Royal College of Art

Materials Science Research Centre

Burberry Material Futures Research Group

Annual dissemination event report

THE LONDON DESIGN FESTIVAL

Special thanks go to:

Burberry Foundation

Imperial College London: Dr James MacDonald, Dr Hannah Leese, Prof. Paul Freemont, Prof. Milo Shaffer.

University of York: Professor Simon McQueen-Mason, Dr Alexandra Lanot and Heather Eastmond.

University of Cambridge: Professor Steve Evans.

DM experts (Mark Hester, Cindy Kohtala, Mariale Moreno, Tom Leech, James Tooze, Hannah Stewart and others) for evaluating the Circular DM conceptual model.

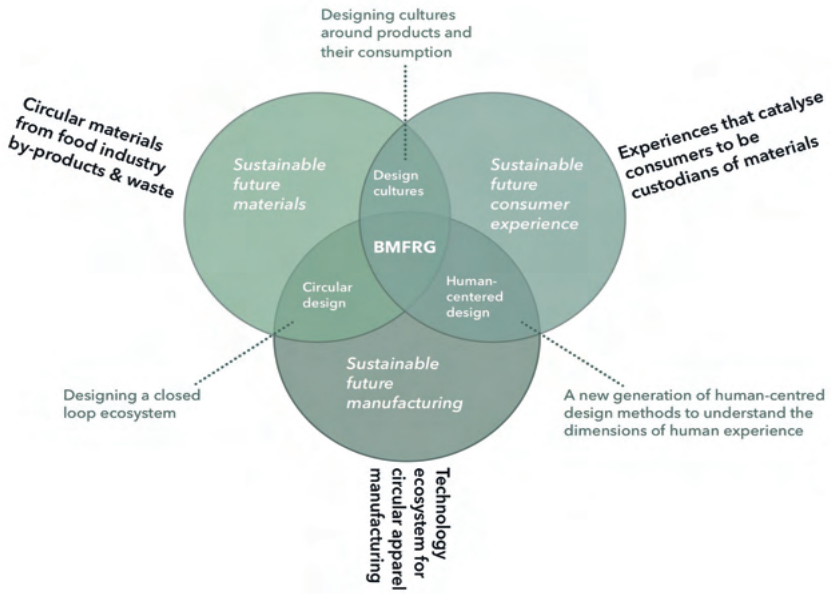
Case companies who attended the interviews.

Graphical layout design: Aine P

In 2017, the Burberry Foundation bestowed a £3 million gift on the Royal College of Art to establish the Burberry Material Futures Research Group, and to expand the Burberry Design Scholarships scheme to support more than thirty students from 2017 to 2023.

The Burberry Material Futures Research Group (BMFRG), marking the first phase of the RCA's Material Science Research Centre, aims to inspire creativity and pioneer more sustainable materials and techniques in the UK creative industries through researching sustainable future materials, manufacturing and consumer experience. By taking a systems approach to materials research that proposes a new coupling of the use of materials resources to human wellbeing and economic development, we aim to offer new realities that will help society transition to a more sustainable existence.

Our systems approach integrates three main themes - **Sustainable Future Materials**, **Sustainable Future Manufacturing** and **Sustainable Future Consumer Experience**:



Integration of the three themes of BMRFG

Read more about BMFRG at:
www.rca.ac.uk/research-innovation/materials-science-research-centre
www.linkedin.com/in/burberry-material-futures-research-group-4026a7184

The Burberry Material Futures Research Group is comprised of:

Professor Sharon Baurley, Chair and Director
Dr Bruna Petreca, Research Fellow in Human Experience & Materials.
Dr Miriam Ribul, Research Fellow in Materials Circularity for Distributed Manufacture.
Professor Marianna Obrist, Professor of Multisensory Experiences, University of Sussex, Visiting Professor for the Sustainable Future Consumer Experience theme.
Professor Philip Purnell, Professor of Materials and Structures, University of Leeds, Visiting Professor for the Sustainable Future Materials theme.
Professor Steve Evans, Director of Research, Institute for Manufacturing, University of Cambridge, Visiting Professor for the Sustainable Future Manufacturing theme.
Katrine Hesseldahl, PhD candidate, Sustainable Future Consumer Experience theme.

Annual dissemination event

Each year the Burberry Materials Futures Research Group hosts a public dissemination of its research during the London Design Festival. In 2019, the Group hosted a half day symposium and a small exhibit of the Feasibility phase of its research programme on Friday 20th September 2019 at the Royal College of Art, London.

www.londondesignfestival.com/event/burberry-material-futures-research-group-symposium

Symposium

Professor Sharon Baurley introduces the agenda of the day

Symposium schedule

1.45pm Introduction by Sharon Baurley, Chair and Director

2-3pm Sustainable Future Consumer Experience

The Sustainable Future Consumer Experience theme uses a Living Lab methodology to investigate the design of experiences around the consumption of products that would catalyse consumers to be custodians of materials, and therefore stakeholders in materials circularity.

Speakers:
Bruna Petreca, Research Fellow in Human Experience and Materials
Alexa Pollmann, Research Associate
Katrine Hesseldahl, PhD candidate
Marianna Obrist, Professor of Multisensory Experiences/Interfaces, University College London, Visiting Professor for the Sustainable Future Consumer Experience theme.

3-4pm Sustainable Future Manufacturing

The sustainable future manufacturing theme focuses on the capabilities, knowledge, digital platforms and enabling technologies required to support local, sustainable and distributed manufacturing models, facilitating designers and SME brands to design and manufacture garments within a circular system.

Speakers:
Patrick Hennelly, Research Fellow in Distributed Manufacture for a Circular Economy
Aine Petrulaityte, Research Associate
Steve Evans, Director of Research, Institute for Manufacturing, University of Cambridge, Visiting Professor for the Sustainable Future Manufacturing theme.

4.20-5.20pm Sustainable Future Materials

The Sustainable Future Materials theme drives the development of fibres and flexible bio-based materials from food industry by-products and waste that are regenerative and circular for a scalable and sustainable manufacture of textiles with both existing and expanded processes.

Speakers:
Miriam Ribul, Research Fellow in Materials Circularity for Distributed Manufacture
Tom Leech, Research Associate
Phil Purnell, Professor of Materials and Structure, University of Leeds, Visiting Professor for the Sustainable Future Materials theme
Professor Simon McQueen - Mason, Chair in Materials Biology and Director of the Centre for Novel Agricultural Products. University of York
James MacDonald, Research Fellow, Imperial College London.

