Co-Design of Creative Products Embedding Recycled Fibers

Sarah Behnam, Giacomo Bonaiti, Severin Filek, and Tamara König

Abstract The involvement of designers in the sustainable transition from linear to circular economy is crucial since they significantly contribute to the realization of products and services. In the FiberEUse project, a multiple-step approach to co-design was employed, starting with the definition of a first and second design brief in order to clarify the task objectives for designers. This was followed by the description of the co-design process, which aims to engage designers to contribute innovative design concepts for recycled composites. By publishing design concepts in the feedback collection software module Idea Manager, designers and users were able to exchange information, insights, visions, and thoughts digitally. The Idea Manager comprises a feedback collection tool that supports a first assessment of design concepts. Depending on the design briefing and/or confidentiality agreements, the feedback collection and the assessment can either be done (stakeholder-)internally or publicly. A flowchart illustrates the multi-step approach of co-design within the FiberEUse project. The feedback collection process was aided by a progress analysis to detect new value chains for business cases. For the selection of product design concepts, a progress analysis partitioned into four main criteria, the following aspects are drawn on for assessment: (i) quantitative and qualitative production feasibility, (ii) closeness to market introduction, (iii) potential volume of the market, (iv) circularity, (v) type of market, (vi) service opportunities, and (vii) take-back/deposit systems. Aside from bringing out the advantages of co-design for consumers as well as production companies, this chapter also discusses general challenges of co-design and co-creation in a broader sense when intellectual property rights (IPR) are not respected appropriately. The participation in a publicly accessible co-design of

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concepts must be clearly communicated and accepted by each participant by agreeing to intelligible terms and conditions.

Keywords Co-design · Creative products · Re-use · Glass fibers · Recycling

1 Introduction

'Design is a crucial element for European competitiveness', said Günter Verheugen, former Vice-President of the European Commission [1]. Design is often misinterpreted as sole aesthetical form-giving for decorative purposes, or as a 'finishing touch'. However, design is far more complex and diverse. Design is a strategic instrument with which entrepreneurs can define how their products and services are perceived on the market [2].

Designers are key for a sustainable transition from linear to circular economy as they contribute products and services within a co-design approach for circular design. The transformation of our current linear economy into a circular economy, which is driven by 'smart consumption' and 'smart products' [3] appears most promising. However, the shift to a circular economy is gradual and not radical, it is a transition and not a switch. Creators and decision makers, such as designers, engineers, and industrial managers, play a crucial role for a successful change. Multi-step approaches in defining targets, analyzing markets and data need to involve players for co-creating product and service solutions that are long-lasting and of high added value, yet flexible in adaption for optimization.

The objective of the co-design methodology for FiberEUse is the development and improvement of circular economy-oriented products via close cooperation with users and/or (end-)customers as well as design professionals to unlock potential profitable circular economy solutions for the re-use of composite material. Open innovation activities in the development phase of co-design projects, for instance collaborative IT-supported feedback collection, is assessed as crucial [4].

The feedback collection accelerates the:

- development of product design concepts based on the FiberEUse circular economy paradigm for composites.
- improvement of these circular design concepts in a collaborative co-design process and by integrating market data.

The following chapter describes the methodology of co-design and feedback collection in detail.

2 Methodology of Co-Design Approach and Customer Feedback Collection

2.1 Exposé and Selection of Co-Design Partners

An exposé on the FiberEUse paradigm for communicating the overall scope of the FiberEUse project is a recommended starting point for each co-design process and its corresponding design briefings. The aim of the exposé is both to raise interest in the industrial, and product design community, and to collect questions and insights into the status quo. A 'Call for Interest' through various media channels supports the promotion of knowledge transfer with regard to experience in designing products made of recycled glass-fiber reinforced plastics (rGFRP) in line with circular-economy principles.

In order to find a cooperation partner, the following criteria are recommended to be met:

- Design and material expertise (especially with composites such as rGFRP).
- Access to research and workshop facilities.
- Knowledge of incorporating circular co-design methods.
- High commitment to co-design for circularity.
- Interdisciplinary working attitude as a common prerequisite for professionals.

