Collaborative Circular Design. Incorporating Life Cycle Thinking into an Interdisciplinary Design Process

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Abstract: To evolve fashion and textiles within the circular economy an interdisciplinary approach encompassing a range of life cycle perspectives is required, facilitating this collaboration requires new thinking and tools. The research presented in this paper was explored through a European Union Horizon 2020 funded project, Trash 2 Cash (T2C), where collaborative 'life cycle thinking' (LCT) tools were developed to integrate multiple expert perspectives within the design process. The research positioned material scientists, industry stakeholders, consumer behaviour and Life Cycle Assessment (LCA) researchers into the heart of an iterative design process, tools were developed between and tested through consortium workshops over a 21-month period. Several key findings proved the value in the use of these interdisciplinary LCT methods, alongside new insights into barriers and opportunities for future circular material developments. Designing tools for collaborative research and the sharing of knowledge in this context was instrumental in helping to promote social exchange and the building of communities within the project and beyond. This work provides an important basis for understanding how to bring the theory of circularity into a networked industry practice.

Keywords: Circular economy, textile design research, collaboration, inter-disciplinary design tools, material recovery

1. Introduction

The emerging field of 'design for the circular economy' (Charter et al, 2018) provides the multi-stakeholder and interdisciplinary approach required for the recycling of textiles through challenging disciplinary boundaries. The 'connected' nature of this challenge can only be achieved through effective collaboration between traditionally unconnected fields yet there are very limited tools which can be called upon to facilitate this collaboration. Existing lifecycle tools are predominantly either for ‘audit’ (scientifically based but post-production) or ‘ideation’ (design driven but lacking in scientific basis). This is demonstrated through the literature which reports that ‘many existing tools fail because they do not focus on design, but instead are aimed at strategic management or retrospective analysis of existing products’ (Lofthouse, 2006).

The T2C project was a 3 year EU-funded project from 2015 to 2018 that aimed to produce high-quality products from zero-waste textiles and fibres through a design driven approach. The consortium was made up of 18 partners from 9 European countries to form a unique multidisciplinary team of designers, scientists, manufacturers, evaluators and SMEs (small / medium enterprises). This multi-disciplinary consortium provided a unique opportunity to develop a systematic, life cycle stakeholder approach from which to explore ‘what designers need to know when designing for circularity’.

The developed processes and tools identified through stakeholder engagement, workshop sessions and reflective interviews demonstrated the complexities and contradictions in designing and developing circular materials. Through mapping material and chemical transformations of fibres from feedstock, through to new fibre and product and back to feedstock, opportunities and challenges where identified for both design and science areas. The brief was to develop innovative uses of recycled materials within the project whilst considering potential end of life solutions beyond the scope of the project lifetime. The developed design concepts within the project were based on three innovative recovery processes for textile waste streams, and were required to incorporate design for recycling to enable the closed loop material visions for the project.

The expertise of the consortium’s commercial designers ranged in industry sector from fashion, children’s wear, performance clothing to automotive applications, with all designers using a typical linear approach to design, from concept to product. For the range of other expert groups within the consortium (scientists, manufacturers and evaluators) they had limited or no experience of working within the design process specifically to drive material circularity. The process of introducing LCT was therefore a new concept and approach to all expert groups within the T2C consortium, other than the design researchers.

The main structure of the process was based around a series of face-to-face workshops (see figure 1) with designers & experts from each sector, developing closed loop material visions for the T2C fibres through the development of interdisciplinary ‘Life Cycle Thinking Tools’ based on design for recycling’. Embedding this LCT approach into the design process ensured the developed concepts incorporated the closed loop material visions in line with the overall project objectives, as described below;

‘The complex process of separating materials and chemicals used to manufacture products is currently problematic at end of life stages and a huge barrier to the recycling of textiles. Mono-material solutions are effective in many product sectors, but not all. Therefore, within the T2C design concepts, both blended and unblended materials are being explored through the development of an interdisciplinary Life Cycle Thinking Tool that used a systematic, life cycle stakeholder approach to support designers during the design stage by equipping them with the knowledge they needed when designing for circularity. Through mapping material and chemical transformations of fibres from feedstock, through to new fibre and product and back to feedstock, opportunities and challenges are being highlighted. The aim is to reveal opportunities within both design and science areas to develop innovative uses of recycled materials within the T2C project whilst considering potential end of life solutions beyond the scope of the project lifetime.’ (www.trash2cash.eu).

