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# Lifecycle Design: A method for supporting design decision-making with LCA knowledge in an interdisciplinary research project

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**Abstract:** This paper presents interim progress of the HEREWEAR project in developing a method for designing out impacts as part of a collaborative and ongoing process between design researchers, commercial designers and environmental scientists. The aim is to support optimal and iterative decision-making concerning materials and processes, acknowledging their high levels of uncertainty in relation to design choices. This work explores bridging the methodological gaps between environmental science and product development in brands through design research interventions.

## The HEREWEAR project

The HEREWEAR project is a European Union, Horizon 2020 funded project, spanning over 4 years and bringing together 15 different partners. The project explores systemic innovation for biobased, circular, and local fashion. New fibres from agricultural waste are developed in a biorefinery process, made into regenerated cellulose filaments, and into textiles suitable for the partner brand's market. As a highly multidisciplinary collaboration, the perspectives of material scientists, engineers, community activators and designers are combined to offer a holistic view of the challenges in the fashion and textiles industry. Part of the project's aim is to integrate environmental science knowledge in the formative stages of the design decision making process. The environmental assessment will contribute to evaluating the potential of biobased materials, local manufacturing, and circular business models to contribute to decarbonise and reduce the impacts of the industry, and operate a shift to socially just practices.

The team involved in this work includes environmental scientists with experience in eco-design, design researchers, and a fashion brand. Input from other partners in the HEREWEAR project was also gathered at strategic points. The demonstrator used to develop this method is the 'Flexi-Dress', a garment prototype using novel filament fibres from straw waste. As the brand designers and the design researchers collaborate to develop a garment that embodies sustainable and circular design recommendations, they have been seeking advice from the environmental scientists. The iterative process of developing collaborative spaces and tools to enable meaningful exchanges between all parties aims to produce a transferable method for future development and is built upon previous work between UAL and RISE (Earley and Goldsworthy, 2019; Goldsworthy and Ellams, 2019).

## Life Cycle Assessment and eco-design

LCA is a specific methodology of environmental science that offers a quantitative review of the environmental impacts associated with the full life cycle of a product or service. It uses an inventory of data on the energy, materials, transport, etc, and subsequent emissions and wastes allocated to the elements of the product service system (ISO, 2006). Environmental impacts are then calculated within several categories, and in some cases further processed into a single score result (PEF Apparel and Footwear, 2023). Requirements on data and procedure and constraints on usage of results for such a full LCA have increased, and in particular when results are used in external communications with different stakeholders including competitors, transparency and reviews are a crucial

element. Other more internal purposes of using data from an LCA study such as choice of materials and production practices might focus on hot-spots and parts of a life cycle and do not have the same constraints as studies involving a wider set of stakeholders with opposing interests. But even in that case, extrapolating and generalising a result can be misleading, as a fabric with low environmental impacts in the production stage and a short lifespan can score better than a more durable alternative. A collaborative process that enables explorative evaluation of potential effects along the life cycle through active discussion at key decision points is recommended.

The LCA method has also been described as falling short of a just representation of the complexity of textile supply chains (Textile Exchange, 2022), albeit without providing alternatives. As LCA requires the data for the full product's lifecycle to be available for full scale production, assessments often come after decisions have been made, offering limited options for revision. This is particularly challenging when the innovation includes new materials and techniques that are only tested in laboratories and pilot plants. Since integration and optimisation is done when scaling up to industry level, resource demand and subsequent impacts of innovative processes tend to be overestimated. Eco-design is defined as "the integration of environmental aspects into product design and development, with the aim of reducing adverse environmental impacts throughout a product's life cycle". Bridging eco-design and LCA was seen as challenging at the time of publishing the global LCA standards in 2006. As put by Millet *et al.* (2007) LCA methods have limited usefulness to the design team. Indeed it "*is limited to an analysis of existing products or well defined products at the final stages of the design process*" (ISO, 2011), and it fails to create a "*learning dynamic*" in companies (Millet et al., 2007).

The HEREWEAR project proposes to challenge these perceived limitations in the design phase by developing a bridge between the LCA and the design team with tools for discussion. It builds on a body of previous research, most notably the Mistra Future Fashion Programme to explore a method for connecting environmental science and design processes into a combined model 'quantified design' that was tested through a set of practice-led developments (Goldsworthy, Roos, Peters and Sandin, 2017; Peters *et al.*, 2018).