5.20pm Closing remarks

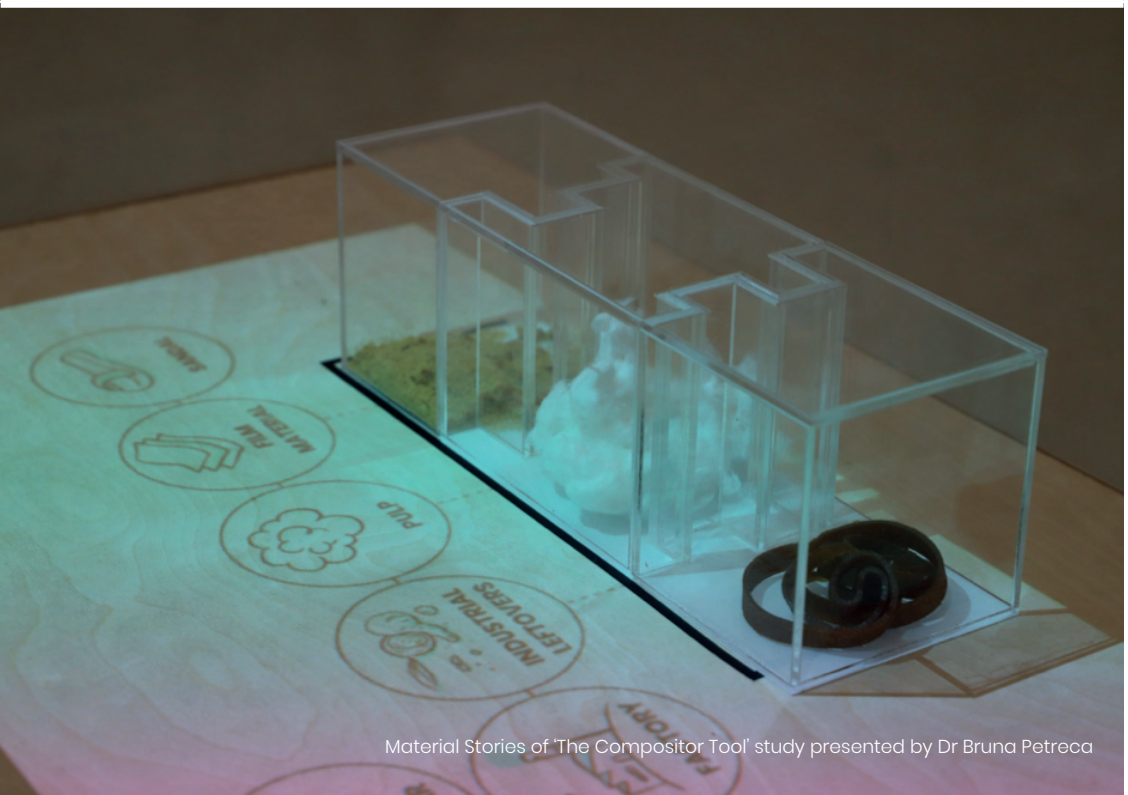
Sustainable Future Consumer Experience

The Sustainable Future Consumer Experience theme investigates the design of experiences involved in the consumption of products that would catalyse consumers to be custodians of materials, and therefore stakeholders in materials circularity. All of the research efforts are directed at empowering consumers to have a key role, and to actively participate in enabling circularity.

The session started with Dr Bruna Petreca introducing the Consumer Experience strand, and the feasibility studies that have been carried out through the year to further inform the development of the programme of research. Exploring our main research question “How can designed experiences catalyse people to be custodians of materials, and therefore stakeholders in material circularity, as a circular design strategy?”, our feasibility studies included testing of designs of experiences that enable the configuration of products, immersive storytelling about materials provenance, future life-cycles, and about the properties of materials. A Living Lab methodology – an experiential environment where diverse methods are used to design and test realities of the future with people – was used to investigate the design of experiences. We aimed to understand if and how new interaction techniques might enable consumers to have more creative and informative interactions to create a deeper connection between people and products, and the materials in their products.

The study entitled ‘The Compositor Tool’, presented new ways of understanding materials’ past, present and future, to inform how people select and configure materials to build their own product (shoe). It consisted of four experiences: (i) component selection, (ii) material stories (understanding provenance), (iii) material futures (future life cycles), and (iv) materials gym (to experience the properties of materials). These were used to provide compelling experiences of materials, to support people in the selection of materials and configuration of products in engaging and playful ways. By using analogue and digital means to add extra layers of information, people were enabled to have a deeper sensory engagement with materials, and to project them in the past (e.g. materials provenance, other applications for the materials) and in the future (e.g. suggestions for pairing the product components, performance and care of the product). The studies were conducted at the Hockney Gallery, Royal College of Art, from 25th July to 1st August 2019. A total of 16 participants who voluntarily responded to the call for participants experienced The Compositor Tool and contributed their opinions.

The initial insights highlight the importance of: (i) customisation for a long life - design to enable people to express their identity through articulating their perceptions and preferences related to the properties of materials; (ii) sustaining relationships – design cultures of products that introduce circularity as part of consumer experience of products and design brands, (iii) living with new materials – exploring the role of design in promoting a shift in consumer perception of the value, desirability, quality, and durability of circular materials/products.



Material Stories of 'The Compositor Tool' study presented by Dr Bruna Petreca

Following this initial set of studies, we have devised the following sub-research questions, which we will continue to explore in the next phase of our research programme:

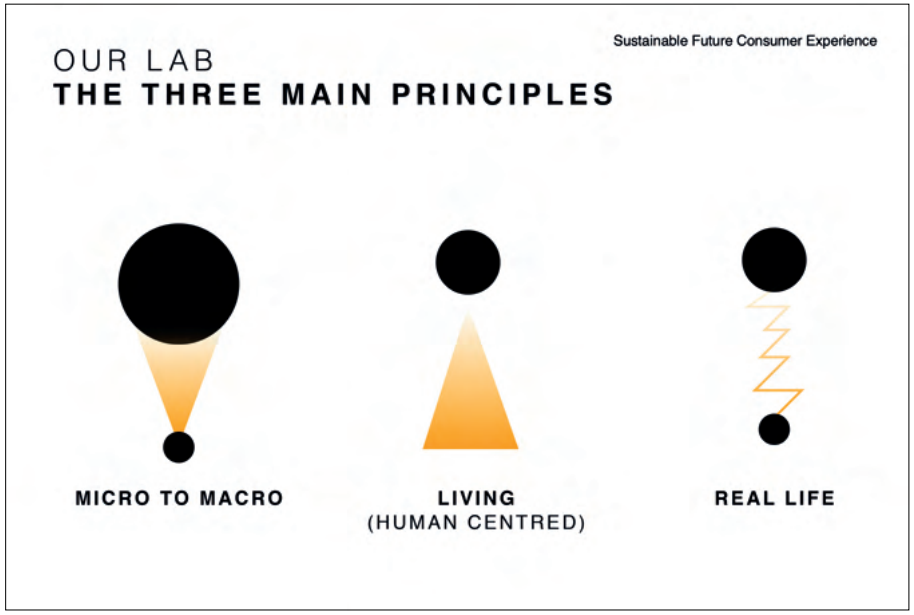
RQ1: What are the requirements of in-store experiences that would satisfy human needs for self-expression, self-actualisation, society, and therefore motivate consumers to participate in the customisation and design of products?

RQ2: What methods would translate the sensory and physical properties of materials into experiences that consumers can engage in, so that they understand materials and their own preferences, and to articulate those as part of a customisation process?

RQ3: What are the requirements of analogue-digital experiences related to materials provenance and potential future life-cycles that would enable consumers to have a deeper engagement with materials?

Dr Bruna Petreca introduces Sustainable Future Consumer Experience theme

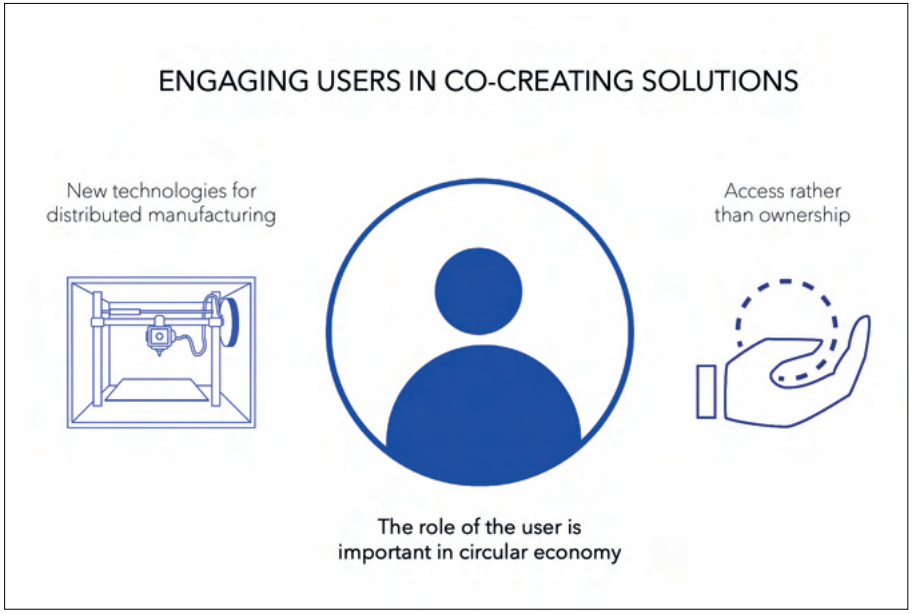
Speakers: Sustainable Future Consumer Experience



Main principles of the Living Lab.
By Alexa Pollmann

Alexa Pollmann:
Compelling Experiences in a Retail Reimagined

Alexa Pollmann presented how we are adopting the Living Lab methodology and enhancing it with the use of innovative and creative technologies, in order to identify the nature and characteristics of catalysts that would turn consumers into prosumers (someone who actively engages in the support of a sustainable approach and understands production, and impact of purchased goods). With the Living Lab, we will create an experiential environment for design ideation, discussion and testing amongst the researchers and stakeholders. To achieve this, we will use diverse design methods and innovative technologies (e.g. sensor-based technologies, mixed reality immersive technologies) to co-create with people new realities of Circular Consumer Experiences. As Alexa conceptualised, the Lab will be based on 3 main principles: Lab Culture (looking at things small scale before scaling them up), Living Aspect (based on a Prototype-Play approach, we will iteratively design, create and test experiences, starting with low-tech/small scale prototypes, but from the outset making our research accessible to live, empirical studies), and Real-world Applications (the most promising designs in small scale prototypes, will be paired with real-world industry partners or organisations to take experiences to implementation, and to test in-the-wild.