The workshops, which were held every 2-3 months, were used as key collaboration points throughout the process aimed to bring the following features into the design development process:

- Multi stakeholder engagement to ensure 'circularity' was developed by involving expertise from multiple representatives of each stage of the life cycle to drive the materials development,
- Interdisciplinary collaboration to drive design concepts towards material circularity,
- Interdisciplinary knowledge exchange through the design then engagement with developed tools as well as interactions during workshops.
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Figure 1 Trash-2-Cash, Developing tools, methods & models to enable the complex collaborations essential for designing circular material scenarios.

2. Background

In developing material flows for the recycling of textiles within the circular economy, where waste streams provide the feedstock for new fibres, a multi stakeholder and interdisciplinary approach is required. The design stage has been identified as a key area to address life cycle impacts of products, with a suggested 80 to 90% of product life cycle impacts determined at this stage through the material and process choices made by the designer (Graedel et al, 1995). Ellams (2016) explains that though an important framing for the role of design in reducing the LCA of products, this estimate is based on the idea that design determines between 70-90% of product manufacturing costs, for real reduction in LCA impacts methods and tools to support designers in the interdisciplinary understanding for material and process choices they make at design stage and the life cycle implications of these on end of life re-cycling are vital in enabling the future recycling and recirculation of material resources. The role of the design process and designer in determining these financial and environmental costs was formalised in the Theory of Dispositions and is used by the European Union within the Eco Design Directive (Directive/2009/125/EC).

The research presented positions material science, industry stakeholders, consumer behaviour and Life Cycle Assessment (LCA) into the heart of an iterative design process, with the aim of equipping designers with tools to integrate LCA within Life Cycle Thinking (LCT), rather than producing an end 'score' as with traditional LCA models. The emerging field of 'design for the circular economy' provides the multi-stakeholder and interdisciplinary approach required for the recycling of textiles through challenging disciplinary boundaries. The 'connected' nature of this challenge can only be achieved through effective collaboration between traditionally unconnected fields yet there are very limited tools which can be called upon to facilitate this collaboration.

There has been a significant body of research exploring other aspects of the overarching project methodology and methods for creating a collaborative foundation to the project (Dell'Era et al, 2016; Hornbuckle, 2017, 2018; Niinimaki, Tanttu, Kohtala, 2017; Niinimaki, 2018; Earley & Hornbuckle, 2018) which are summarised in the upcoming report 'Applied DDMI' (Tubito et al, 2018). This paper focusses on new tools and methods developed by UAL to enable knowledge sharing for Life Cycle Thinking within the project, (see figure 2) from the first introduction at the 6th project workshop, held in London in November 2016, through to the 11th in Gothenburg in 2018 where Life Cycle Assessment (LCA) became more embedded through collaboration with LCA experts within the project. Findings, insights, data collected and analyses are presented which provide recommendations for how this tool can be used in future multi-stakeholder and DDMI projects.

