

Compatible blending for circular textiles with next-gen materials

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Abstract: Emerging next-gen materials such as recycled, renewable, or regenerative fibres promise lower impacts in resource extraction and transformation processes than their conventional fibre counterparts. These materials can be instrumental in a shift to a more sustainable fashion and textiles industry. A key contribution to this transition relies on reducing impacts and waste through circular design measures such as increasing lifespans and recycling at end of life. However, as these next-gen materials tend to have properties and costs that deviate from optimised industry norms, they are often used in incompatible blends, thus negating their circularity potential. This paper puts forward a framework to understand material flows and lifecycles as a relation between fibre type and recycling route for designers to operate within the principles of circularity. The research results in a guidebook to support designer's choices of material combinations in line with recycling trajectories, and in a series of samples produced by industry project partners and students demonstrating the application of the framework. The samples use a selection of five example next-gen materials, which are integrated to each practitioners' applications and aesthetics. The underlying aim of the research is to foster a systemic approach to textile design with an increased understanding of material properties and their relation to current and emerging recycling technologies.

Introduction

The fashion and textiles industry is reckoning with its large, negative impact on the social and climate crises of our time and attempting a shift in the right direction (Fashion for Good & Accenture Strategy, 2019; Global Fashion Agenda, 2017). Next-gen materials (Sustainabelle, 2024) or 'preferred materials' (Textile Exchange, 2020) are seen as a promising category of materials with lower impacts than conventional fibres. As defined by (Duarte Poblete et al., 2024) these emerging materials which respond to sustainable and circular design expectations include materials from waste, renewable, and biofabricated materials. These materials can contain recycled textiles or food and agricultural sources to name but a few.

As part of a decarbonisation agenda, they have potential to reduce our dependence on virgin resources and intensive agriculture (Canopy, 2018) and could contribute to a greater diversity and sovereignty of materials (Coléchi, 2023). The benefits of these materials' overall environmental impacts are beginning to be quantified, with WRAP assigning a potential 12% carbon reduction and 18.2% water use reduction to the use of recycled fibres such as

mechanically recycled polyester and cotton in fashion (WRAP, 2023).

Designers and innovators are increasingly expressing interest in using these materials, as demonstrated by the growing communities brought together under initiatives such as the Future Fabric Expo (Sustainable Angle, 2024) or the Biofabricate events (Biofabricate, 2024) and they are being supported by the investment community to develop at pace (Sustainable Ventures, 2024). The exciting innovations involved in fibres from mushrooms or algae and the sustainability credentials connected to the use of recycled fibres are seen as great assets to designers hoping to do the right thing. However, there are a range of barriers to their use in textile products. These materials often differ in their technical performance to widely used conventional resources and can pose challenges when incorporating them into established production lines or when considering the technical performance or durability of textiles. They also tend to come at a price premium compared to optimised and large-scale fibres. This results in them regularly being blended with other less novel fibres to compensate for performance or price deviations. However, if the materials in these blends belong to different recycling processes,

then the textile is no longer recyclable and will be destined for downcycling, landfill or incineration.

In a circular textiles economy, multiple strategies to increase the lifespan of materials coexist. Blending different resources may extend their use by decreasing their propensity to wear and tear (Hardingham, 1978). The use of next gen materials may increase emotional durability through a connection to the materiality of a product (Earley & Forst, 2023). Ultimately, products and materials will reach the end of their useful life, and, as a last resort, this is where textile to textile recycling must remain an option for the resources to be recirculated as new fibres.

The aim of this work is therefore to help increase the uptake of these next-gen materials with great potential for reduced impacts, while recommending their use in textiles that are designed for longevity and recycling at end of life, therefore balancing blending for longevity with design for recycling. This paper lays out the work carried out to provide designers with a guidebook and illustrative textile samples that can increase their awareness of materials lifecycles.

Methods

This work was carried out as a one-year collaborative project between researchers at a higher education institute and a range of non-academic partners representing key stakeholders in sustainable fashion such as community activators, textile designers, and recyclers. It was funded as part of the Future Observatory Design Exchange Partnership, an exciting new programme fostering collaboration between design research and businesses.