User role in Circular Economy. By Katrine Hesseldahl

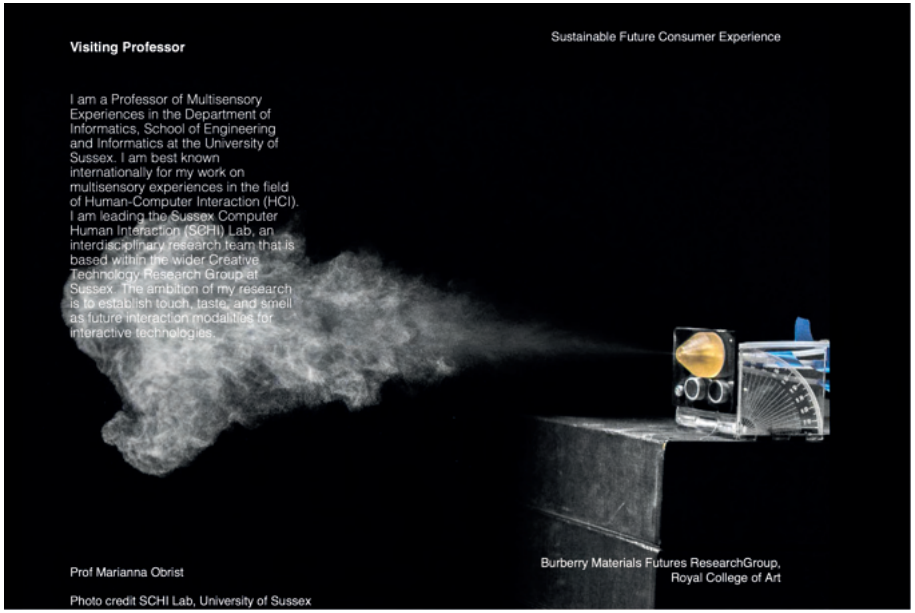
Katrine Hesseldahl: CE products and systems

Katrine Hesseldahl introduced her research proposal, and explained how it complements the theme's endeavour. The primary aim of her project is to establish a strategy for designing garments and consumer experiences that contribute to a circular economy by inviting and empowering consumers to participate in closing the material circles. The design strategy is developed through a practice-based project, through designing a collection of key garments which map out key moments in a product's lifecycle where users can contribute to the circular flow. Through this design experiment, Katrine intends to explore and establish beneficial relationships between designer, product and consumer in order to realise the potential of engaging the user in the circular economy.

Marianna Obrist: Analogue-digital interfaces for multisensory experience

As we now inhabit both realities (physical and virtual), we are very interested in investigating the diversity of experiences that we can design in this space – perhaps adding layers to products that could not exist otherwise, or even stimulating us in ways that we don't yet know. Professor Marianna Obrist brought us a glimpse of her research as Professor of Multisensory Experiences by sharing diverse projects that illustrate how she has established dedicated experimental spaces for multisensory experiences research, including a dedicated olfactory interaction room and novel scent-delivery device that is currently commercialised through a Sussex University start-up (i.e. OWidgets).

Professor Marianna Obrist introduces her work at the BMFRG symposium



Sustainable Future Manufacturing

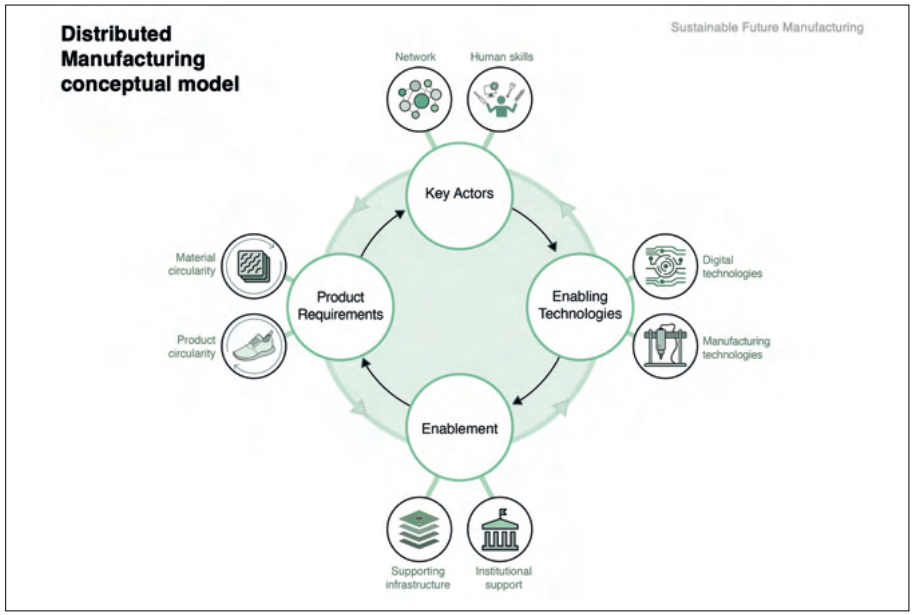
The Sustainable Future Manufacturing theme investigates what technologies, knowledge and capabilities need to be developed that would enable UK SME apparel brands and designers to design and manufacture the circular life of garments. The feasibility study focused on developing and testing a Circular Distributed Manufacturing model for BMFRG. The research presented at the symposium included a literature review on Circular Economy and Distributed Manufacturing, and Circular Distributed Manufacturing conceptual model development, its testing and insights from exemplar case companies.

The Sustainable Future Manufacturing session began with an introduction to the theme by BMFRG Research Fellow Patrick Hennelly (RCA), who also introduced the definitions of Circular Economy (CE) and Distributed Manufacturing (DM) with an emphasis how DM defers from centralised mass production.

The future plans for the Sustainable Future Manufacturing research are to explore how materials databases and platforms can support circular product manufacture and what are the implications for supply network design. Additionally, we will investigate how physical manufacturing technologies need to be developed to enable a more circular model of production, and to understand what the requirements for cloud manufacturing and digital platforms are to improve product circularity and life-cycle management.

Patrick Hennelly introduces
Sustainable Future Manufacturing theme

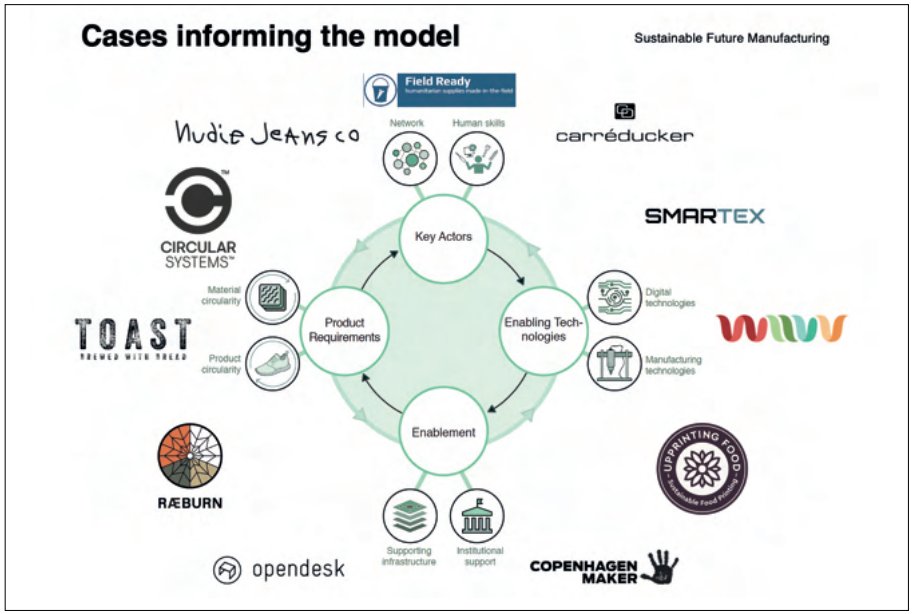
Speakers: Sustainable Future Manufacturing