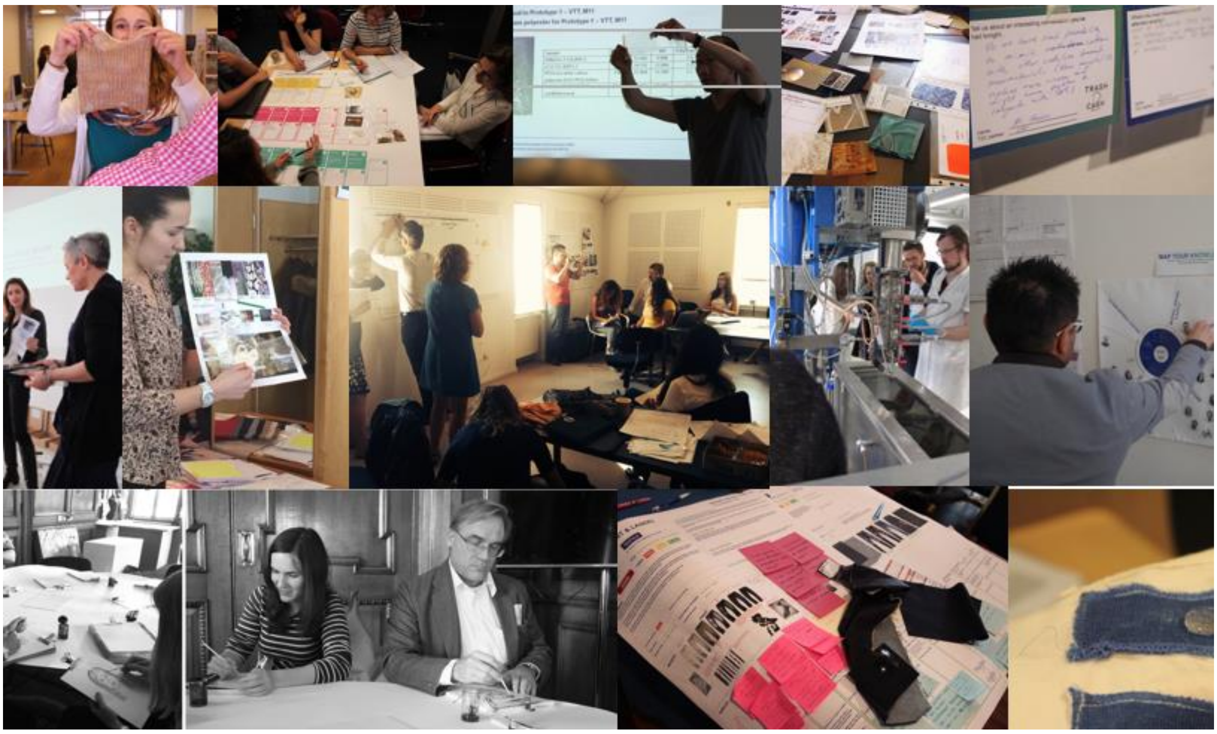

Figure 2 Trash-2-Cash workshops during 2017-2018, exploring tools for 'collaborative circular design'.

3. Development of a life cycle thinking (LCT) approach

The developed tools identified through stakeholder engagement, workshop sessions and reflective interviews the complexities and contradictions in designing and developing circular materials. Through mapping material and chemical transformations of fibres from feedstock, through to new fibre and product and back to feedstock, opportunities and challenges could be identified by the researchers in both design and science areas to develop innovative uses of recycled materials within the project whilst considering potential end of life solutions beyond the scope of the project lifetime. The tools were developed through iterations tested over the course of the workshops and took several forms of varying complexity (see figure 3).

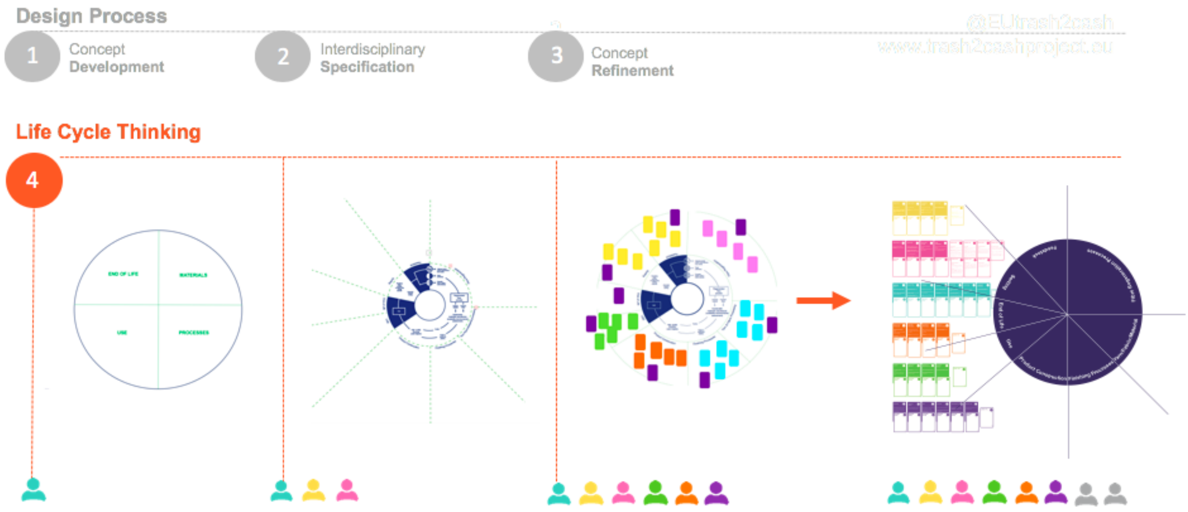

Figure 3 The progressive development of circular design tools in the project. An iterative process.

3.1 Stage 1: Circular Baseline

This part of the process focussed on introducing designers to life cycle thinking through simple product visualisation exercises and also identifying stakeholder expertise and influence through a mapping exercise.