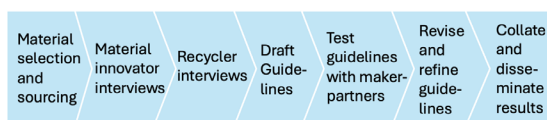


Figure1. Project workflow

The brief presented to the project maker-partners asks them to interpret the circular textile design guidelines in their own practice, using the selection of next-gen materials provided. The makers were provided with the draft guidelines and the selected materials in sufficient quantities to produce examples, and

were supported with regular meetings throughout the project.

The project is rooted in design practice research. As described by Kaszynska and Kimbell (2024) this approach responds to three conditions, the three S's: that it should be *sited* in a real world situation, here the textile production system, it is *situated* in relation to a body of academic knowledge, here the theoretical explorations of a circular economy for textiles, and *situating*, producing objects and knowledge that effect a transformation. As also defined in *The Routledge International Handbook of Practice-Based Research* (Vear, 2022), one of the distinguishing characteristics of practice research is the role of the artefact and the forms of knowledge that arise from it. In this sense, the making of textile samples and their contextualisation within the developing frameworks for circular design are key contributions of the work.

The *site*, or context, for the research is understood as the rules and parameters set by the supply chain for textiles from production to recycling. The guidebook that constitutes a key output of the work is a visual summary and representation of the elements and interconnections in the textile recycling lifecycle. To gather the knowledge relative to this fluctuating field and test the assumptions described in the guidebook, a series of interview with material innovators, designers, and recyclers was carried out. The interviews took place online, first in the early stages of the work to define the parameters required for the guidelines, and then in the final stages to confirm the recommendations with experienced stakeholders in recycling systems. The interviews with the material innovators were based on a full lifecycle description approach (Forst et al., 2023) and enabled a comprehensive understanding of the material's properties and transformation processes to related them to recycling criteria. The information concerning recycler parameters was drawn from previous project experience and then validated in a short series of discussions with experts in the field, most notably with The Circular Textiles Foundation, an organisation which acts as a mediator between brands and recyclers to enable change in the sector.

The work is *situated* within the context of sustainable material innovation. To make the

outcomes concrete, five materials were selected for experiments. They each represent a type of next-gen material that is currently finding its way into the market. The selection comprises of a recycled cotton, a recycled wool, a bio-polyester, a yarn from pineapple leaves, and a regenerated cellulose from hemp and flax waste. These materials represent the type of resources that designers currently strive to include in their collections as a strategy to reduce environmental impacts.



Figure 2. Selected Next-Gen materials

As a means for *situating* the knowledge of recyclability criteria explored in this work, a series of samples were produced collaboratively with a range of actors in the textile design system. Three partners provided their in-kind support to this work by taking on the emerging guidelines in their own commercial or community-based practice. These textile designers were selected to represent a spectrum of practices 'from contract to community'. One designer produces interior textiles manufactured in the UK for luxury homes and offices, one makes hand-woven designs for the fashion industry, and the third engages with a community of sustainable fashion enthusiasts through a monthly knit club. In addition to the independent practices of these partners, guided experimentation was carried out by a cohort of textile design students

in undergrad and postgrad courses. Reflecting on the ease or challenges in adopting the circularity guidelines for next-gen materials with each of these stakeholders supported the iterations and refinement of the project outcome. The textile samples produced by each maker constitute a key outcome as an illustration of the application of the theoretical framework for circular textile design with next-gen materials.

Results

Two key project outcomes aim to disseminate the knowledge of circular textile design across its target community of textile designers and makers.

The Compatible Blending Guidebook

The guidebook for circular textile design with next-gen materials¹ constitutes a resource for designers wishing to take onboard the project principles. This succinct reference identifies the pathways to recycling for eight material types which include the five chosen next-gen materials explored in the project as well as others they can be used in combination with. By using the diagram which is at the centre of this guidebook, designers can identify what combinations of fibre types can be traced to the same recycling process and therefore be used together in the same textile. The flow chart is meant to act as a checkpoint when designers are considering combinations of resources for various aesthetic or functional reasons.

