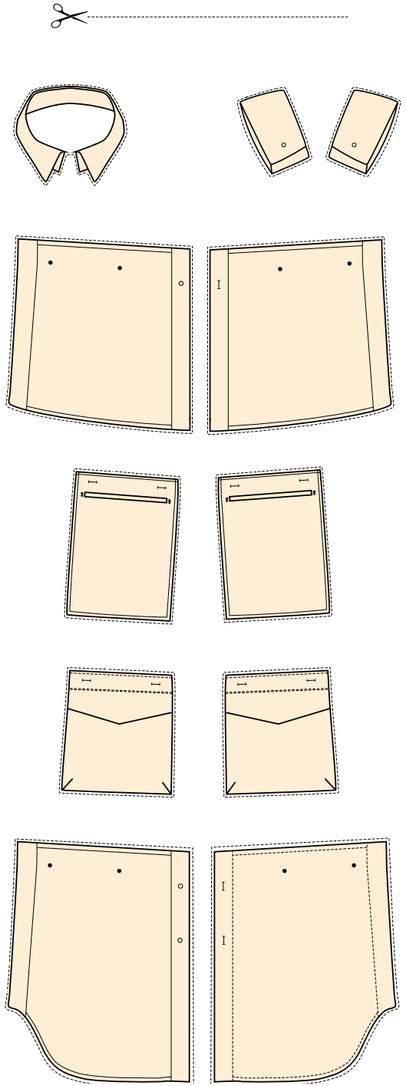
The Circular Shirt Builder encourages participants to engage directly with garment construction, fostering a hands-on connection that makes them more likely to value and care for the final product. Involving consumers in co-design deepens their understanding of garment construction and craftsmanship and enhances their appreciation for the clothing they create.

The Circular Shirt Builder promotes several wellbeing dimensions: it supports playfulness and self-expression through creative customisation, fosters learning and effort as consumers understand garment construction, and encourages future-thinking by emphasising adaptability. It also instils optimism about circular practices and creates attachment to clothing due to personal involvement. Moreover, affordability is addressed through enabling modular updates rather than completely new purchases. At the same time, self-worth is built by making something unique.

The Circular Shirt Builder shifts consumers from passive purchasers to active co-creators, enhancing wellbeing and promoting healthier consumption boundaries—reducing waste and fostering genuine value for garments.

The modular shirt was created in collaboration with fashion designer Morag Seaton.





BioFibre Explorer

Enhancing consumer understanding and perception of new biobased textiles

In today's fashion industry, many consumers are unaware of the origins and processes behind their clothing. This lack of knowledge leads to uninformed purchasing decisions that neither support individual wellbeing nor promote circularity goals. To help consumers make better choices, creating enjoyable and engaging experiences that empower them with information while enhancing their overall wellbeing is essential.

The Biofibre Explorer is an Augmented Reality tool that makes learning about bio-based textiles an engaging and playful experience. It offers an interactive, step-by-step demonstration of the wet spinning process used to create cellulose-based textiles. Through Augmented Reality, consumers can have a multisensory immersion in the materials' origins and potential fashion applications. It facilitates learning and invites users to envision their future-selves participating in more informed and healthy consumption behaviour. Features like phone vibrations enhanced physical involvement and immersion. By demonstrating the complexity and innovation behind biobased materials, the tool deepened the emotional connection to these materials.

Our research shows that the Biofibre Explorer enhances material understanding and inspires more informed and circular consumption habits. By educating consumers through immersive experiences, the Biofibre Explorer promotes transparency, supports circularity, and encourages more conscious decision-making within the fashion industry.

Developed in collaboration with Materials Circularity and 1upstudios.

FarFalla

An immersive multisensory narrative to deeply engage consumers in textiles circularity

We all recognise the urgency for greater sustainability, yet traditional approaches, such as fact-based campaigns, often overwhelm consumers, leading to disengagement rather than action. The FarFalla project takes a different approach, leveraging virtual reality and multisensory storytelling to make textile circularity engaging, rewarding, and personal. By focusing on positive and hopeful messaging, FarFalla avoids fear-based narratives, fostering a sense of agency and collective purpose.

FarFalla immerses users in a narrative that showcases the environmental impact of textiles through visualisations of carbon emissions, water use, and land degradation, complemented by scents of petrol, fresh air, and grass. The experience integrates olfactory, tactile, visual, and auditory elements, allowing users to explore materials like denim and regenerated twill using mid-air haptic technology. Consumers repair and personalise old garments using bacterial cellulose 3D printing, with the scent of heated cellulose reinforcing their actions. The journey concludes with a collective sustainability pledge displayed on a digital board, symbolising community-driven impact.

This multisensory experience fosters wellbeing by addressing key dimensions: learning about innovative materials empowers consumers; a focus on future self instils optimism by presenting actionable paths to sustainability; the shared pledge promotes a sense of community and collective achievement. Together, these dimensions encourage emotional resonance and behavioural change.

Guided Journeys

The Guided Journeys is a method used to invite participants to explore the lifecycle of materials through interactive stations at the Regenerative Fashion Hub. It encourages reflection on their relationship with materials, sustainability practices, and their role in the circular economy.

Now, we invite you to embark on your own Guided Journey by reflecting on what you have encountered in this book so far.

- How might wearing clothing made from bio-based textiles make you feel?
- Did the touch help you understand the materials better?
- Would you consider to co-design or customise more of your clothes and accessories? What factors would help or hinder you from doing this?
- If you put together your own shirt or other clothes, do you think you would feel differently about them than something you found on the High Street?
- What might you want from a physical retail space that offers co-design or customisation options?

What role could you play in the Circular Economy? Select from the patches on the next page.

Enquête d'âme (Inquiry of the Soul)

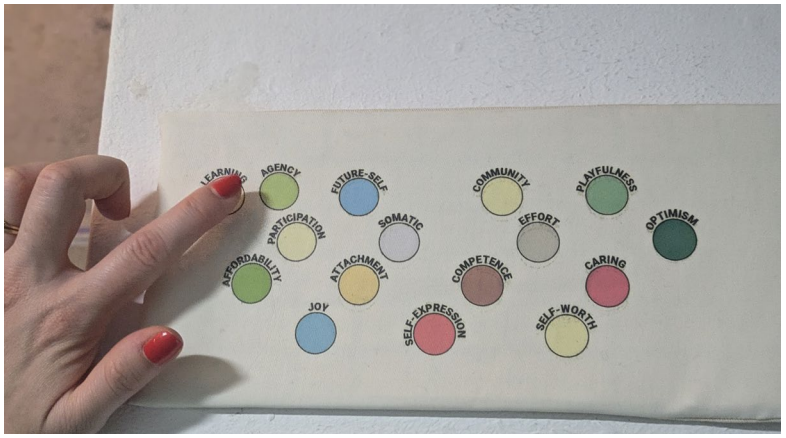
Exploring the articulation of human wellbeing in the context of textiles and fashion circularity