Designers were asked to express concepts which were already in development as a lifecycle using a simple four quadrant map to enable designers to gain basic understanding for and a means to communicate the material journeys of these emerging concepts (see figure 4). Introducing LCT at this stage also provided the opportunity to establish the level of life cycle understanding that already existed within the designer's knowledge base. The tool prompted designers to think about the four key areas of a textiles product life cycle, these being; raw materials, production, use and recovery stages in relation to their design concepts. In completing the task designers began to link specified material attributes for their design concepts to life cycle implications (environmental and cyclability).

These basic life cycle maps were incorporated within the Design Concept posters and presented to partners by designers during the next physical meeting.

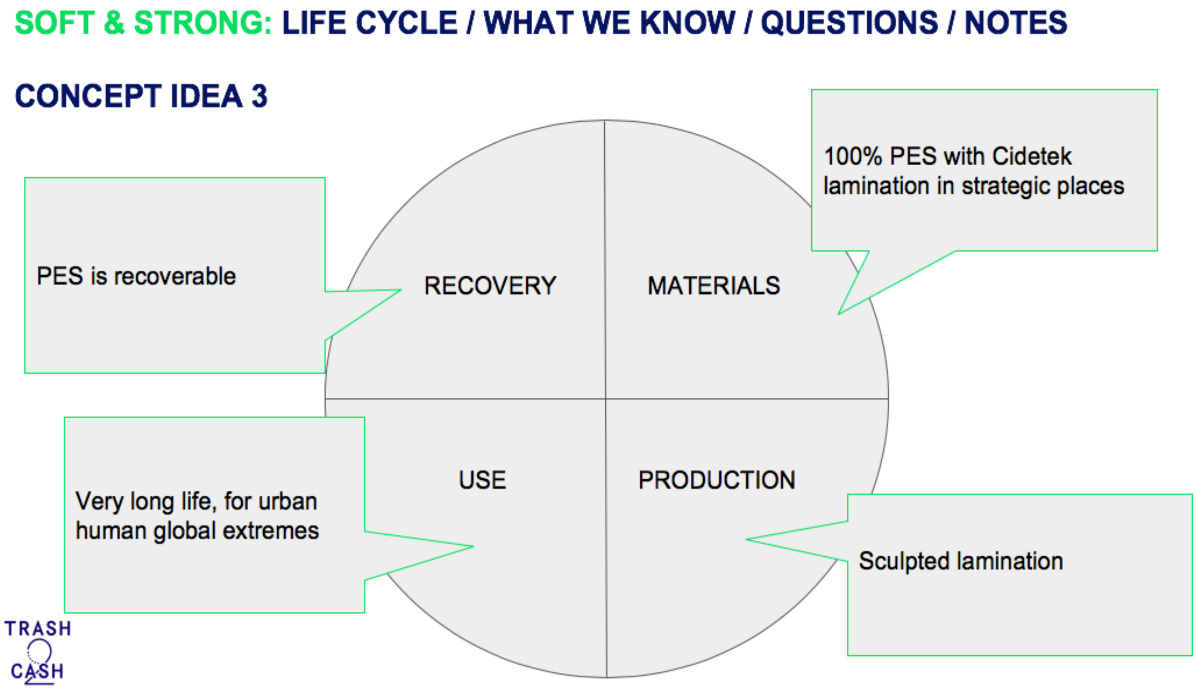

Figure 4 Example of Life cycle template for one of the design concepts explored.

During this next meeting another LCT exercise was introduced to all involved stakeholders based around the T2C Concept Diagram (see figure 5). The aim was to develop circular understanding for materials within all members of the consortium by setting a baseline amongst the group for the material life cycles design concepts would need to be developed within. This enabled all stakeholders within the consortium to be identified and linked to their specific expert area. Material scientists, production experts, industry designers, LCA experts, business model experts and user perspectives from social science were all represented.

The life cycle template developed for the workshop session mapped three design concepts as life cycle stages around the cycle diagram. These were then used to provide the focal point for group discussion and the collective development of a circular product journey. The aim of the session was to introduce through these life cycle visualizations the principles of LCT and highlight some of the interdisciplinary challenges faced in developing circular materials.

During this session 'Meeting Life Cycle Thinking' the consortium was split into three expert area groups; Designers, Scientists and Manufacturers. Expert groups rotated in turn around the three Design Concept life cycles. The disciplinary groups were hosted by a facilitator at each life cycle table and together discussed the barriers to creating material circularity for the specific Design Concept example. The data captured during the workshop session, along with partners immediate feedback from the session, was used to develop the next stage of LCT for use within the following workshop.