The guidebook is targeted to textile designers who have a direct influence on multiple stages of the creative process, therefore focusing on smaller studios. The guidebook aims to support them when sourcing yarns and considering how to combine them in woven or knitted materials. While the same logic can be used by designers in other fields involving next gen material sourcing, the project targets this specific type of designer-maker as those closest to the fibre's properties. The guide recommends that designers access next-gen materials as yarns in their least processed forms, and indicates the requirements of each recycling process regarding dyes and finishes as well as concerning blends. While the guidebook has mainly been used in the creation of new textiles inside the project, it is also adapted to repair

¹ Available at
<https://ualresearchonline.arts.ac.uk/id/eprint/23536/>

practices in which the fibre types of yarns used for patching or darning must be compatible to base fabric.

The guidebook consists of three double spreads, the first one offering an introduction to the overall theory for circular textiles,

adoption of emerging materials (Forst et al., 2023). These antecedents contribute to a better understanding of the correlation between textile properties and recyclability specifications which translates to the context of emerging materials in this work. The guidebook offers a simplified classification of material types according to

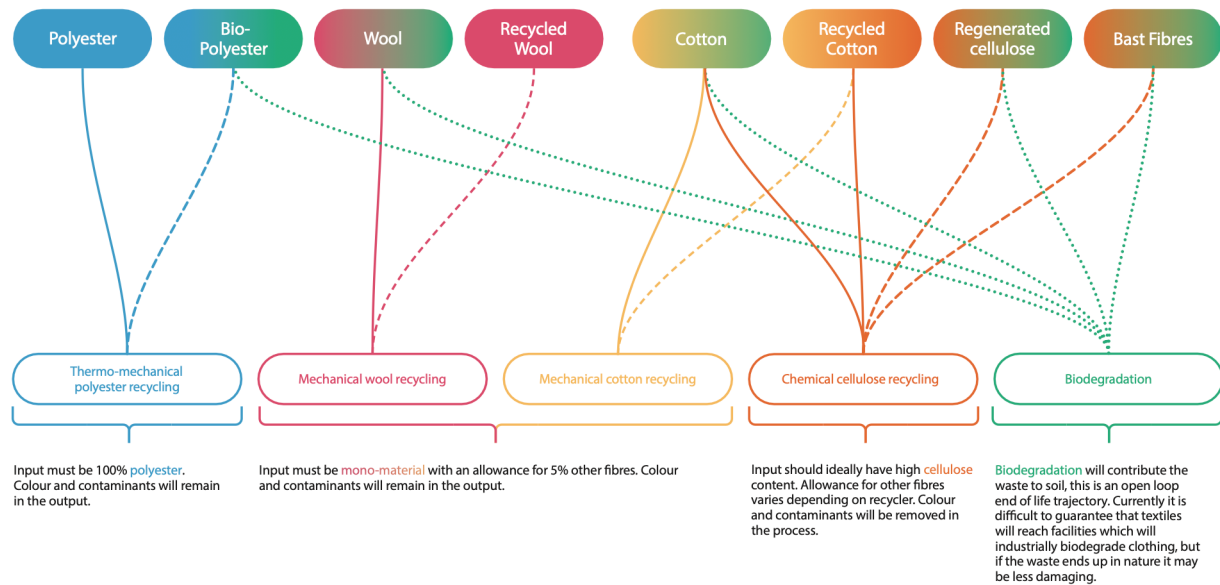


Figure 3. Compatible blending diagram

contextualising the recommendations within current and emerging recycling systems. The second puts forward a list of questions for designers to get to know their chosen Next-Gen material better. The third is the most important, and shows the diagram for compatible blending seen in figure 3. This guidebook was iteratively tested and refined through discussion with the project partners and in workshops with members of the community. Through these exchanges, the resource was sense-checked and made more user friendly to accompany the making process. A key modification in the trials

was to remove detailed information on material production and transformation and focus on a small set of questions and prompts for designers to interrogate their choice of materials at the start of the creative process.