Distributed Manufacturing conceptual model for BMFRG. By Aine Petrulaityte

Aine Petrulaityte: The development of Distributed Manufacturing conceptual model

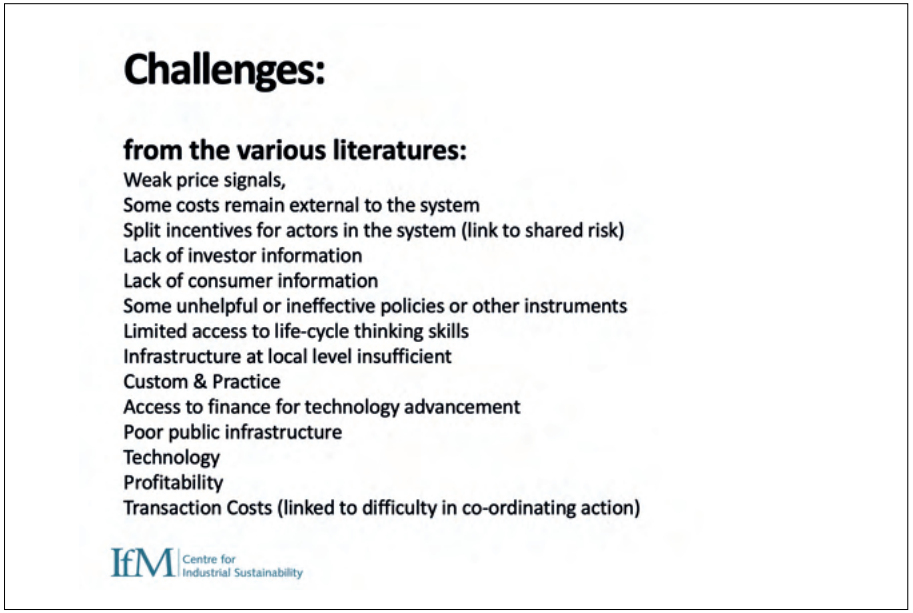
The aim of the model was to understand structural and infrastructural characteristics and drivers for Distributed Manufacturing elements relevant for BMFRG. First of all, Aine introduced four DM elements identified through a literature review and from previous research by Patrick Hennelly and herself: Circular product requirements, Enabling technologies, Enablement, and Key actors. Additionally, Aine specified how DM features, such as on-demand production, monitoring of product performance, etc., can be applied along the product life cycle to enable Circular Economy. The conceptual model (Figure above), has been built by Patrick and Aine by applying the literature review, secondary case study analysis, and primary data from previous research by both researchers. Data collected using all three research methods allowed the identification of drivers, attributes and challenges for each DM element, which were later clustered and synthesised to address the research aims of BMFRG. Finally, the conceptual model and its elements has been validated with DM experts. The final model comprises the following elements (with the first two being key for future research): **1.Product Requirements**: Materials Circularity (sustainable materials, materials provenance, waste ownership); Product Circularity (product architecture, circular economy strategies, track-and-trace). **2. Enabling Technologies**: Digital Technologies (material libraries, digital platforms, cloud manufacturing, software); Manufacturing Technologies (physical manufacturing technologies, additive manufacturing, availability/capacity, mini-factories). **3. Enablement**: Supporting Infrastructure (circular economy-enabling infrastructure, availability); Institutional Support (institutional incentives, policies). **4. Key Actors**: Network (Stakeholders/Communication) (key stakeholders, consumer-facing strategies, communication); Human Skills (knowledge and capabilities, skill shortages, training and education).



Cases informing the Distributed Manufacturing conceptual model for BMFRG. By Patrick Hennelly

Patrick Hennelly:
Cases informing the Distributed Manufacturing conceptual model

Patrick Hennelly continued with 'Cases informing the model'. Patrick presented research involving unstructured and semi-structured interviews with respondents representing 11 exemplar case studies that are implementing CE and/or DM models. Companies interviewed included: **Nudie Jeans** (jeans retailer with consumer product return and repair strategies); **Field Ready** (made-in-the-field humanitarian supplies with knowledge sharing to enable replication of models globally); **Carreducker** (bespoke London shoemaker); **Smartex** (AI-based solutions for textile manufacturers to enable zero-waste production); **WIIVV** (personalised footwear made using additive manufacturing); **Upprinting Food** (3D printed snacks made of recycled bread using modified additive manufacturing process); **Copenhagen Maker** (maker community connecting key infrastructure in the city); **OpenDesk** (office furniture for on-demand local production); **Reaburn** (fashion studio that uses recycled materials); **Toast** (Beer made of local bread waste); **Circular Systems** (material science company transforming waste into materials for fashion industry). Patrick presented the key findings which were clustered to illustrate each DM element in the conceptual model: Product requirements (Access to materials, Provenance, Modularity/Architecture); Enabling technologies (Modifying, Scaling, Connecting); Enablement (Infrastructure/Availability, Institutional Support, Policy Push); Key Actors (New Production Knowledge, Coordination, Knowledge Transfer Local to Global).



Circular Economy implementation challenges. By Steve Evans

Steve Evans:
Why is going Circular hard? & How are some succeeding?

Professor Steve Evans presented CE challenges from various literatures, including limited profitability, lack of information to consumers and investors, poor public infrastructure, etc. Steve highlighted three key issues preventing CE implementation: The challenges of creating circular business models, implementation of these business models, and a shortage of circular materials market places. Steve introduced success stories of companies, such as Elvis & Kresse, British Sugar, Riversimple and Ecover, who implemented “less linear” business models, that can be called a pathway to a circular future.

Professor Steve Evans presents CE challenges and success stories

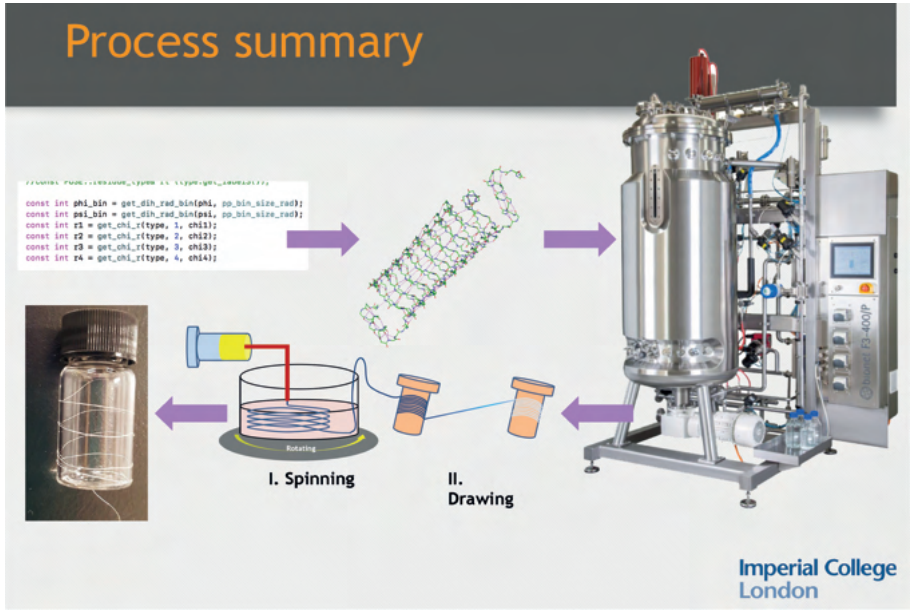
Sustainable Future Materials

The Future Sustainable Materials theme investigates how circular fibres and flexible materials for textiles from food industry by-products and waste can be designed and developed. During the feasibility phase, the research investigated the technical and circular feasibility of two biopolymers that are found in food and in textiles, namely cellulose and protein. The aim of the feasibility phase was to identify the material focus for the Sustainable Future Materials theme between September 2019 and July 2022. Exploring the question 'Is it possible to design and develop circular materials from food industry by-products and waste?', we have developed proof of principle studies which were conducted in collaboration with the University of York and Imperial College London.

The Sustainable Future Materials session began with an introduction to the theme by BMFRG Research Fellow, Dr Miriam Ribul (RCA). The session concluded with a summary of the findings from the feasibility phase by Miriam Ribul. The context of the Sustainable Future Materials research is the development of textiles from food industry by-products and waste in order to free up land use for food production for a global growing population and to enable biodiversity. By exploring food, we create a new diversity of materials to provide alternatives to polyester, cotton and animal fibres. The research is aligned with, and at the intersection of the Ellen MacArthur Foundation 'Make Fashion Circular' initiative for creating new textile economies and the 'Food Initiative' to make the most out of food. The work will explore local materials in two of the three EMF flagship cities of Sao Paulo (GCRF networking grant from the British Academy) and London.