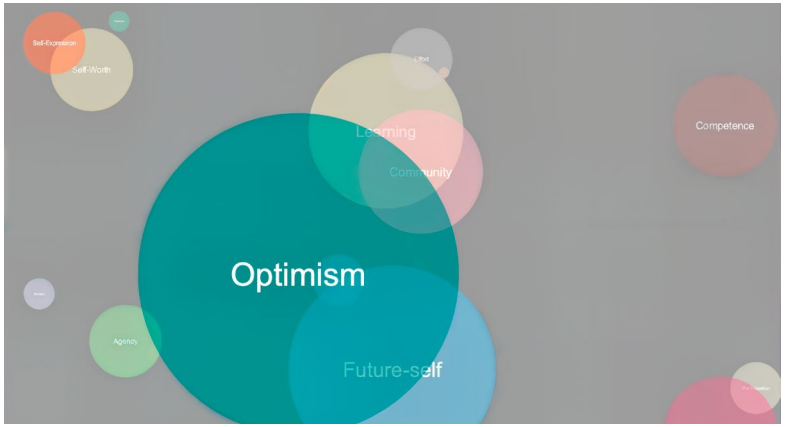
We have developed The Wellbeing Framework for Consumer Experiences in the Circular Economy of the Textile Industry to align consumer experiences with circular principles, offering a tool for professionals to create more meaningful experiences for their customers and for consumers to reflect on their wellbeing.

Reflecting on their wellbeing empowers consumers to explore the deeper connections between their actions, values, and overall quality of life. By considering their emotional, physical, and social needs, individuals can make more intentional and fulfilling choices, aligning their behaviours with what enhances their wellbeing.

The interactive installation Enquête d'âme [Inquiry of the Soul] brings this concept to life. Using a tailored keyboard as a medium for reflection, each key represents one of the 16 wellbeing concepts identified in the Wellbeing Framework for Consumer Experience. After going through an experience designed through the Framework participants are invited to press the keys that resonate with their current state of being, weaving their threads into the larger tapestry of collective wellbeing.

As visitors engage with the installation, their input generates a dynamic visual composition. Each wellbeing concept is translated into a unique graphic element that seamlessly blends into a vibrant and evolving visualisation, symbolising the interconnectedness of individual and collective wellbeing. This interactive experience is a tool to assess and measure the wellbeing dimensions present in a consumer experience.





Circular Supply Chain

Chapter Editors

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Collaborative circular business model designed to circulate the flows of value, information and materials in distributed localised supply chains

Circular Supply Chain

A collaborative place-based Circular Supply Chain system, conceptualised as a Social Production Network

Our research has focused on developing a networked community-based approach to the circular economy through a localised circular supply chain system. In this section we present the methods and tools we have developed for researchers, businesses, councils, and communities to research, design and evaluate local circular economy systems as a whole.

The Social Production Network concept integrates all the work from across the Textiles Circularity Centre. Through interdisciplinary research, we have identified how Materials Circularity and Consumer Experience strategies can enable the circular flow of clothing in a town or city. Drawing on the team's expertise in design engineering, behaviour science and systems, we developed approaches and tools for researching, designing and evaluating Social Production Networks. We packaged these into the Circular Systems Design Toolkit, which has three components - Locality, Distribution and Future.

We carried out a number of studies using our tools to answer these key questions about Social Production Networks:

- What are the attributes and values of localised circular supply chains?
- How to scale this localised circular supply chain system in the UK?
- What are the barriers and drivers to a future where this localised circular supply chain is adopted in the UK?

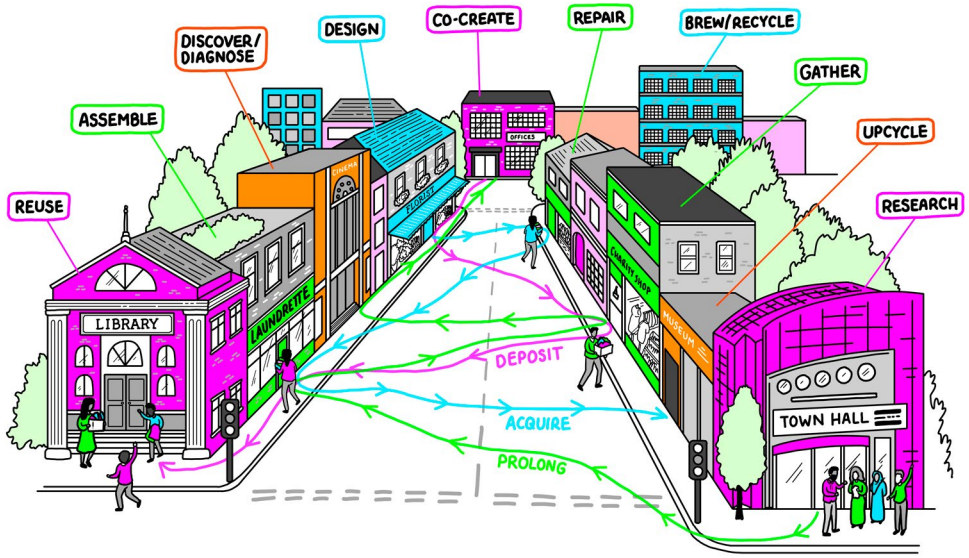
Social Production Network

A placed-based supply chain system of diverse interdependent actors whose collective behaviours emerge into a circular economy

The Supply Chain strand's work centred on the concept of the Social Production Network which is based on our understanding of complex systems, distributed manufacture and social production function. We define a Social Production Network as a placed-based supply chain system of diverse interdependent actors whose collective behaviours emerge into a circular economy. In the Social Production Network, human actors, including wearers and other stakeholders, and non-human actors, such as technologies, products and materials, interact as interconnected components of a whole system. We are interested in the ability of this system to self-organise in towns in ways that facilitate circularity, and how this is made possible by the behaviour of many actors, rather than the isolated efforts of individuals.

The Social Production Network is place-based, meaning the entire system's behaviour is characterised by the specific attributes, capacities, and capabilities of actors which can vary across locations. The local focus is rooted in the Textiles Circularity Centre's objectives, which centre on supporting small businesses and start-ups, individual designers, innovators and makers, as well as promoting co-creation as a new way of acquiring clothing on the high street. All of these activities exist within local communities and outside the vast linear global supply chain. Recognising the need for systemic change, we understand transformation within these systems is driven or constrained by multiple factors bounded by the regions where these networks exist. These factors include human behaviour, culture, policy, as well as broader macroeconomic and environmental influences.

The Social Production Network concept, alongside our understanding of its principles, value potential, and factors for adoption are useful for exploring and implementing circular economy practices in town centres across the UK. By focusing on the interactions between local actors, the Social Production Network can contribute to a more resilient and adaptive system. Circular practices not only reduce environmental impact but also enhance the quality of life for community members. Implementation of collaborative supply chain models that support work and leisure of local actors in a social enterprise can promote circular practices, drive sustainable innovation, create local jobs, and foster a sense of belonging.