3.2 Stage 2: Circular Mind-sets

Following stage 1 specific product concept maps were defined and subsequently developed between expert groups, building from a generic understanding to a tailored life cycle material journey for each Design Concept to directly inform the design process.

The circular life cycle template was developed into a flow chart format to further develop the life cycle information base for each concept. This ensured designers recorded and considered technical information of these key life cycle stages during an interim period between workshops as the creative ideas for design concepts developed.

Figure 5 'Meeting Life Cycle Thinking' session in action.

Once designers had provided descriptive information relating to 'what they knew' they were instructed to expand on 'what they didn't know' and pose questions relating to information they 'wanted to discuss or find out more about' with experts at the next meeting for each life cycle stage.

At the following session, an exercise was developed with the aim of incorporating life cycle thinking into an interdisciplinary exchange between designers and other life cycle experts.

A lead designer for each concept was selected to present the concepts using the pre-prepared questions from partners. The partners were divided into six expert groups including: sorting; feedstock; fibre science; manufacturing; consumer behaviour, business models and LCA. Creating these expert area life cycle groups ensured design concepts were reflected on from all necessary perspectives.

During the session expert groups rotated around the room spending an allocated period of time with each lead designer in order to discuss critical aspects in achieving desired material attributes. They provided designers with information/ feedback recorded directly onto the design specification sheets. Feedback was colour coded to each expert area linking to the T2C life cycle area it related (see figure 6) to ensure designers could follow up with specific experts post workshop, and that the analyses of feedback post workshop could be used to inform the next stages of LCT development. Feedback from each design concept was shared digitally post workshop with the full consortium to support designers in developing the next iteration of design concepts focusing on areas of the life cycle that had been highlighted within the workshop.

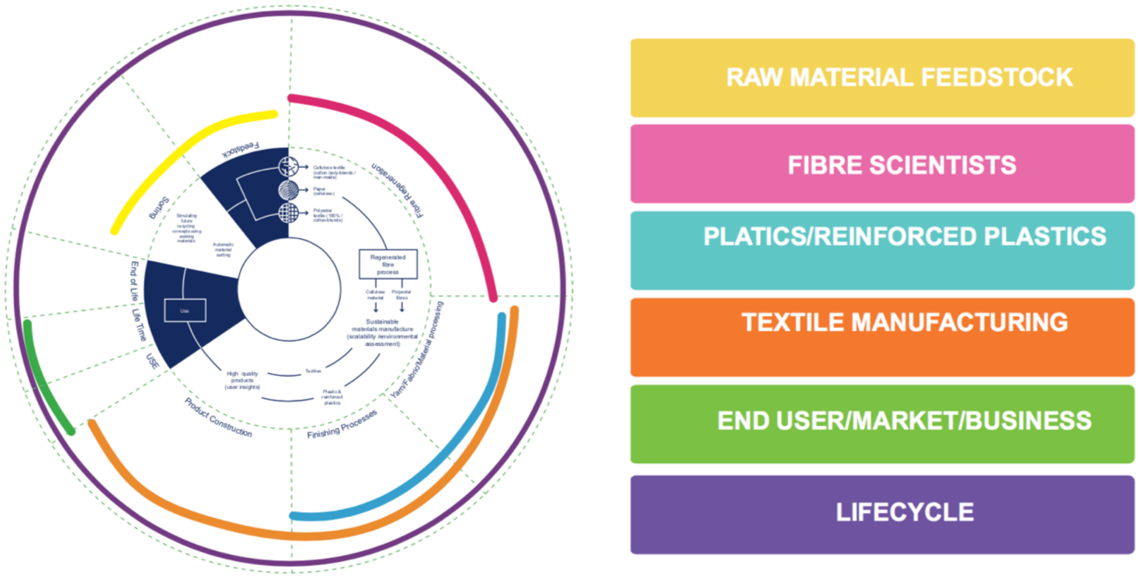

Figure 6 Expert area colour code related to T2C material life cycle

3.3 Stage 3: Circular Co-Design

For this next stage designers refined their concepts informed by expert review. LCA/LCT interplay was used to support design decisions with the aim of improving environmental impacts around the cycle through the circular design process, ultimately enabling the development of closed-loop life cycles.