Dr Miriam Ribul introduces Sustainable Future Materials theme

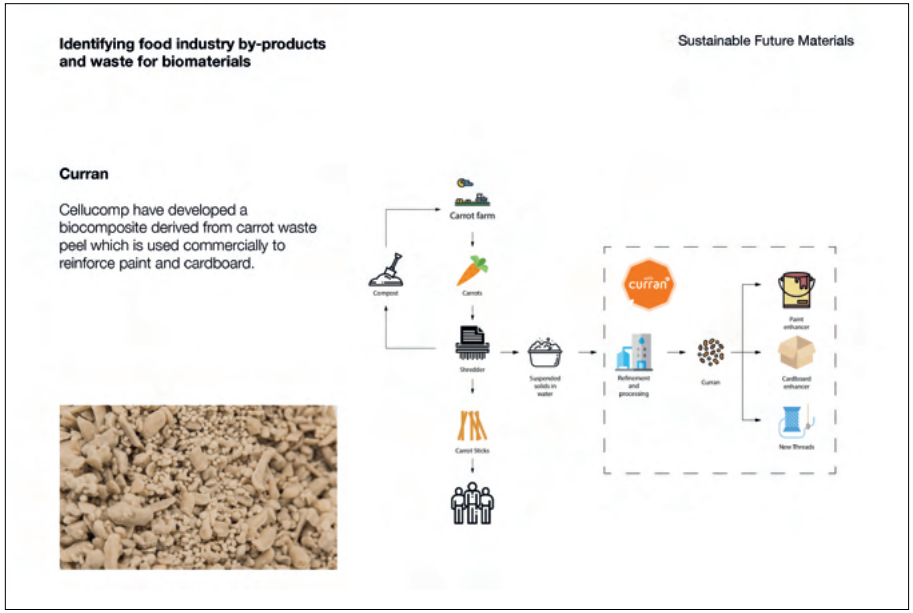
Speakers: Sustainable Future Materials



Computationally designed protein fibres.
By Dr James MacDonald

James MacDonald:
Synthetic designed polypeptides for high performance textiles

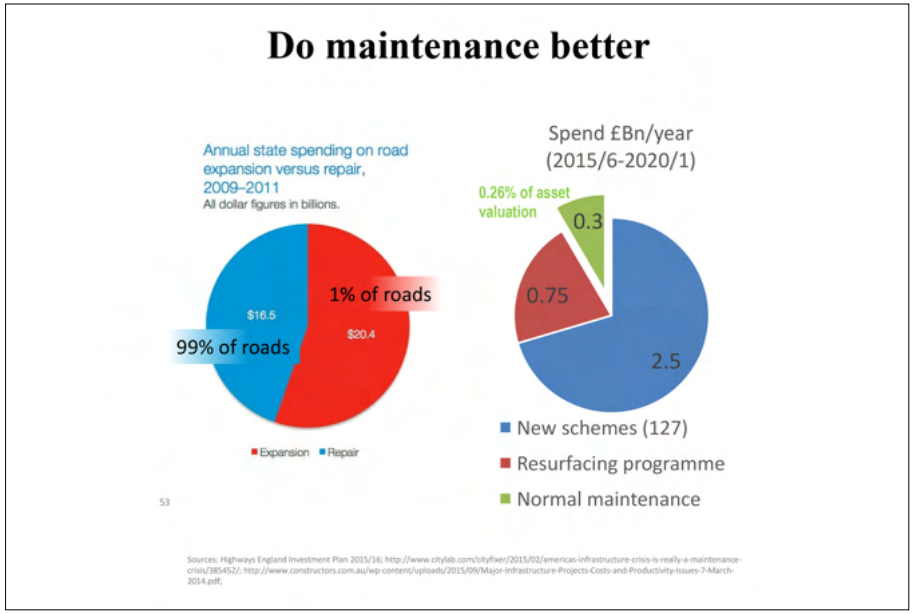
Dr James MacDonald, Research Fellow in the Centre for Synthetic Biology, provided insights into the computationally designed protein fibres he developed at Imperial College London. He uses DNA programming language to design protein de novo for a new class of fibres that present novel properties which natural or synthetic fibres cannot achieve. The collaboration with the Burberry Material Futures Research Group proposed to introduce food industry by-products to feed the bacteria that are used in this process, as well as to investigate circularity opportunities to recycle the fibres at the end of life by using these bacteria. The collaboration outlines four types of food industry by-products and waste with a high nutrient content: potatoes and potato peels are one of the largest waste streams in the UK; spent grain from the beer brewing process can be sourced locally in urban microbreweries and used for animal feed; old bread can be found in both commercial and domestic food waste.



Curran feedstock supply. By Thomas Leech
Curran Source: Cellucomp.com

Thomas Leech:
Identifying food industry by-products and possible feedstocks for new biomaterial development

BMFRG Research Associate Thomas Leech has contributed to the feasibility phase in the Sustainable Future Materials theme through the completion of the scoping research and benchmarking of materials developed from food industry by-products and waste. His presentation discussed key facts in food consumption and waste and introduced the food recovery hierarchy as a guideline for selecting unavoidable and low vale processing by-products that are unsuitable for human or animal consumption. The research has found that waste is hidden at different stages of the food supply chain and proposed the development of process maps as a tool to identify where unavoidable food waste is produced. Once these by-products in the supply chain are identified, these visual maps can be used to engage future stakeholders and help add value to new material development with increased transparency. The twenty-six 'food material cards' developed during the feasibility phase were presented as global examples of current biomaterial developments that have the potential to be scaled in the near future. His research contributed to the identification of food industry by-products and waste for a scalable manufacture of materials in the UK.



Doing maintenance better can help to implement Circular Economy. By Phil Purnell

Phil Purnell: Aspects of the Circular Economy

Professor Phil Purnell is Visiting Professor in the Burberry Material Futures Research Group for the Sustainable Future Materials theme. His presentation argued that there is more than one circular economy that needs to be addressed with the following strategies: do recycling better; do design better; do maintenance better; and do policy better. Phil analysed household waste in England in 2017/18 and compared the use of food waste and textile waste as the resource flow in the Sustainable Future Materials theme. His presentation concluded that food waste is the largest waste stream of household waste, whilst the smaller proportion of textile waste demonstrates a strong opportunity to reduce carbon emissions.

Simon McQueen-Mason: Waste to Textiles

Professor Simon McQueen-Mason presented the collaboration of the Burberry Material Futures Research Group with the Centre for Novel Agricultural Products (CNAP) he directs at the University of York between July and September. His presentation explored how industrial biotechnology can find solutions to produce materials that are currently dependent on petrochemicals. His research centre focuses on waste biomass as a low carbon replacement of petroleum, which includes lignocellulosic plant biomass and the biological fraction of Municipal Solid Waste (MSW). He introduced the audience to the concept of bio-refinery by using the example of the feasibility study we conducted in his lab, in which we introduced wheat straw and bioMSW as the raw material for fermentation with Acetobacter and production of bacterial cellulose.