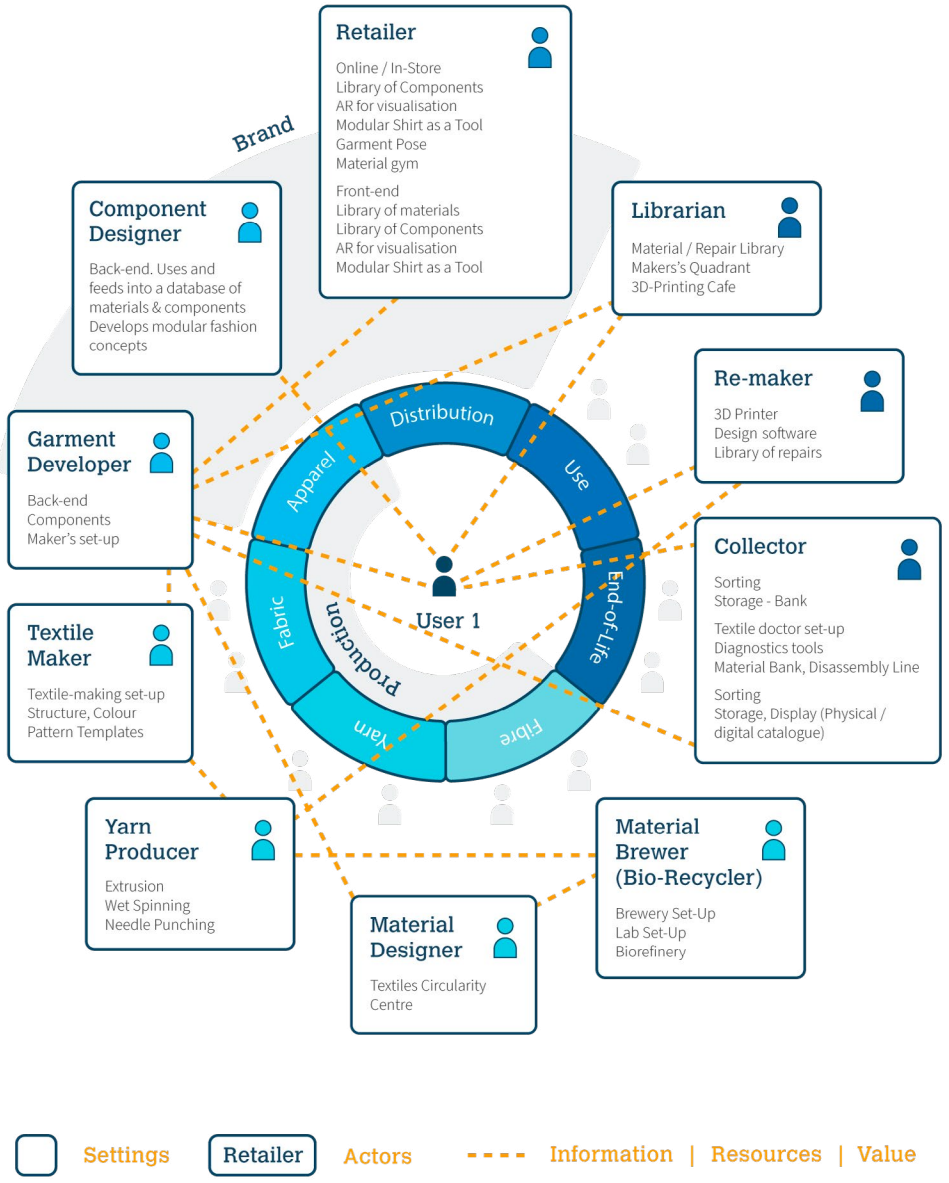


The Textiles Circularity Centre's Role in the Social Production Network

Embedding the strategies of the materials circularity and consumer experience strands into a localised circular supply chain

It is our understanding that applying a place-based perspective to system design can facilitate the adoption of a circular economy. We have focused our research on niche innovators, whether individuals or communities. The Supply Chain research strand has had the role of bringing together knowledge about systems that conform to the Social Production Network concept. We have done this by working across disciplines in the wider team, grounded in design, to devise ways of incorporating specific Materials Circularity and Consumer Experience strategies into our conceptualisation of the Social Production Network and localised circular supply chains.

As part of cross-strand workshops, we produced a simple tool for mapping the actor network, with a particular focus on how our social and technological innovations contribute to the development of a place-based circular economy, see image. The workshop tool consisted of three interrelated system layers, each contained on tracing paper, layered on top of a system blueprint showing phases of the resource flow (e.g. origin, production and consumption). On each layer, we annotated relevant system actors, interactions and settings in various circular supply chain configurations, showing how the Textiles Circularity Centre and other system actors can collaboratively enact circularity. These configurations explored circular economy goals, such as providing a repaired shirt, an altered shirt, or a reconstructed garment.



Locality: Configuring Localised Circular Supply Chains

Exploring attributes and values of localised circular supply chains

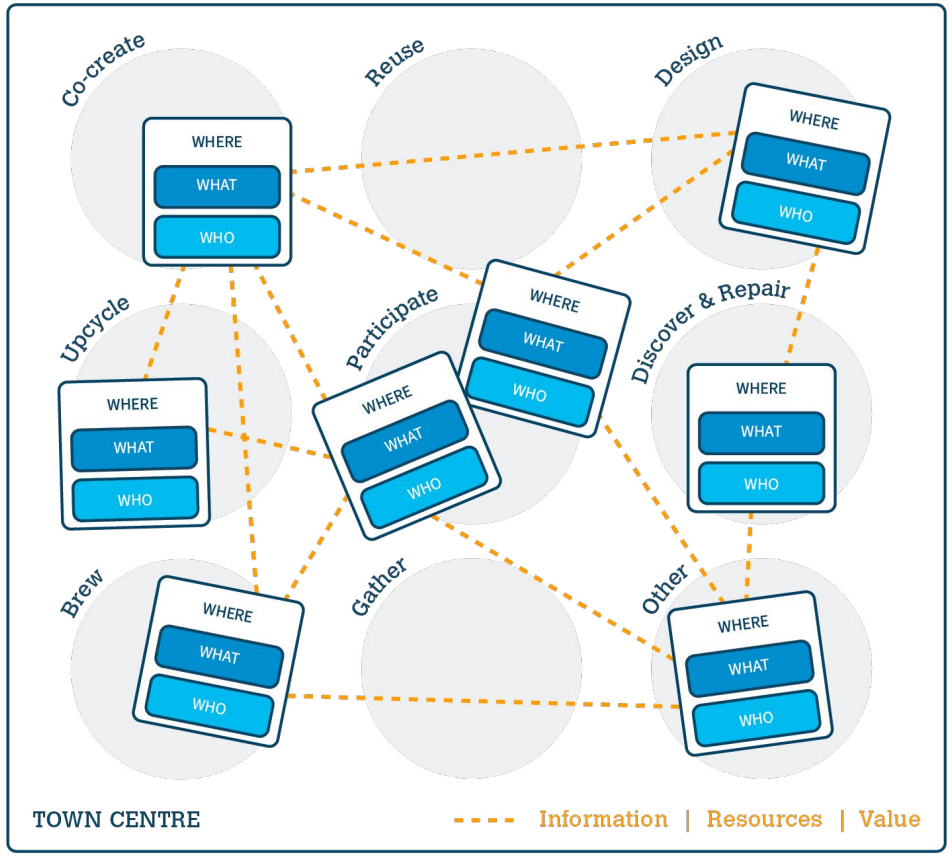
Local networks of people, things and places – wearers, retailers, tailors, dry cleaners, shop displays, online stores, retail spaces, libraries, community centres – exist in our neighbourhoods, high streets and town centres. By building on these existing intertwined social and technical structures, we can introduce new systems and rules to support our community in achieving circularity. Circularity is a social and creative endeavour that requires the collaboration that established social networks can offer. In the context of neighbourhoods, circularity is about retaining and extending the use of the products, components and materials that are already available to us 'on our doorstep'. Currently there is an abundance of materials in our homes, bins and charity shops. We can reuse locally sourced products without modification, or modify clothing for reuse through repair, alteration and upcycling using textiles, buttons, threads that are retained and available locally. These resources are a valuable part of our product and service system.