The guidebook builds on previous work exploring material circularity either in creative practice (Forst, 2020), or in industry collaborations (Forst et al., Forthcoming). It is also informed by research on material literacy and transparency aiming to support the

their presumed recycling path, thus highlighting what fibre types can be compatible for recycling in blends. The recyclability criteria are built on interviews with recyclers and previous work in this field, they combine current technology requirements with assumptions for the evolution of the sector. In the diagram, the paths to recycling that are not yet workable at scale but which might be improved in the future are represented as a dotted line. The underlying aim of the guidebook is to provide a framework to understand material flows and lifecycles as a relation between fibre type and recycling route for designers to operate within the principles of circularity.

Demonstration Samples

Focusing on tangible textiles making, a key component of this work's results is the range of samples produced to exemplify the use of the guidelines. The designer-maker partners each interpreted the guidelines in their own practice, as is intended for these resources to be used beyond the timeframe of the project. During the

making process, frequent exchanges with the designers enabled regular feedback into the guidelines to increase their useability.

Samples were produced by different partners and participants in the research using the five selected next-gen materials in combination with a range of other sustainable or conventional materials. They demonstrate the range of composites that can be creatively assembled while fitting within the parameters of circularity, including durability through well thought-out material combinations, and be recycled at end of life. In these samples, blending occurs mainly at the yarn level, or more rarely, at the fibre level when the yarns sourced are already a combination of different fibres. This type of material combination fits with the experience of a textile designer sourcing yarn. It can be contextualised within a broader landscape of blend types as defined by Hall *et al.* (2023). The samples demonstrate a range of uses of the selection of next-gen materials, from technical properties aiming for physical durability, to emotional connections through the poetic power of natural fibres.

Two samples are selected and described here to demonstrate the range afforded by the circularity and compatible blending guidelines. These were produced in radically different settings with one being developed as sample for commercial applications, fitting within the company's identity, and the other made by an amateur textile enthusiast with strong crochet skills as a reflection on the material properties and no specific application in mind.



Figure 5. Wool and cotton sample made by Salt.

This sample explores the combination of a cotton and a wool yarn to provide complementary aesthetics and durability performance within the same material for an interior application. As the two resources are

listed as incompatible for recycling in the guidebook, a design for disassembly approach is used, with a soluble yarn (visible in red) to connect the two layers of the textile. This work is in line with the partner's sober aesthetic which emphasises the material's qualities and explores themes of emotional durability.



Figure 6. Crochet sample with recycled wool (green) and Irish wool (white) made by a community workshop participant.

This crochet sample is made from a combination of recycled wool and virgin Irish wool. The participant started working with the recycled wool and then saw that it was liable to break while she was crocheting, she decided to reinforce the structure by replicating the zigzag pattern as an overlay, using a compatible material for mechanical wool recycling. This is one of 21 samples made by participants in the second of two community workshops held to reflect on the guidebook in development.

The portfolio of textile samples that is created as an interpretation of the guidelines serves as inspiration for other designers to take onboard when considering circular design with next-gen materials. It also provides a demonstration for the use of the five selected materials in a range of applications. These samples demonstrate a textile design approach which is based on an understanding of materials in a future recovery context, informed by the categorisation provided in the guidebook. The samples harness the aesthetic and functional properties of the next-gen and other chosen fibres in complementary blends, showing how the shortcomings of one resource can be compensated by another while still fitting in a circular textile-to-textile recycling flow.

Discussion

Next-gen materials are still in the process of infiltrating the textiles landscape, but it is not too early to consider how to use them in line with circular design principles. These materials offer great promise for reduced impacts in resource extraction and transformation processes (Solanki, 2018), yet they can easily be integrated into textiles and products in ways which negate their end-of-life recovery (Ellen MacArthur Foundation, 2017). To leverage the sustainability potential of next-gen materials, they must be understood across a full life cycle perspective, including design for longevity through strategic blending, and circulation of resources. It is therefore key to lay out the parameters for recyclability of these emerging innovations whether they are used as mono-materials or in blends.