First, stakeholder knowledge was combined using the feedback provided to designers by expert groups and key issues were identified:

- Designers were not always developing circular Design Concepts; solving one barrier to recyclability was often creating another. For example, in creating stretch without using elastane designers were driving material development that created stretch through a blended CEL/PET structure. However, during it was pointed out by the sorting expert group, this structure would actually prevent the blend being recognised at end of life sorting by the Near Infra-Red (NIR) technology being explored in the consortium (Wedin et al, 2017).
- Expert area groups were often repeating feedback to each designer; for example, removal of components & linings and possible issues in chemical recycling of finishes used. This repetition across all design concepts regardless of material or application area suggested that ‘common circular boundaries’ could have been applied to the design process if designers had been informed of these interdisciplinary circular boundaries at the outset of the design process.
- Designers not absorbing technical information provided through written deliverables; experts provided in depth technical information, but this information was not always absorbed by the designers and into the design concepts. For example, key guidelines which were given to designers on the best available techniques for were not incorporated by designers into the design concepts until discussed in face to face workshops.
- Contradictions in the needs of specific life cycle experts / areas for material recycling; each expert area group was providing designers with feedback based on the needs of processes for their specific area. When collated the feedback was at times contradictory, meaning it

was impossible for designers to meet the needs of each life cycle area without sacrificing the creative output of their Design Concept. Designers needed to be aware of barriers to recycling at each life cycle stage to allow them to then design tailored life cycle maps for material recycling pathways.

The above insights were used to conclude that designers needed an LCT tool that combined and communicated to designers the interdisciplinary life cycle knowledge of the consortium as an all-encompassing overview. This would support designers in evaluating Design Concepts, taking into account not just 'product spheres' but also business models, service dimensions, disposal etc. The aim of the tool was to embed the circular expertise of consortium stakeholders within the design process through the development of a tangible LCT design tool that communicated key life cycle information to designers enabling the exchange of disciplinary knowledge that would result in designers being able to make informed life cycle decisions for their Design Concepts, focusing on specific routes to recycling designed within their design process.

A Circular Evaluation tool was developed, based around the colour coded areas of the T2C life cycle which aimed to capture the knowledge of each expert group to communicate to designers. Technical information provided through deliverables was used to develop 'expert area cards'. These were collated into a PowerPoint template for each life cycle group. The relating set of expert cards was then shared with key experts from each group, for example work package leader or relating technical expert for review. This enabled the key experts to input and feedback further suggestions (recycling barriers) over a 4-week period which resulted in the final iteration of the tool 'Circular Evaluation'. The cards were incorporated into a worksheet for designers to use a means of evaluating their design concepts in preparation for the next workshop (see figure 7).

Figure 7 'Circular Analyses LCA meets LCT' session in action.

During the third workshop in the LCT series the prepared design specification sheets were used with a specifically developed 'Life Cycle Thinking Evaluation Tool' to encourage designers to 'critically reflect' on their design concepts with the support of expert groups based on the key Life Cycle Thinking criteria for T2C. The aim of the 'Circular Analyses; LCA meets LCT' session was to link the concepts & prototypes for analyses through an interdisciplinary approach. Design and technology expertise combined to evaluate & provide feedback taking into account not just 'product spheres' but also business models, service dimensions, disposal. Design specification sheets where presented to expert groups who then worked with designers to fill in the circular evaluation tool. Data collected from this session was used to inform the decision making in selection of the final design concepts.

The data from the three, life cycle thinking tool iterations were used to inform a final tangible life cycle map. Working closely with partners, a cross disciplinary method for master case life cycles was also completed and used to communicate selected master cases. Reflective interviews with both expert group members from each area of the T2C life cycle and designers were conducted. The data has been used to inform the final LCT tools produced as well as our final recommendations.

3.4 Stage 4: Circular Evaluation

During the final stage, designers refined the concepts into life cycle maps which could be used to evaluate and improve the concepts based on feedback form the LCA expert group using existing data. This LCA/LCT interplay was essential to support design decisions that led to an improvement of environmental impacts around the cycle to support circular design process and develop closed-loop lifecycles.

4. Reflections

Iterations of the collaborative LCT tools developed between and tested through consortium workshops provided an opportunity to understand their usability and gain insights for future development. Additionally, reflective interviews capturing the designers' views on their success during the project were conducted to provide key learnings from this stage of the research. Several key findings proved the value in the use of these interdisciplinary LCT tools, alongside new insights into barriers and opportunities for future circular fashion developments. This work provides an important basis for understanding how to move the theory of circularity into an industry reality.

The following four themes (see figure 8) were identified as essential steps in the process which could be adapted and refined for future use by similar interdisciplinary research projects or industry schemes in order to embed circularity into the heart of any material and product development process.