In order to embed circularity in local everyday living, there are a few things we need to do. Firstly, we need to ensure that each of us is playing our role so that the chain can function properly. We need to collaboratively design the physical set-up around us to allow us to carry out the necessary actions. And we need to constantly evaluate our systems, and use this evaluation to inform our activities.

We developed the Circular System Design Tool to enable data collection for our study which aimed to identify the attributes and value of localised circular supply chains. We carried out a number of research workshops in which the tool was used by groups of various people ranging from businesses, designers, makers, innovators, to local authorities and NGOs. Through this, we found that the Tool supported these groups to map, describe, negotiate and evaluate the configurations of a localised circular supply chain in a hypothetical town centre and specify the key elements and necessary interactions for the system to achieve reuse, through repair, alteration and reconstruction. Our research findings are incorporated in the Tool in the form of Principles and Value cards, to inform the mapping process.

Circular System Design Tool

The Circular System Design Tool is an approach to mapping interactive networks of people, things and places that facilitate circular flows of clothing in the hyper-local economy of a town. It also allows us, system actors, to evaluate our local supply chains in order to successfully support our behaviours. The Tool has several stages of mapping, or layers (see Figure X). The bottom layer is a blueprint of various settings - or behavioural contexts (e.g. reuse, repair, participate), an important component which guides the mapping. These settings represent key activities associated with work that goes into prolonging the lives of products and materials. Then, on top of this goes an actor layer, which requires mapping who, what and where nodes. These are the human, non-human elements, and places where they are situated at and enact their roles. Then, there is an interaction layer to represent the links between actors and places, by specifying flows of resources, information and value between them. Finally, there is a whole system evaluation layer, where you examine the configuration to understand whether and how this circular supply chain configuration can bring value to the local community.



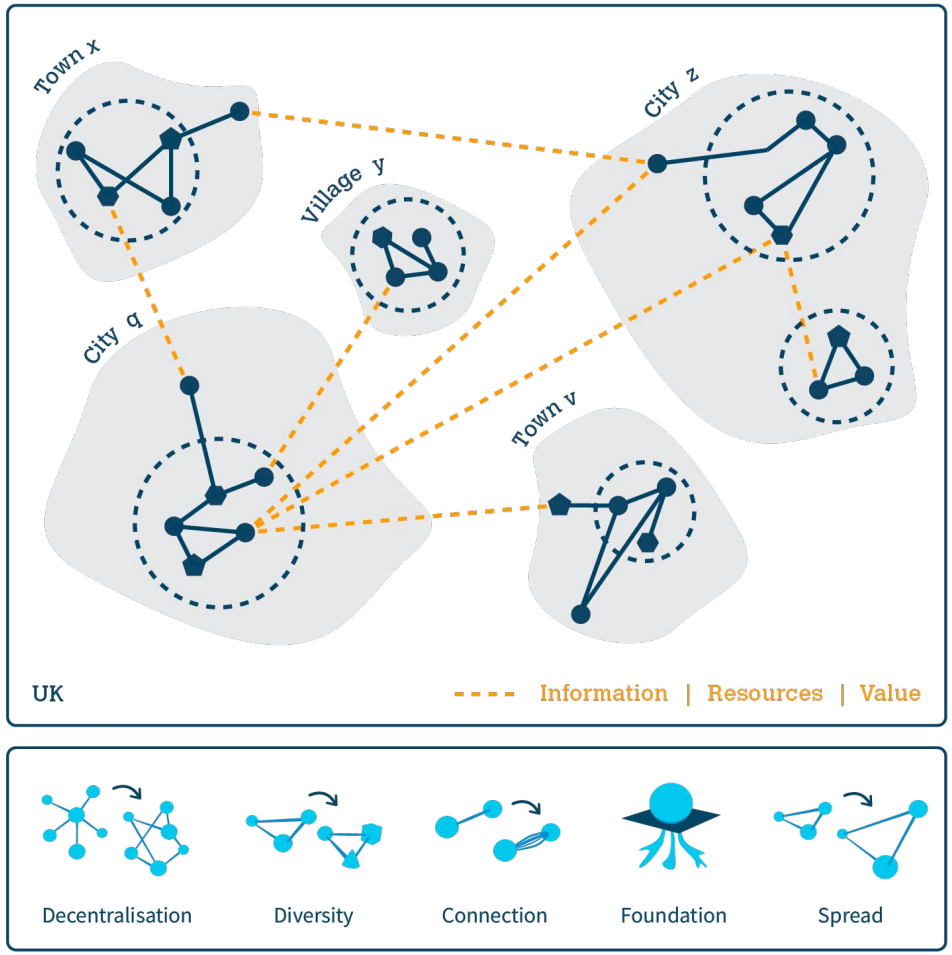
Distribution: Recombining Supply Chains to a System of Distributed Communities

Exploring how to scale a localised circular supply chain system in the UK

Our work on localised circular supply chains provided an understanding of the actors and system attributes needed to align local economies to circular strategies. From this, we identified that we need to think about how these systems can be spread across the UK and how communities can foster relationships between them to maximise reuse of clothing, reduce waste and develop collaborative business models that increase their collective wellbeing and prosperity. We developed and applied a System of System Design tool for use in participant studies in which we investigated the opportunities for scaling a localised circular supply chain to identify how local communities might network across the UK. Participants, who brought diverse expertise and interests, explored what distribution might look like for a particular circular goal and evaluated their configuration to speculate on how it might benefit different communities.