Currently recyclers are limited in their ability to accept non-standard materials or materials that represent a small share of the market as efforts are geared towards the bulk of textile waste made of conventional cotton and polyester. However, the technology holds potential for the recycling of fibres which are similar to more conventional ones such as bio-polyester theoretically being compatible with polyester recycling, and viscose or other regenerated cellulose being recycled chemically with cotton. This research speculates a future in which circularity is the norm across all fibre types and a balance between material selection and future recyclability has been achieved. In line with this exploratory approach, it is mainly directed to micro and small businesses in the fashion sphere, who are some of those with the most freedom to spearhead the circular material landscape of the future, and yet face strong barriers to accessing innovative materials. The guidebook offers itself as a framework to interrogate textile design practice starting with where materials are from and how they are made, all the way to thinking about their next life through recycling.

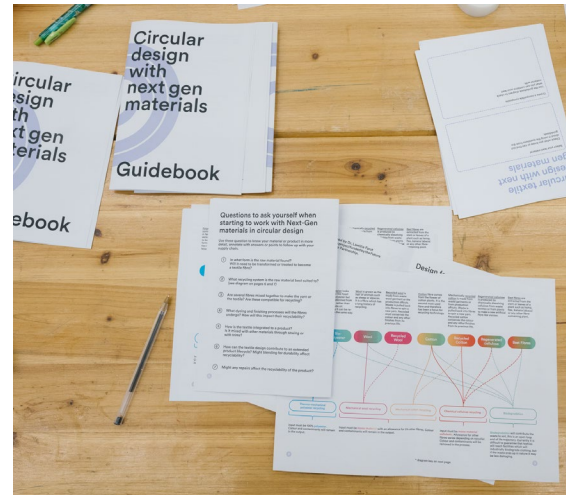


Figure 7. The guidebook in use during a workshop.

It aims to influence the practice of designers towards a holistic, circular approach. As put by one of the students participating in the project:

“Typically, my work relies more on intuitive and spontaneous creative processes, whereas this time I had to follow specific material choices and combination guidelines from the handbook. This taught me to think more systematically about the properties of materials and how to combine them effectively, bringing new challenges and insights to my creative process.”

The collaborative process of developing the guidebook and testing it through textile sampling has highlighted some of the challenges faced by designers aiming to include next-gen materials in their offer.

There is still a lack of transparency over the composition and the processes involved in these materials, leading to difficulties in assessing their relative sustainability and their adequate recycling path. The guidebook offers a simple list of questions that designers can use as a starting point to open discussions with their supply chain to better understand materials.

Accessing next-gen materials remains an issue for designers as minimum order quantities or costs can be prohibitive. Relationship building with innovators can be a slow and time-consuming process (Lee et al., 2020) which designers can ill afford. In this work, sourcing the materials centrally removed a barrier to access these fibres and enabled faster experimentation with the makers.

Conclusions

To achieve a circular textiles economy all materials must be considered as part of a journey from resource, to product, and back to resource. To match the impact reduction potential of fibre-to-fibre recycling (Nellström et al., 2025), alternative fibres which offer a chance to reduce the industry's reliance on virgin and fossil-based materials must also be considered in terms of their circulation through use and recycling systems. Optimal properties can be achieved through blending, leading to longer lifespans for products designed with functional and emotional durability in mind. This paper presents a guidebook with a material flow diagram intended for designers to follow when using innovative materials. This method is supported by a range of textile demonstrators showing the broad spectrum of creativity available with circularity parameters. While recycling technology is still evolving and improving, broad categories for compatibility between fibre type and recycling route are defined here. These serve as a framework for designers to adopt a circular textile design approach when using next-gen materials. The samples produced by the project partners show that creative expression can be supported within circularity parameters. There is an opportunity to review the samples produced by following the guidelines and assess them in terms of their functional and emotional performance to better define their role in extended material lifetimes. Future work may also expand on a wider range of fibres and develop more technical details for combination techniques and approaches for circular textiles.

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