4.1 Circular Baseline: identify the expertise

Within this stage the concept of life cycle thinking was introduced & expertise of stakeholders identified. A shared understanding of relevance to individual expert roles began to develop, At the beginning of the design process, once a design brief and application is understood, life cycle thinking should be introduced to all involved stakeholders representing as many parts of the product cycle as possible. In T2C we included material scientists, production experts, industry designers, LCA & business model experts and user perspectives from social science.

The purpose of this stage is to ensure a shared understanding of the expertise relevant to individual roles. All partners are asked to 'map themselves' into a lifecycle segment map in order to show the area of their expertise. This enables the group to understand where there is expertise and where additional inputs or support might be needed. It also highlights areas of overlap which encourages useful debate from different perspectives. At this stage disciplinary 'differences in language' can also be identified and addressed.

4.2 Circular Mind-sets: define a shared understanding

The second stage of the process focused on visualising and collectively developing a circular map to enable a shared understanding of the material life cycles. Defined specific product concept maps could then be developed, building from a generic understanding to a tailored life cycle material journey for each design concepts to directly inform the design process,

The second stage involves setting a baseline amongst the group for circular understanding. The visualisation and collective development of a circular product journey can enable a shared understanding and circular mind-set.

A useful exercise here is to present example design scenarios as physical life cycle maps to provide a focal point for group discussion. This allows the demonstration and exploration of the group's expertise as part of a prospective design process, 'in the round'. The main points of discussion can be captured and reviewed following the activity in order to develop the next round of design tools tailored to the application area. By defining example product-concept cycle maps the group can build from a generic understanding to a more product specific understanding and inform the design process.

4.3 Circular Co-Design: combine knowledge through iterative process

During this third stage stakeholder knowledge was combined through iterative knowledge exchange in the form of circular evaluation to inform the final design concepts.

This is the most complex of the activities and should run through several iterations designed to share knowledge and to inform the design process. By mapping the emerging concept as a lifecycle journey and refining it during several rounds of facilitated discussion, the expertise of the stakeholders can be embedded within the design process. Tangible provocation tools and information gathering tools should be used to capture insights and enable the exchange of disciplinary knowledge.

The circularity of the cycle should be constantly reviewed and adapted throughout this stage and insights collated and cross-checked across the expert groups. It is useful to engage design facilitators for these activities both during and between workshops to ensure their smooth running.

4.5 Circular Evaluation: refine concepts through LCA/LCT interplay

The final stage of the process communicates final product concepts as a fully-formed, detailed, life cycle maps in order to finalise the LCA impacts and refine the design if necessary. The LCA/LCT interplay can support improvements of environmental impacts around the cycle. This final collaborative resolution of the designs is essential to ensure maximum positive impact is reached.