## Combined Design/LCA Approaches

Eco-design is put forward as a method that enables the transfer of LCA knowledge and modules into design. Many guidelines have been developed for designers to follow eco-design principles, from generic cross-discipline approaches (Luttropp and Lagerstedt, 2006), to sector-specific ones (Bauer *et al.*, 2018). Important common elements in these methods include the process of transparently defining stakeholders, defining the product, identifying supporting systems, detailed options analysis and synthesising strategy. These approaches were explored by researchers the Mistra Future Fashion Programme, using 'interconnected design thinking' and The TEN in alignment with the Higgs Index (Earley *et al*, 2016:75). The integration of LCA principles and design were tested via the Circular Design Speeds project through a series of design workshops conducted in-house with a fashion brand (Goldsworthy, Earley and Politowicz, 2019; Earley and Goldsworthy, 2019). In particular the bringing together textile design researchers and an environmental scientist working with the brand's in-house team enabled the refinement of circular garment concepts based on projected impacts of design adaptations.

## HEREWEAR Approach

Here the integration of the design research and environmental science methods into a combined process involved the use of a lifecycle map and of garment scenario canvas to facilitate conversations where the research process from each discipline were responsive to one another. Thus, new insights were drawn relating scientifically based environmental impact research to the design process. By integrating these two models circular design is placed at the centre of the design process and backed up by scientific evidence. It is not intended that 'absolute' metric judgements will be made, rather that design decisions will be linked to impacts on a scale which a designer may understand and utilise in their process.

The design work was based on a new set of guidelines named the BIO TEN (Earley and Forst, 2023) adapted from existing circular and eco-design guidelines, in particular The TEN

(Earley and Goldsworthy, 2013), to be made specific to the HEREWEAR pillars of biobased, circular, and local. These guidelines inform the design of the new concept which is reviewed here. The direct discussion between environmental scientists and designers bolsters the decisions supported by the use of the BIO TEN guidelines. The aim of this study is to understand where the quantitative analysis insights can be translated into the detailed decision-making process for a specific garment. This format asks, "is A (generally) better than B from an impact perspective?". Further distinction is often necessary if A is better than B in a defined context, for example when biobased materials are better if they are sourced from waste, organic cultivation practice or specific regions.

## Key Tools for Collaboration

As put forward by Sumter *et al.* (2021), key competencies for design in a circular economy are collaboration and interpersonal skills. It is part of the role of the designer-facilitator to provide the tools for effective collaboration. Two key tools supported the discussion between LCA and design researchers.

### *Lifecycle map*

Using the full lifecycle approach of LCA, the mapping shown in Figure 1 highlights all the different stages of the lifecycle of a biobased, circular, local garment. The development and use of this tool is further discussed elsewhere (Forst and Earley, Forthcoming). Here this visualisation was useful in communicating with environmental scientists on how impacts of material or process choices might be calculated, and guide the development of garment concepts.

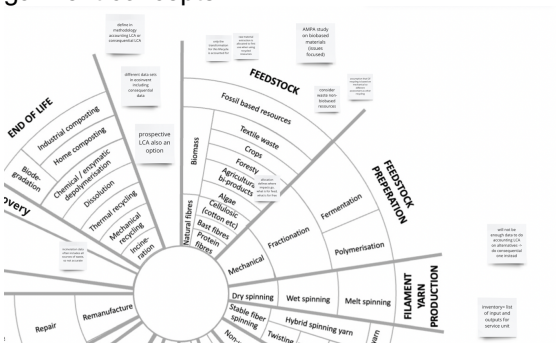


**Figure 1. A screenshot of the lifecycle map tool used in a guided discussion to identify impact hotspots and how they are assessed.**

### *Garment scenario*

Based on the lifecycle map, a format for garment scenarios was developed which accounts for the multiple design decision points available. It asks questions for each stage of the lifecycle to prompt design decisions. This was also used to facilitate cross-disciplinary conversations to identify how features of the product might affect their environmental score. This format provided a holistic view on the full garment system, including business models and associated services, which are key to understanding the potential for a feature such as modularity to have a meaningful impact reduction effect.

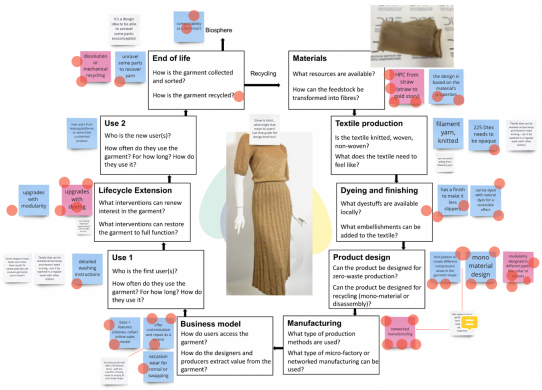


**Figure 2: The garment scenario for the 'Flexi Dress' concept with annotations from a collaborative review.**

## The Lifecycle Design Method

The impact of LCA insights in the design decision making process were reviewed over 3 stages of developing a garment concept. The method followed a Define, Redesign, Refine approach, with each phase here including collaborative discussion and executive decision making. These collaborative design and discussion moments were structured to support the direct sharing of knowledge between disciplines, Matching requirements for the progression of each aspect of the work.