System of systems design tool

The System of Systems Design tool is particularly useful to identify how individuals and collectives can leverage their existing relationships and establish new connections or system conditions for expanding the system and cooperation across regions to make supply chains more sustainable and resilient. As the goal is to maximise value while keeping clothes in circulation for longer, towns and cities can support each other by harnessing the strengths and specialisms of the individuals who live there whether they are designers, apparel brands, repairers, upcyclers, recyclers, manufacturers, biomaterial brewers. Our research findings are incorporated in the tool in the form of Scale cards, that guide the mapping of factors for scaling the Social Production Network across the UK. The tool is particularly suited to policymakers, SMEs and community groups focusing on textiles circularity.



Futuring: Pathways to an Alternate Reality

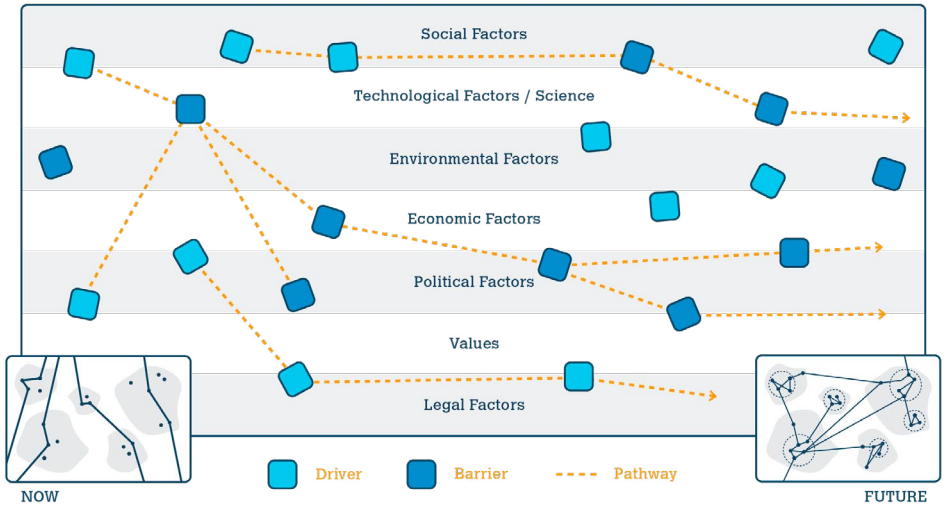
Exploring barriers and drivers to a localised circular supply chain system future

We researched various factors that may hinder or drive system change. Together with system actors who already take part in circular practices, we articulated an array of social, technological, economic, environmental, political and legal barriers and drivers. These point to possible routes for transforming current linear clothing supply chains towards a future where Social Production Networks are a norm in the UK. Having foresight into these factors is valuable, as it helps us understand the possibility of system change, what possible future events we should be aware of that are significant to this transition, and what events we think are necessary to happen for us to arrive at this preferable scenario.

Futuring circular systems tool

We developed a Futuring Circular Systems tool for data collection in our research study by combining existing futures research approaches. The tool guides the mapping of interrelated influencing factors on a pathway to an alternative reality. We used the tool to build pathways between:

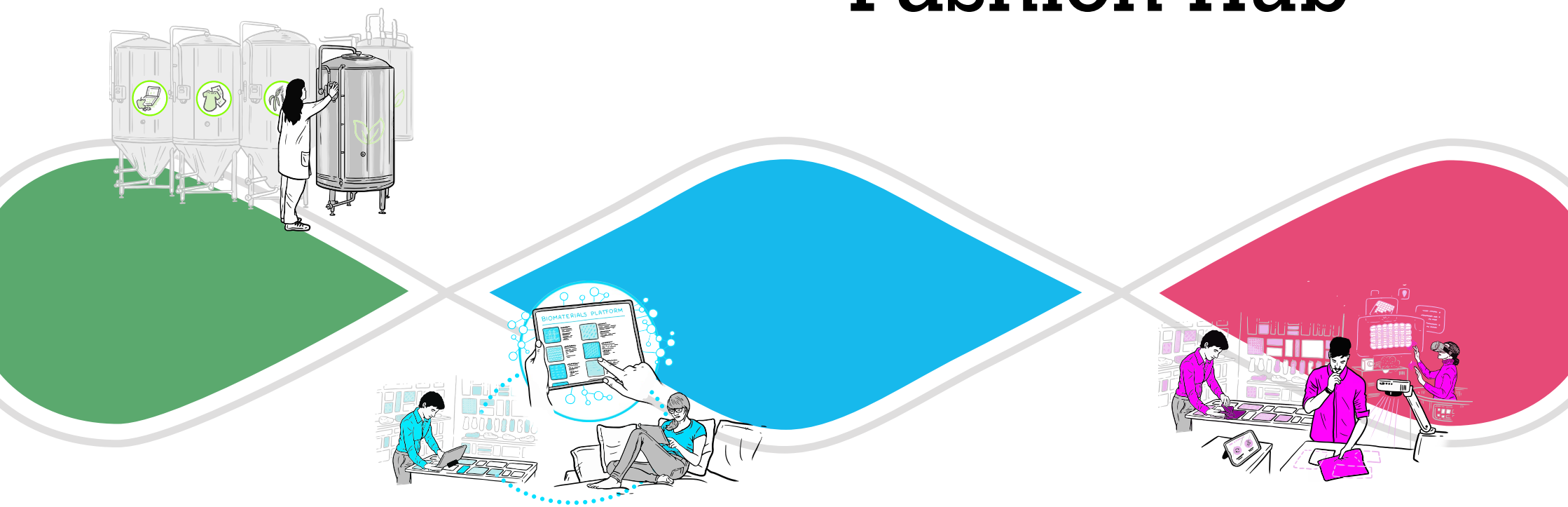
- The Now: a linear fast-fashion supply chain, characterised by the UK apparel-textile sectors operating in a global system whereby mass production, overconsumption and resource intensive processes cause environmental degradation



- And the Future: a preferable scenario where Social Production Networks are a norm in the UK – a distributed circular supply chain, characterised by UK-based communities operating in resilient supply chains, where distributed manufacture, repair, care, reuse, etc., support a system of regenerative fashion.

To align study participants with these two realities, the tool enabled a process of defining more deeply each scenario using a multi-level approach for specifying the social, technological, economic, environmental, political and legal aspects. The tool enabled our research participants to identify the social, technological, environmental, economic, political, value-based and legal barriers and drivers, through evaluating events they think are likely to happen in the future. As a result, our research revealed an array of possible events that could hinder or lead towards the development of a Social Production Network in the UK. The tool can also help us to forecast various other future scenarios, as depending on the pathways mapped, we can define alternative future social, economic or environmental states.