The communication phase between co-designing partners helps reveal the level of engagement and intensify the flow of information. Keeping up a high-quality level of communication is key for success of the co-design process and its outcomes. As soon as the co-design partners were defined, a document (the design brief) was drafted to outline the scope of the cooperation project. The following design process flow chart illustrates the co-design process from the first design brief to the actual results, namely circular-designed product proposals (Fig. 1).

2.2 The Design Briefings

The first design brief of the FiberEUse project included the following five activities for co-design to be performed:

- market research and analysis on the status quo of designs complying with circular economy and circular co-design practices in special regard to end users and/or end consumers needs;
- material research on recycled composites, including physical testing and development of a comprehensive material characteristics information sheet;
- examination of current waste streams in Europe to understand the transition points from linear to circular economy;

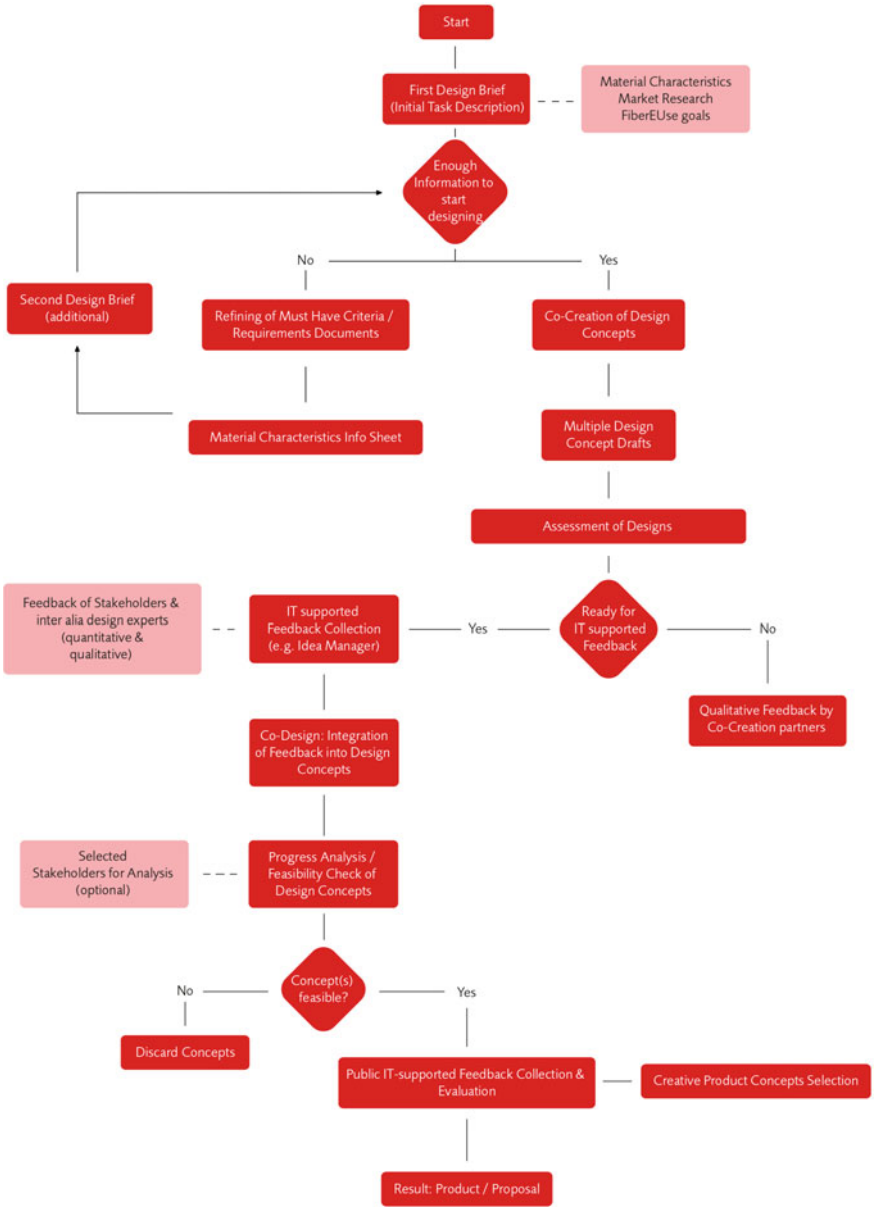

Fig. 1 Design process flow of co-design and feedback collection in the context of creative products embedding recycled fibers

- creation of a design brief to provide description on tasks/objectives and to support the individual task descriptions for designers from various expert backgrounds, e.g. designers providing specific chemical and technical expertise or designers specialized in interior design (furniture), exterior design (construction/architecture);
- Multi-step co-design processes through personal meetings and IT-support.