### *Define*

This corresponds to the inspiration and research phase of the design process. The team were asked to provide reference fabrics, existing products from partner brands, and examples of resources and production processes by competitor brands and projects to emulate. Collectively reviewing these elements showed characteristics to benchmark the new garment concepts against. While this "framing

the problem" (Cross, 2011) phase is typical of a design process, from an LCA perspective, it sets the reference to calculate the impact savings achieved through redesign decisions.

*Redesign*

In the redesign phase, speculative garment concepts were developed. This paper focuses on the "Flexi Dress" concept which was based on a new material sample. As opposed to a standard redesign approach, the garment shape and function were extrapolated from the material properties, in particular the lustre of the knitted material. This garment concept draws light to the current limitations of LCA to provide intermediate insights in the design process: as the concept is entirely new and not based on an existing product, the improvements are more difficult to assess and quantify. The concept was built using the garment scenario format. This canvas supported discussion amongst the different technical experts and designers in collaborative workshops online and in person to imagine a full garment lifecycle and weigh the impact of decisions.

*Refine*

In this phase direct facilitated discussion between environmental scientist and the brand designers helped refine the concept. In the redesign phase, many of the BIO TEN guidelines had been applied to the flexi-dress concept, such as zero-waste pattern cutting, repair, or modularity. Reviews of eco-design approaches have shown that some strategies may be more effective than others in reducing impacts (van Hemel and Cramer, 2002). For a realistic product development, a specific circular design strategy was selected for assessment. The designers questioned the benefit of modularity for this concept. It is foreseen that to enable this feature, then parts of the dress must be designed with an attachment system which could incur more complex manufacturing and more materials, possibly affecting the environmental score.

Designers understand that sustainable and circular design strategies must be approached critically, bearing in mind possible impact shifts, but often this understanding is limited by the unavailability of data and the complexity of measuring impacts across various indicators. One of the challenges of designing in this way is that no strategy is a clear win or loss, and most often the LCA experts' answer will be "it depends". Where it is possible to elaborate and clarify on what parameters and factors it depends on this can potentially lead to a valuable dialogue and can be used to iteratively co-create innovative design.

## Challenges of embedding LCA insights in a design process

The methods used in design and in LCA are so different that it is often a challenge to mesh both practices together. The eco-design approach inspires designers to make garments with the potential for longer life and recyclability, but it is generally difficult to objectively measure the benefits of such practices. On the other hand, LCA is the methodology and measurement behind sustainable design, but it if is used to evaluate distinct scenarios and parameterized concepts, it is not suitable as a creative ideation approach. Quantitative assessment of uncertain parameters is well established, but emerging topics for which no data or methods are available cannot be included, known unknowns and unknown unknowns will thus be missed in an assessment. To enable a shift to circular practices, the creativity of designers must be bolstered with evidence for better choices in material, manufacturing process, use, and end-of-life management, with a clear documentation of trade-offs. LCA experts usually perform assessments at the end of the concept development phase, their work involves collecting data from all processes and treatments in the product's lifecycle but can also be carried out for intermediates and preliminary stages. Their experience provides tacit knowledge of how a decision might be weighted in the LCA balance. These qualitative insights from LCA can be useful in conversation as a product concept is developed.

It was therefore valuable to put in place mechanisms like the life cycle design method and tools such as the lifecycle map and the garment scenarios to support conversations between the designers and the environmental scientists throughout the different stages of the decision-making process.

## Conclusions

This paper shows how environmental science expertise can be drawn into key phases of the design decision making process to support the inspiration provided by design guidelines with a product specific follow up. At each of the define,

redesign, and refine stages designers can be supported in selecting materials and processes with reduced environmental impacts by nurturing a conversation that balances achieving a desirable design outcome while reducing impacts. Tools that visualise the decision-making process and a garment concept with a full lifecycle approach were found to be useful in nurturing these conversations. The research carried out in the HEREWEAR project has demonstrated the potential for qualitative LCA insights to be used in the design process without waiting for the garment concept to be fully defined to perform an assessment. In the next phases of the research, full assessments will be made for the final version of the Flexi Dress concept and others to measure the effect of the lifecycle design approach.

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