The Regenerative Fashion Hub



The Textiles Circularity Centre Stakeholder Engagement Platform

Regenerative Fashion Hub

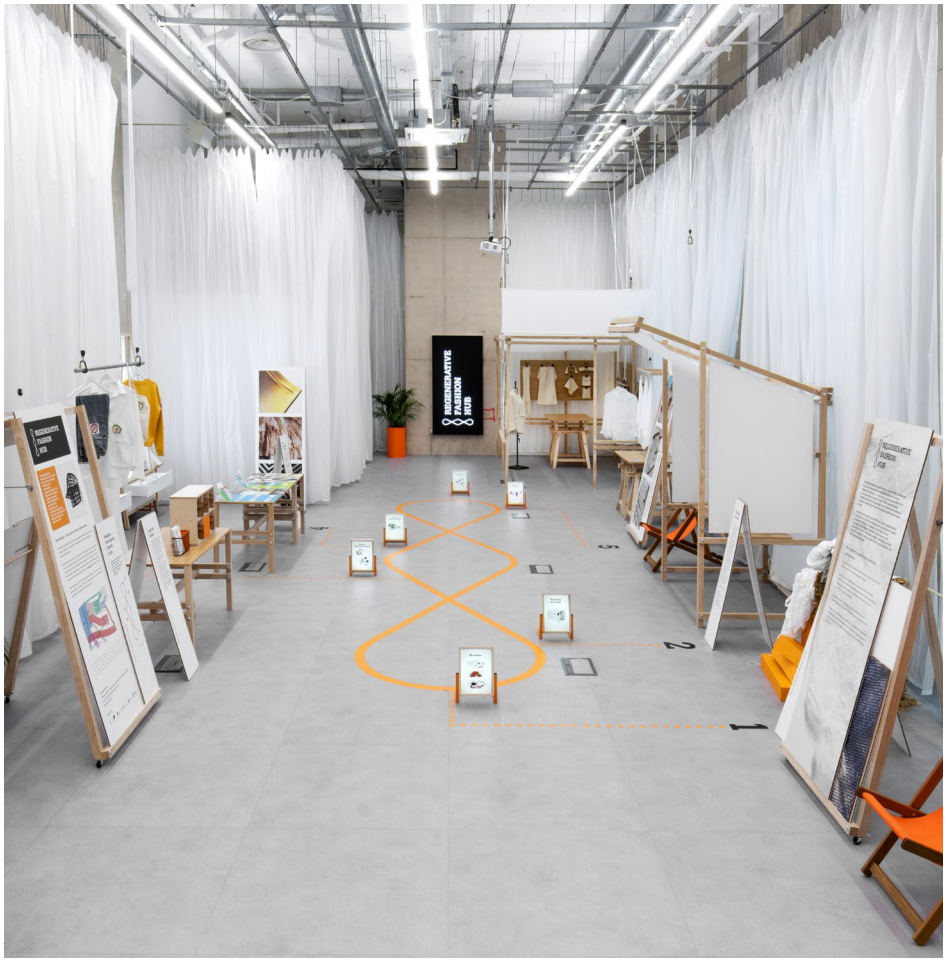
The Textiles Circularity Centre stakeholder engagement platform

The Regenerative Fashion Hub is an on-the-high street exhibition of our research, and has been designed to allow for the co-creation of research with stakeholders as well as our 'one to many' knowledge exchange approach. We use the Regenerative Fashion Hub to conduct research, engage with our stakeholders and members of the wider public, disseminate and discuss our ideas.

Sustainability needs to be embedded in our culture. It is only through direct engagement with community stakeholders that we can bring about a significant change in the culture of production and consumption.

Throughout the course of the Textiles Circularity Centre, the Regenerative Fashion Hub held three main iterations. Between October and November 2022, the first interactive exhibition was held at Lab E20 in East London. The second ran between November 2023 and February 2024 in Wandsworth. The third Regenerative Fashion Hub involved a month-long residency at Rich Mix in Shoreditch, East London. The exhibitions were designed to be in dialogue with the neighbouring community; and by locating them on high streets made the exhibition more open to the general public, encouraging passersby to engage with the work. Each exhibition featured a series of events, including research studies, workshops, panel discussions and seminars to engage visitors, and creating opportunities for them to make new connections.

Stakeholders found that this platform provided an important opportunity for citizens, industry and policymakers to appreciate the holistic challenges in circular economy research and envisage a future in which they are active actors in circular economy systems.



Textiles Circularity Centre's Interdisciplinary Approach to Co-creating Visions for Transition

A reflective account of our methodology, values and contributions

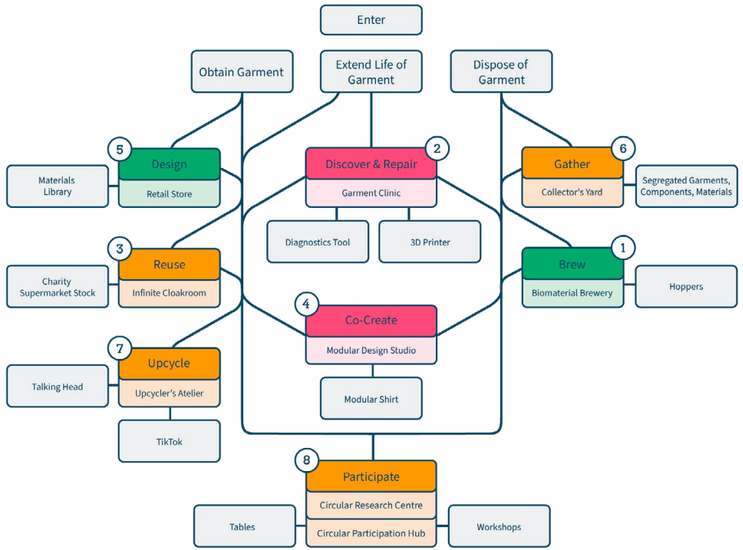
Interdisciplinarity is critical for addressing the complexities of Circular Economy research, where diverse expertise and perspectives are required to navigate systemic challenges. However, it has its own difficulties, demanding collaboration across disciplinary boundaries, integration of knowledge systems and synthesis of methodologies. At the Textiles Circularity Centre, we explored how interdisciplinarity can drive the co-creation of visions for transition in the textiles sector, revealing its dynamics and potential.

We collaborated across the three research strands, each led by researchers with a design background, to synthesise our areas of focus into a coherent approach. Each strand brought varied perspectives and expertise to mapping the web of different individuals and businesses and the flow of materials that constitute clothing supply chains. Our interdisciplinary collaboration enabled the conceptualisation and activation of the Social Production Network through the Regenerative Fashion Hub, a stakeholder engagement platform encouraging participants to engage with circular economy principles, inspiring action through an interactive narrative.