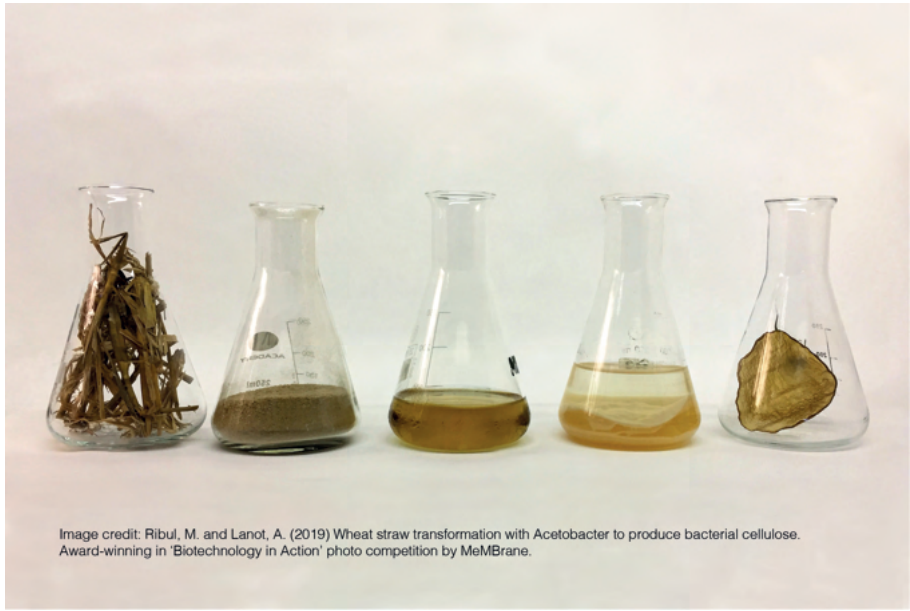


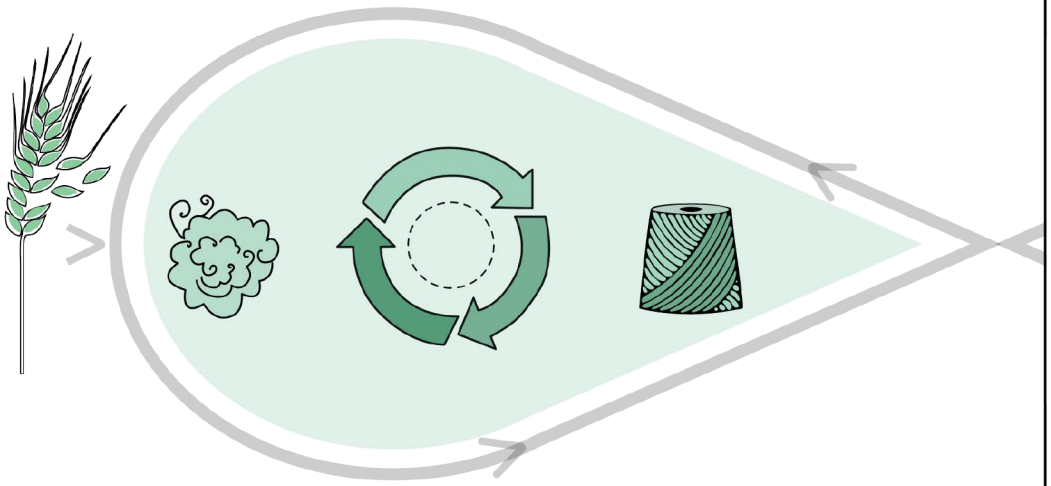
Image credit: Ribul, M. and Lanot, A. (2019) Wheat straw transformation with Acetobacter to produce bacterial cellulose. Award-winning in 'Biotechnology in Action' photo competition by MeMBrane.


Exhibition

Exhibits included displays, material samples and prototypes. The displays defined each BMFRG theme and contained films illustrating different scenarios.

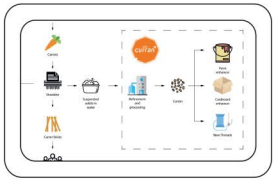
Sustainable Future

Materials



Identifying food industry by-products and waste for biomaterials

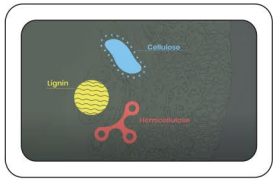
Mapping low value and unavoidable food industry by-products and waste streams that are homogeneous and uncontaminated for scalable manufacturing of materials.



Process maps are used as a method for transparency in the food processing industry to identify waste streams for the development of a local circular bioeconomy.

Strategies for Materials Circularity

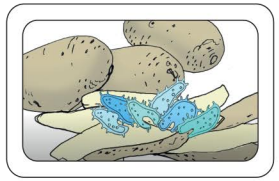
Using all components at the raw material stage of food industry by-products and waste as nutrients for biomaterial development.



The research to process wheat straw for fermentation with Acetobacter and production of bacterial cellulose was conducted in collaboration with the Centre for Novel Agricultural Products (CNAP) at the University of York between July and September 2019. With thanks to Professor Simon McQueen-Mason, Dr Alexandra Lanot and Heather Eastmond.

Repurposing and recycling with bacteria

Bacteria are used to transform food industry by-products and waste into textile fibres and flexible materials, enabling new recycling and manufacturing processes for textiles.



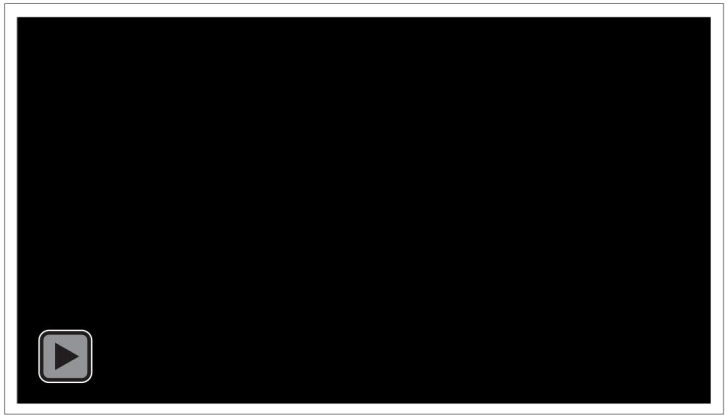
A collaboration to introduce food industry-by products and waste to feed bacteria that are used to produce computationally designed protein-based fibres developed by Dr James MacDonald at Imperial College London. With thanks to Dr James MacDonald, Dr Hannah Leese, Prof. Paul Freemont, Prof. Milo Shaffer.

How can circular materials (fibres and flexible materials) be designed and developed from food industry by-products and waste?

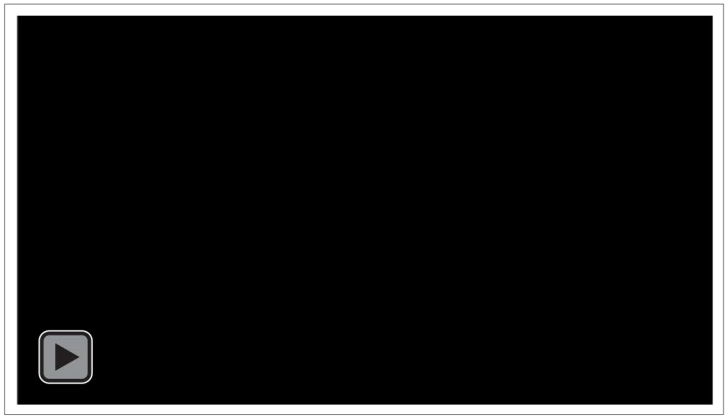
What types of biomaterials can be made from biodegradable food industry by-products and waste for materials and product circularity?

What techniques from biological and materials sciences would modify wheat straw for textile fabrication, and thus inform the modifications that need be made to additive manufacturing technologies to fabricate with biomaterials?

What circular recycling techniques can biotechnology and the biological sciences inform to avoid or reduce the use of chemicals in fibre and flexible materials production?



Cellulose digester. Production of bacterial cellulose with Acetobacter by using the hemicellulose component in wheat straw. Together with the cellulose component, we propose to develop regenerated cellulose fibres for textiles in a zero waste biorefinery with the Centre for Novel Agricultural Products (CNAP) at the University of York.



Protein feed. Coding DNA and transforming bacteria that are fed with different types of food industry by-products and waste to grow and produce protein. The protein is then separated, extruded and spun into computationally designed protein fibres developed by Dr James MacDonald at Imperial College London.