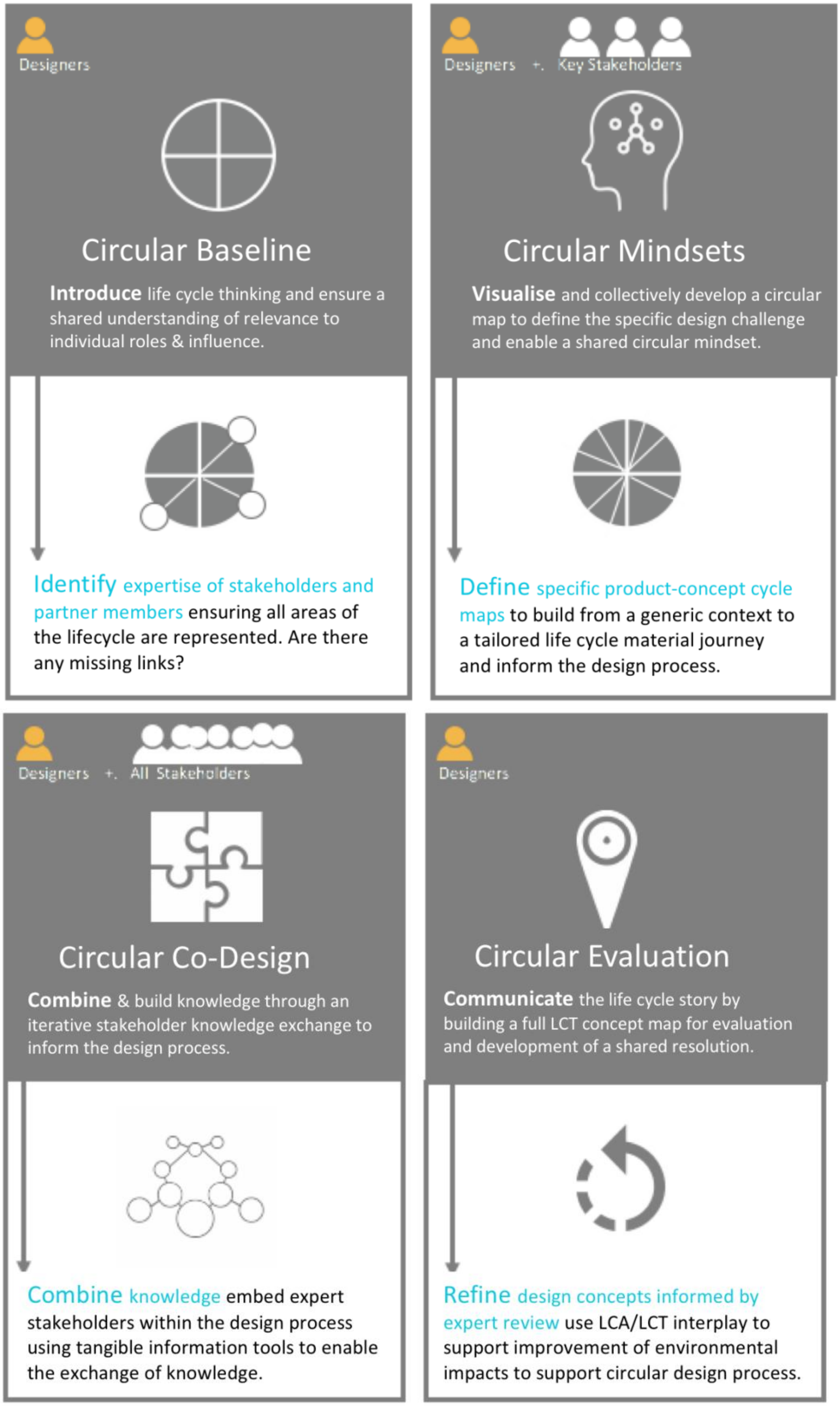

Figure 8 Recommendations for a four-step process towards collaborative and inter-disciplinary circular design.

5. Conclusions

The insights which have emerged from this work were identified through analysis of participant interviews and include the following key themes; visualisation, interdisciplinary stakeholder engagement & knowledge sharing tools. Future circular design projects should include these elements for accelerated collaborative innovation. These concluding recommendations, summarised below, relate to all four stages of the circular design process outlined in the reflections above.

5.1 Life Cycle Visualisations

- Introducing life cycle thinking to the full consortium early in the design process ensured a shared understanding of relevance to individual roles.
- Visualising and collectively developing a ‘circular map’ for each iteration of the design concepts enabled an ongoing circular mind-set in the collaborators and reflection on the challenges and opportunities.
- Presenting circular maps for review by technical partners provided a focus for evaluation and expert input in order to inform the ongoing development of the design process in a truly embedded way.

5.2 Interdisciplinary stakeholder engagement

- Identifying expertise of stakeholders and partner members on a circular map ensured all areas of the life cycle were represented. This exercise allowed participants to appreciate the connective nature of material life cycles and need to collaborate across disciplines
- Coding discipline experts to specific life cycle stages developed a collaborative process allowed identification of specific expertise required at different life cycle stages. This was essential in providing a basis for understanding where to go when challenges emerged.

5.3 Knowledge sharing tools

- Refining design concepts through LCA/LCT interplay supported improvement of environmental impacts around the cycle. Designers were able to question relevant expertise, at the appropriate development stage, on the various impacts and barriers to recycling.
- Building knowledge through iterative stakeholder knowledge exchanges informed the design process and ultimately guided identification of opportunities for innovation in circular materials.
- Developing and using tangible information tools was essential in the exchange of disciplinary knowledge to support designers in the circular design process.

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The project ended in November 2018 and all outputs can be seen on the project website at

https://www.trash2cashproject.eu/

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Kate Goldsworthy is Reader in Circular Textile Design and co-founder of Centre for Circular Design at Chelsea College of Arts, University of the Arts London. Her practice research explores future manufacturing and material recovery contexts through interdisciplinary design.

Dawn Ellams worked as a post-doctoral researcher with the Centre for Circular Design (UAL), for the duration of the T2C project. Her specialist expertise was instrumental in the development of the lifecycle communication and interdisciplinary design tools for the project.

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