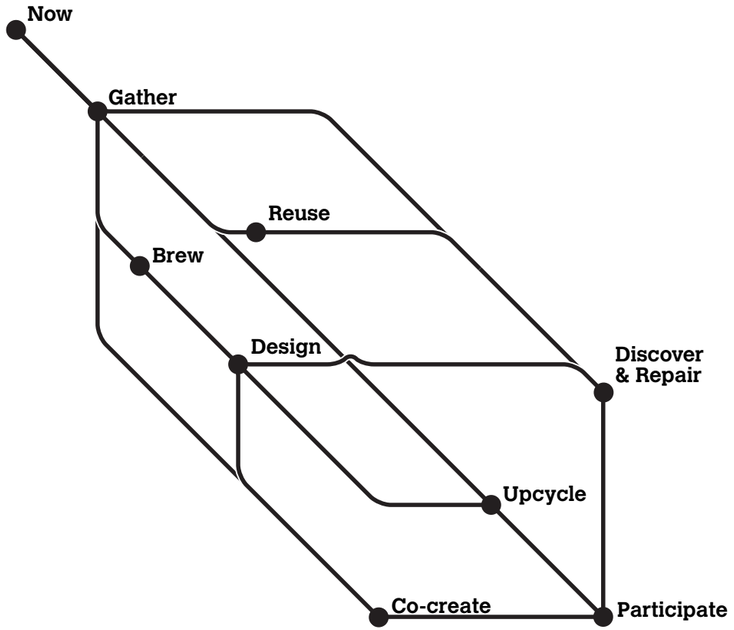
To guide visitors' journeys, we developed maps incorporating strategies from Materials Circularity and Consumer Experience and guest exhibitors who brought in real-life examples of circular practices.

This was a way of exploring and combining social, scientific and technological aspects of our work with the broader system, empirically testing it while aiming to make our research understandable to stakeholders.

Taking a design-led interdisciplinary approach with workshops, living labs and tangible artefacts enabled stakeholders to envision desirable futures while addressing socio-technical complexities. By reframing supply chains as systems of care, wellbeing and prolonged use, we showed how interdisciplinarity can transform relationships between science and society.



Sketch of the Regenerative Fashion Hub incorporating the concept of the Social Production Network.



Journey Map illustrating the difference routes through the stations in the Regenerative Fashion Hub

Stations in the Regenerative Fashion Hub

Reuse

Using garments that have been previously worn by other users

Reuse promotes the circulation of garments or textiles through services that enable consumers to access clothing that has already been used by others. This could be done through services such as resale, rental and leasing.

There are many different people and services in the supply chain who enable consumers to reuse clothing, such as charity shops, rental services and resale platforms. They encourage a circular approach to fashion by promoting the ethos and practice of reusing and rewearing.

Discover & Repair

Diagnosing the quality of clothing and developing strategies to extend their lifespan.

Sometimes, this involves repairing the garments to bring them back to a usable state. This may include using traditional mending methods, as well as innovative technologies.

Using damage diagnostics tools, a material specialist investigates the quality of material, seams, buttons and decides whether and how the garment and its components can be repaired. Depending on the extent of the damage, the repairer can replace a button or fix a torn or worn seam. Additionally, they might use a 3D printer to deposit strengthening material on a shirt sleeve or other areas that require reinforcement.

Gather

The collection, sorting, and storing of textiles for redistribution

At this part of the network, elements are collected for potential reuse, repair or recycling. They could be garments or other textile products, components of products, such as buttons, zips or textiles, or scraps of materials.

Once the components have been gathered, collectors, sorters and quality-graders can then use the infrastructure of the Social Production Network to ensure that these materials are reused and do not go to waste.

Participate

Local communities assembling to engage research and democratic decision-making about how products and garment-textiles flow within, into and out of their local area

Participation involves citizens collectively understanding and incorporating interventions that encourage circular strategies, such as reuse, repair and upcycling, adopted by everyone in their area.

In the Social Production Network, citizens from all walks of life are encouraged to participate in the production of knowledge and the democratic decision making that can lead to greater social and environmental wellbeing. They are joined by businesses, NGOs, policymakers and local authorities, as well as researchers and educators, in this inclusive engagement.

Design

Planning, prototyping and creating materials, components and products.

Design is a key phase in the lifetime of a garment, as a lot of the decisions made by designers and makers at this stage influence how it flows through the rest of the Social Production Network.

Within the Regenerative Fashion Hub exhibition, this station displayed a design studio developing concepts, technologies and processes to make and remake biomaterials and components for garments.

Co-create

Brands create a modifiable garment that consumers can adapt to suit their preferences

By co-creating, the consumer is involved in making the decisions about the design and manufacture of the clothing they buy. To co-create, retailers and consumers can use libraries of materials and components, innovative technologies and personalised experiences.

Upcycle

End-of-use garments and components are reused in the making of good-as-new and unique clothing items

Skilled artisans and designers use secondhand components - like those collected in the Gather stage - to create new garments. This creative process of redesign promotes longevity and reduces waste by keeping clothing components in the system longer.

Brew

A biobased recycling process in which consumer textiles waste is transformed into bacterial cellulose

'Brewing', in the context of regenerative fashion, refers to a vision of how the biobased recycling process we have developed through our research could be applied to the High-Street, to allow bio-waste and post consumer textile to be transformed into pure bacterial cellulose.

By transforming waste into new biobased materials, the intention is to add value to end of life waste materials and produce circular materials.

'Brewers' in this context are experts in fermentation and produce bacterial cellulose, a biobased material that can then be designed to re-enter the material stream as high value textiles.

Behavioural actions needed to establish a circular economy

At the **consumer level**, slowing down decision-making during consumption and using strategies to satiate human wellbeing needs supports better purchasing choices. This increases the likelihood of garments satisfying needs, which is crucial for their use, and critical to avoid them being discarded or returned. Our research has revealed the following insights about behaviours that would slow down consumption: the effort of participating in circular consumption is a 'reward'; playfulness and self-expression in garment life extension activities, such as the Circular Shirt Builder, make circular behaviours 'intuitive', leading consumers to view garments as adaptable investments rather than disposable items; multisensory learning enhances understanding of the origin of biobased materials, fabrication processes, and properties, enabling consumers to reflect on their needs and preferences.

At the **business level**, the Circular Materials Design Toolkit and the Maintaining Materials Toolkit can help brands transition to a circular economy in the near term by promoting behaviours of collaboration and cooperation in local ecosystems of businesses, brands and consumers. The Circular Materials Design Toolkit enables brands to visualise alternative process flows by designing creatively unique interventions in their value chains using the circular materials and technologies that we have developed. The Maintaining Materials Toolkit provides material longevity strategies for the product use phase. It offers brands an expanded vision for circular manufacturing that uses advanced technologies in place-based settings, such as on the high street, to maintain and extend the life of materials already in use.

At the **system level**, our research into social production networks suggests that the circular economy emerges from the collective behaviour of supply chain system actors, when all actors align with the values and goals of a circular community and enact their behaviours in cohesion. The social production network is a system of systems, in which 'glocal' UK communities collaborate, forming codependent relationships between individuals and groups. Existing communities provide the foundations for circularity to grow, characterised by local social interaction and making. A key aspect of these systems is that actors self-organise, meaning that the system behaviour is established through their spontaneous interactions.

Value and flows of values

We aimed to design ways in which the flow of clothing, particularly that made from virgin fibre, can be reduced to minimise environmental impact. Flows are driven by exchanges of value or perceptions of value.