Sustainable Future Materials

Zero Waste Biorefinery of Wheat Straw

Using wheat straw for fermentation with Acetobacter and production of bacterial cellulose through the following stages:

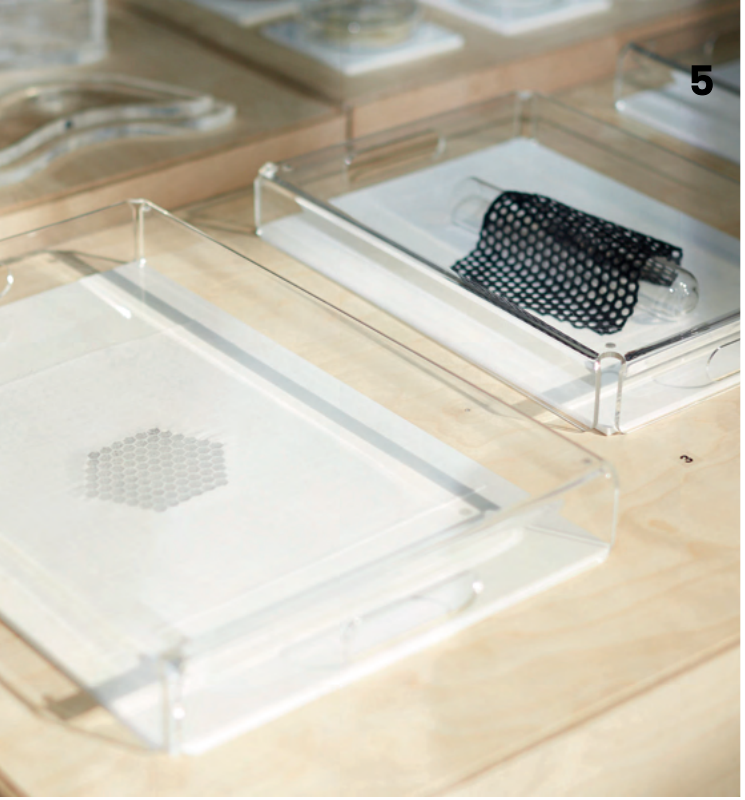
1] Wheat straw from wheat: identifying large scale and low value food industry by-products in the UK for scalable material manufacturing.

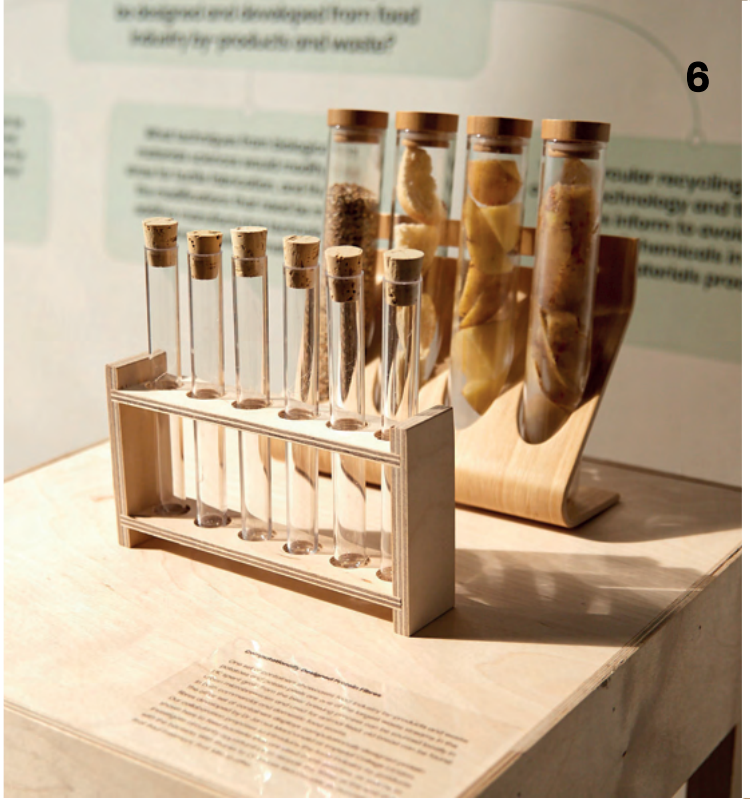
2] Petri dishes: testing if Acetobacter can produce bacterial cellulose from glucose and waste biomass (wheat straw).

3] Moulds: growing bacterial cellulose films produced with Acetobacter in the shape of footwear elements.

4] Material samples: bacterial cellulose films and composites with regenerated cellulose fibres demonstrate the potential of this waste stream for the development of textiles and flexible materials.

With thanks to Professor Simon McQueen-Mason, Dr Alexandra Lanot and Heather Eastmond at the Centre for Novel Agricultural Products (CNAP), University of York.





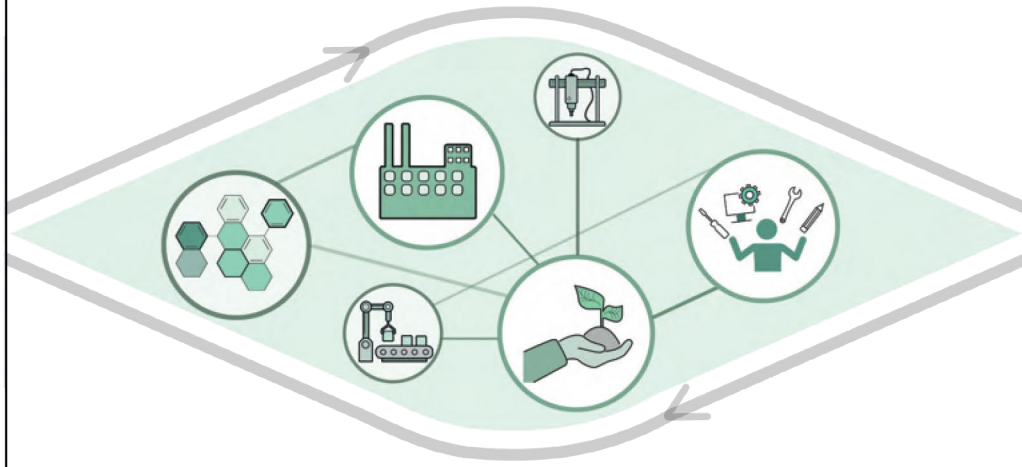
5] New Textile Processes with Regenerated Cellulose. These textiles demonstrate new processes with regenerated cellulose obtained from post-consumer textile waste in the context of a circular bioeconomy. Each textile is produced with and can be reintroduced into a non-toxic circular chemical recycling process for regenerated cellulose textiles. Developed by Dr Miriam Ribul during her PhD research with the Centre for Circular Design at the University of the Arts London and the London Doctoral Design Centre.

6] Computationally Designed Protein Fibres. One set of containers showcases food industry by-products and waste: potatoes and potato peels are one of the largest waste streams in the UK; spent grain from the beer brewing process can be sourced locally in urban microbreweries and used for animal feed; old bread can be found in both commercial and domestic food waste. The other set of containers displays computationally designed protein fibres. We proposed to introduce the food industry by-products shown here to feed bacteria that are used in this process, as well as to investigate circularity opportunities to recycle the fibres at the end of life with the bacteria. With thanks to Dr James MacDonald, Dr Hannah Leese, Prof. Paul Freemont, Prof. Milo Shaffer.

7] Food Materials Cards. These cards map the global developments in local biomaterials derived from food industry by-products and waste. Each material card shows the type of material and the feedstock used. The materials are grouped into leather alternatives, fibres and soft or hard composites. The range of materials, manufacturing processes and development stages were used to analyse the current and future possibilities for food materials. With thanks to Tom Leech, Research Associate.

Sustainable future

Manufacturing

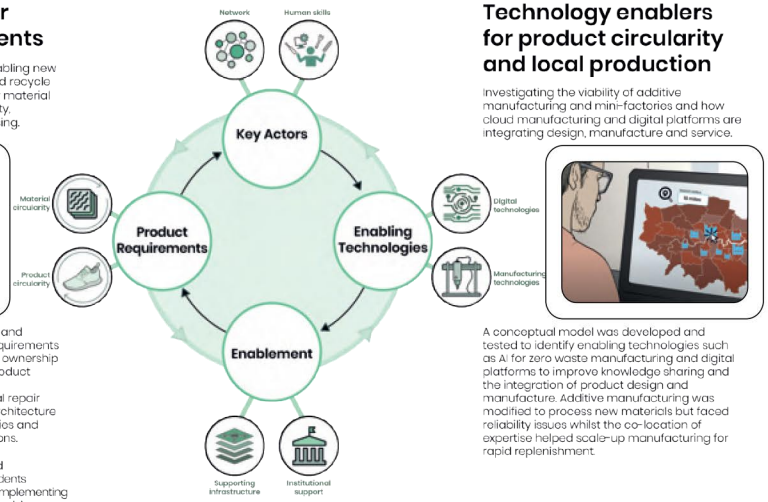


Identifying circular product requirements

Product life extension strategies enabling new models of product re-use, repair and recycle and future requirements for circular material use such as waste stream availability, accessibility, collection and processing.

A conceptual model was developed and tested to identify circular product requirements such as material provenance, waste ownership and track and trace technologies. Product circularity was enhanced through customisation, product tracking, local repair networks and changes to product architecture to reduce components and inventories and offer through-life management options.