This first briefing helps to clarify issues—most commonly regarding functions and aesthetics of design concepts, timing, and budget. Furthermore, it simplifies eventually demanded cooperation agreement contracts. Those first considerations lead the way to a second, more detailed, design brief.

The second design brief encompasses processes and contents to determine basic objectives and scopes of designs that are going to be optimized in the co-design procedure.

- Activities/content chapters include purpose, function, deadlines;
- Designs should have high social, emotional/aesthetical, and functional utility;
- Marketing objectives are determined, e.g. strengthening the unique selling proposition (USP) or market position through product/material innovation; quantity/quality requirements foresee high-volume and medium-quality products and high-quality and medium-quantity products respectively;
- Material analysis and development of an extensive document that contains relevant material characteristics data for the design project to gain the best results in the conceptualization.

Furthermore, written information on the recycled material to be used was collected and shared. This material is the recycled fiber reinforced plastic material called ‘Glebanite’ [5]. It is grinded scraps of glass reinforced polyester with unsaturated polyester resins. In addition to the written documents, examples of early stage use-cases of Glebanite, such as prototypes of home décor pieces, as well as handy-size samples of Glebanite were provided to convey both written data and a haptic impression of qualities and characteristic.

Since Glebanite is a material for manifold purposes, a catalogue of criteria of ‘must-haves’ provides for the continuous alignment with the respective project’s objectives and to create a framework for the product design development.

‘Must-haves’—design criteria for creative products embedding recycled fibers:

- Design for circularity: First of all, designs for potentially slowing the resource loops by creating designs for reliability and durability are demanded. Research results of potential reuse, repair, redistribution, remanufacturing, and refurbishment should be incorporated in the design concept to help open up discussions on the feasibility of product concepts and their related services in IT-supported co-design.
- Design for resource recovery: products need to be easily traceable and collected after their end of life or for maintenance.
- High significance of social, functional, and emotional utilities.
- Willingness to present product design concepts publicly.

- Products shall contain 100% Glebanite if possible.
- Continuous integration of feedbacks by end customers generated via digital tool Idea Manager by Holonix as part of the co-design approach.

Furthermore, the development of products and services follows open innovation principles. That means that product development does not necessarily follow close-to-market principles but focuses on finding optimal solutions for current or future problems in an open and interdisciplinary manner [6]. For the FiberEUse project it was commonly agreed to develop creative design products with high functionality, high value to public society, as well as of high aesthetic demands.

The second brief marked the beginning of the co-design process. Immediate actions after the design briefing comprised field surveys among potential customers differing in education, age, residence, and financial status, as well as desk research by designers.

2.3 The Co-Design Procedure

A multi-step approach employing analog and digital co-design encompasses ad hoc meetings (online and offline) for direct interaction with the designers. In FiberEUse, it was beneficiary to involve designers in all creation phases until the completion of prototype production.

The first offline co-design phase shall result in the collection of design drafts. Open innovation online tools such as the feedback software Idea Manager by Holonix benefit the collection of design concepts and feedback quantitatively and qualitatively.

The use of online feedback tools. In general, a web-based software tool for continuously gathering customer feedback and for supporting product co-design and improvement along the phases of the product design process assists in amplifying the coverage of a collaborative environment. It is recommended to make use of digital tools in a multi-step process including several pre-tests in order to provide time for further optimization, to build up acquaintance with the tool among potential participants, and to raise engagement in contributing.

In a first feedback collection, stakeholders can take part by registering and contributing comments. The detailed methodology of the Idea Manager will be described in more detail in Sect. 3.