Value: Our Material Flow Analysis highlighted changes in the financial value of clothing. Our interdisciplinary value flow analysis showed that many flows are also driven by other values, including social and wellbeing. Intervening in these flows could help design a more sustainable system, based on lower material consumption and higher reuse and repair. Our work aimed to engage consumers more

deeply with material flows, helping them value their clothes and the materials from which they are made. We found that the effort of participating in a circular clothing economy works as a reward, thus adding value, but we need to reduce the 'intention-action gap' by making circular actions intuitive. Slowing decision-making and adding interactive, multi-sensory elements to the clothing selection experience helps consumers to choose clothing that fulfils deeper needs and is kept for longer.

Flows of value: Physical UK clothing flows are shown in the story of the now. We analysed the flows of value between different clothing lifecycle stages. The key flows to be targeted include:

- Those between the 'use' and the 'preparing for reuse' phases, dominated by the charity sector (driven by social, emotional and environmental value with limited cash value), platforms such as Vinted (similar, but with more cash value) and retailer 'take back' (about which we know little).

- Those between the 'repair/upgrade/repurpose' and 'retail' phases (involving our bioprocess) driven by cash, environmental and brand values.

Understanding how these flows can be amplified by encouraging consumers to place greater value on clothing and diverting flows from 'fast fashion' is key to our research.

Environmental impacts

The current impact of the clothing industry at the material level is not known well enough for substitution strategies to be effective. For example, generic estimates of the embodied carbon of cotton and polyester clothing are 25 +/- 20 and 32 +/- 12 kg CO_2 per kg respectively. Thus, the carbon saving in switching from polyester to cotton as often proposed, nominally about 20%, is in fact unknown without product-level analysis. In any case, such marginal savings would be overtaken by sector volume growth within 5 years. The same applies to substitution with recycled fibre, which offers a similarly nominal saving.

Combining new biomaterials, manufacturing and repair techniques with social innovations would dramatically extend the life of clothing. Reusing an item causes 70 times less environmental impact than making a new one. Swapping the satiety associated with consumption of cheap items for preservation of cherished items and curation of the personal and community narratives they support would grow the reuse sector, changing the desirability of reused clothing so that it displaces more new clothing. Combined with validated use of low-carbon and recycled fibre, this could reduce the impact of the UK clothing system by between 25% - 70% depending on the strength of policy measures put in place; a carbon saving of 8 - 23 million tonnes of CO_2 per year.

Bioprocesses are not automatically sustainable. They may divert water from drinking and sanitation or land from food crops. Our bioprocess, using waste as a feedstock and low-energy bacterial processes, enables our novel repair technologies, consumer experience innovations and social production network, creating environmental savings through longevity and reuse.

Technological, policy, economic, data and societal requirements for change

Here we identify the technological, policy, economic, data and societal changes that would be needed for adoption of our solutions. These changes could create the conditions for growth in the reuse sector by encouraging consumers and the creative industries to work with biomaterials start-ups and innovators, advanced manufacturing SMEs, repair and upcycling businesses, and NGOs and local government.

Technological requirements

In order for system actors to enact their roles in localised supply chains, there is a need for an array of enabling technologies, materials, tools, and associated processes:

- **Enabling technical elements**, technologies, products and materials, and associated processes collectively developed by and for system actors to aid their roles in localised supply chains (social production networks).
- **Enabling industrial infrastructure**, such as a national bio-refinery pilot facility for textiles, incentivised by also servicing packaging, paper and composites.
- **Advance manufacturing capabilities** for textiles longevity whilst enabling businesses to creatively differentiate their apparel offerings.
- **New techniques in createch** for services and experiences that satisfy wellbeing needs.

Policy requirements

The development of an Extended Producer Responsibility scheme for apparel-textiles as part of a Circular Design Standard could promote the adoption of our solutions. The standard would guide system actors engaged in the following collaborative design interactions:

- **Collaborative co-design** of materials and products for unique or standardised outputs that incorporates maintaining materials in use, customisation, modularity.
- **Collective system co-design** of interconnected people, processes, services, products and infrastructures that enable their roles, incorporating localised circular supply chain design, distributed circular supply chain design, new process flows and value chains design, cooperative design, advanced textile fabrication technologies.
- **Holistic circular design**, addressing the journeys of resources through the system and associated impacts, incorporating design of experiences, circular design of materials.

Economic requirements

A new economic model needs to promote a social circular economy, encompassing aspects of:

- **Participatory economy**, allowing communities to share ownership, collectively govern and participate in the decision making.
- **Wellbeing economy**, prioritising social and environmental needs over monetary wealth;
- **Service economy** that centres on access, sharing and services.

Data requirements

The Social Production Network is a system of things and people, co-producing and transferring information across the network. The following information, data and knowledge flows are needed to uphold the system:

- **Guidance** on how to adopt circularity and apply circular fabrication technologies creatively to value chains.
- **Education and training** opportunities for actors, for example, datasets on touch behaviour provide valuable insights into how people experience and understand fabrics.
- **Communication** between actors, for example, a digital procurement platform for biomaterials can accelerate biomaterial adoption.
- **Tracking** of resource stocks, flows, and impacts is needed, for example, via a National Materials Data Hub.
- **Research** to support new knowledge development that is inherent in advancing the systems' activity through circular economy hubs.

Societal requirements

A number of our contributions are social measures that would promote adoption of circular solutions by advancing a culture of belief related to care and value of resources, including:

- The **Social Production Network concept** would enrich the lives of people and regenerate community structures in a network of trust.
- The **Wellbeing Framework for Circular Consumer Experiences** can drive the social health benefits of circularity, as well as encourage acceptance of new materials produced from waste.
- The **Circular Materials Design Toolkit** and the **Maintaining Materials Toolkit** enable knowledge exchange and cooperation in supply chain ecosystems.

Circular Design Manifesto for a culture of circular economy in society

In a circular economy, everyone is a circular designer: people interact and exchange with others to innovate, problem-solve and help make the circular economy mainstream. This process encourages designers to:

Foster cultural shifts toward circularity

Move beyond the superficial. Go deeper. Situate design interventions in people's real-world contexts that respond to their community wants and needs. Create accessible, engaging narratives. We need stories.

Re-localise communities

Develop a place-based circular economy. Be inclusive. Make it collaborative. Involve many system actors with different perspectives, experiences and hopes. These are key to a holistic circular economy.

Be part of a supply chain system

Help supply chain actors reframe supply chains as systems of care, wellbeing and prolonged use.

Immerse in new realities

Create alternative circular realities through immersive, tangible and experiential engagement in concepts, artefacts and experiments. Nurture optimism. Imagine and design new futures you want to be a part of.

Create new practices

Be interdisciplinary. Promote design-led methodologies. Innovate to transform relationships between science and society. Connect people and advanced technologies for circular design.

Design for wellbeing

Stop the scare. Reduce waste. Embed wellbeing and circular design in consumer experiences. Encourage people to build long-term, evolving relationships with their garments.

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A full list of Textiles Circularity Centre publications is available on our website textilescircularity.rca.ac.uk

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