The research involved unstructured and semi-structured interviews with respondents representing 10 exemplar case studies implementing circular or distributed manufacturing models.



Technology enablers for product circularity and local production

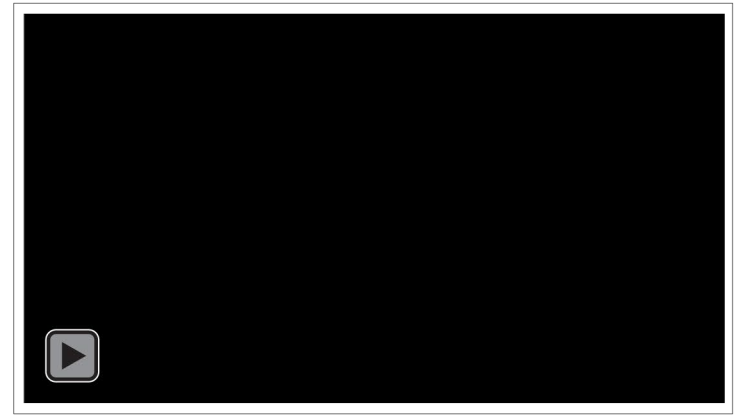
Investigating the viability of additive manufacturing and mini-factories and how cloud manufacturing and digital platforms are integrating design, manufacture and service.

A conceptual model was developed and tested to identify enabling technologies such as AI for zero waste manufacturing and digital platforms to improve knowledge sharing and the integration of product design and manufacture. Additive manufacturing was modified to process new materials but faced reliability issues whilst the co-location of expertise helped scale-up manufacturing for rapid replenishment.

What technologies, knowledge and capabilities need to be developed that would enable SME apparel brands and designers to design and manufacture the circular life of garments?

How can material databases and platforms support circular product manufacture and what are the implications for supply network design?

What physical manufacturing technologies need to be developed to enable a more circular model of production and what are the requirements for cloud manufacturing and digital platforms to improve product circularity, conformance and life-cycle management?

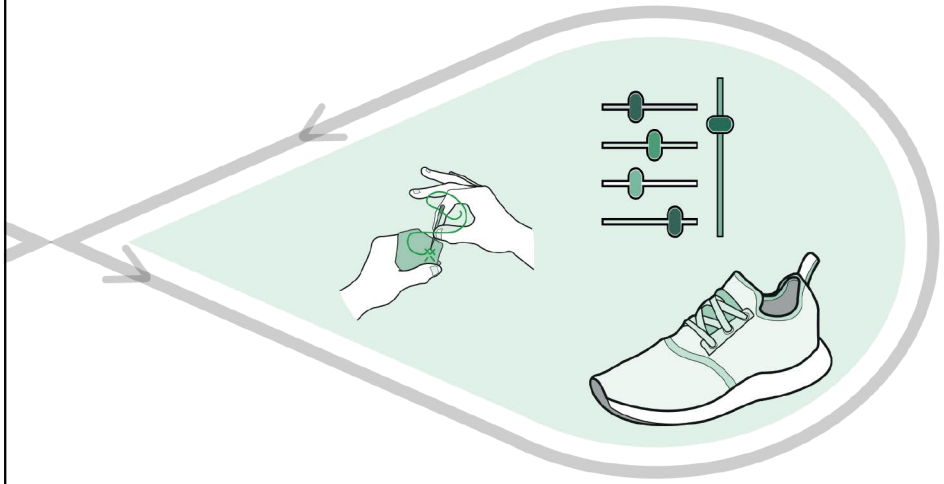


Material Properties and Sourcing. Material libraries and platforms providing access to materials and new material properties for circular product design.

Locating Manufacturing for Circular Production. Technologies supporting circular production through locating local manufacturing capabilities.

Sustainable future

Consumer experience



Customisation for a Long Life

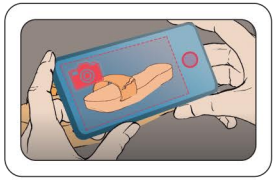
Design of customisation (selection and configuration) experiences in a retail setting to enable people to express their identity through articulating their perceptions and preferences related to the properties of materials.

A Living Lab* is used to investigate the design of experiences for configuration of products, exploring means of enabling people to articulate their perceptions and preferences.

With thanks to Marijke Bruggink, footwear expert and founder of assembly-line.nl - © 2018, ASSEMBLY-LINE.NL
Further thanks to RCA Fashion for their support to the project development.

Sustaining Relationships

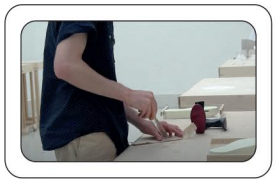
Design cultures that introduce circularity by enabling update and upgrade of products through reconfiguration.



Scenario development through speculative design is used as a method to explore how product reconfiguration may promote a new type of relationship between consumers and design brands, and between consumers and their products.

Living with circular materials from food industry by-products and waste

Investigating the types of experience design that would promote a shift in consumer perception of the value, desirability, quality, and durability of circular materials/products.



A Living Lab* is used to investigate the design of experiences to engage consumers in immersive storytelling about materials provenance and their potential future life-cycles, as well as enabling understanding of the sensory and physical properties of those materials.

How can designed experiences catalyse people to be custodians of materials, and therefore stakeholders in material circularity, as a circular design strategy?

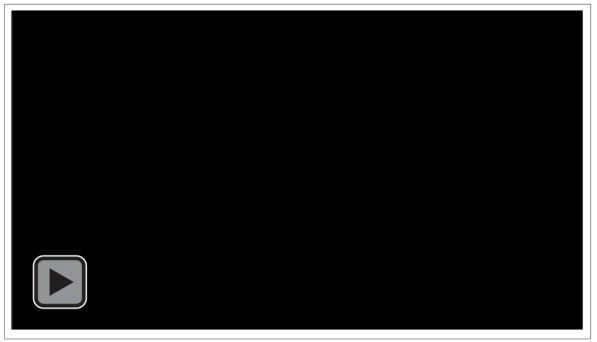
What are the requirements of in-store experiences that would satisfy human needs for self-expression, self-actualisation, society, and therefore motivate consumers to participate in customisation and design of products?

What methods would translate the sensory and physical properties of materials into experiences that consumers can engage in so that they understand materials and their own preferences, and to articulate those as part of customisation?

What are the requirements of analogue-digital experiences related to materials provenance and potential future life-cycles that would enable consumers to have a deeper engagement with materials?

*Living Lab is an experiential environment where diverse methods are used to design and test realities of future (sustainable consumer experiences) with people.

Imagining Future Lifecycles. Design that enables people to participate in extending the life of materials and products, through embedded activities of update and upgrade. Design cultures around products that introduce circularity as part of consumer experience of products and design brands.



Continual Relationships. Customisation through modular design and component selection locates people in a place where they can express their identity through articulating their perceptions and preferences related to the properties of materials.

Sustainable Future Consumer Experience

1] The Compositor Tool. The study presented new ways of understanding materials' past, present and future to inform how people select and configure materials to build their own shoe. It was comprised of four experiences: **component selection**, **material stories** (interactive station that enables understanding of material's provenance), **material futures** (interactive station that enables people to project materials into future lifecycles), and **material gym** (interactive station where people experience properties of materials). These were used to provide compelling experiences of materials, to support people in the selection of materials and configuration of products in engaging and playful ways. We hypothesise that compelling experiences should inform/educate, inspire, entertain, and enable expression of perceptions and preferences. By using analogue and digital means to add extra layers of information, people were enabled to have a deeper sensory engagement with materials, and to project them in the past (e.g. provenance, similar applications), and in the future (e.g. pairing suggestions, performance, care).

1

2] Shoe Design Inspiration ASSEMBLY-LINE. Simple design: Slipper designed with reduced component parts and modular design. Designed for long-life: possibility to replace component parts. With thanks to Marijke Bruggink, footwear expert and consultant, and founder of Assembly-Line ©2018, ASSEMBLY-LINE.NL

3] Shoe Design Adaptation Component Selection. Simple design 2.0: reduced components to only sole and strap. Single-material sole. Strap designed to auto-lock, eliminating buckle.

4] Material Stories. Participants put together the stories of material provenance by connecting the puzzle pieces. Each puzzle piece contains a trace of the different stages of material transformation. Participants should identify which puzzle corresponds to the material they are exploring.

5] Material Gym. Participants experience sensory properties of the materials, what they do, and how they make them feel in the current presentation.