The second phase of the online and offline co-design process can be rounded off by a presentation and feedback collection from a wider public, respectively customers.

Design concepts feasibility analysis. A feasibility analysis assists with the selection of the most promising product design concepts matching the aforementioned criteria and ‘must-haves’ of the design briefing.

Uploading the revised and adapted product design concepts by the design teams of the NDU to be presented publicly to the Idea Manager software kicked off the second IT-supported feedback collection. The link to access the Idea Manager was sent to

the consortium to be passed forward to existing customers and relevant stakeholders and published in the various networks of FiberEUse. This procedure allows a broad definition of product-use-oriented customer groups to enhance feedback quality and reduce potential bias caused by the selection of narrow-defined target groups.

A public audience is invited to take part in the IT-supported co-design sessions evaluating selected product design concepts. The access to the feedback collection demands several promotional activities, such as social media activities. In general, frequent feedback collection activities must be part of an overall communication plan to raise the engagement of interest groups.

Recommended proceeding is the advance notice of release dates of preliminary and final results. A frequent and organized direct communication that informs about all aspects relevant for targeted stakeholder groups via convenient media channels is key to a sustainable success of dissemination achievements.

Analysis and operationalization of criteria and assessment scale. Pre-screening design concepts from an industrial point of view includes feasibility, potential business case, and their relevance to the focus of the project on circular economy principles. Accordingly, four criteria including a brief operationalization for each of them are defined for assessing the design concepts:

- Production feasibility
- Closeness to market introduction
- Potential volume of market
- Circularity.

In the following, a brief operationalization is given for each criterion to clarify the analysis (Table 1).

In order to quantify the assessment of the design concepts, each design concept is assigned a score on a Likert scale of 1–5 corresponding to each above-mentioned criterion (1 representing least promising to 5 as the most promising) (Table 2):

Subsequently, web-based tool Idea Manager for collecting and assessing creative product design concepts aiming to support the co-design process is introduced.

3 Digital Co-Design: The Idea Manager by Holonix

3.1 Defining the Scope and Objectives of the Idea Manager

The Idea Manager (IM) is a web-based software-tool designed to provide and support activities along the process of idea generation and co-design.

The IM can be accessed via: https://fibereuse.holonix.biz/ideamanager.

According to the recommendations on the user-centered software development that enhances usability and user experience, the following steps have been taken into account to implement and adapt the Idea Manager for the FiberEUse co-design and feedback collection:

Table 1 Analysis and operationalization of criteria for assessing the design concepts

Criterion	Operationalization of criterion
Production feasibility	This criterion is measured based on complexity as well as economic points of view in terms of production and packaging. In particular, the criterion is assessed depending on several factors such as the shape/properties of the product; the applicability of using semi-finished material for its production (which is cheaper and easier from the production point of view); the required technologies for its production; the need of manual input in the production process (related to production costs), etc.
Closeness to market introduction	This criterion is assessed based on the approximate level of the product's introduction to the market, which is evaluated mainly based on the benchmarking with products already on the market with the same/a similar functionality, as well as the usefulness/necessity of the product for final users
Potential volume of market	This criterion is assessed depending on the potential volume of the production, which is a factor depending jointly on the type of the market for the product and on the volume/amount of recycled material in each product piece. Basically, the larger the potential market of the product, the higher this criterion is assessed
Circularity	This criterion is assessed based on the potential of the product for improved circularity in the value chain. In this regard, diverse factors of circularity (e.g. life cycle of the product) as well as the efficiency of the take-back system for collecting the product after its life has ended are taken into consideration (ease refers to applicability but also the ability to offer services with the product for improved take-back system)

Table 2 Assessment scale interpretation

Criterion	Assessment scale interpretation	
	1	5
Production feasibility	Least feasible/expensive	Highly feasible and easy/cheap production
Closeness to market introduction	Far from market introduction	Close to market introduction
Potential volume of market	Low-potential market volume	High-potential market volume
Circularity	Most difficult take-back system/short product life cycle	Easiest take-back system/long product life cycle

- identifying and selecting appropriate dialogue techniques;
- defining the sequence and timing (dynamics) of interaction: order of actions as to register, submit contribution, search for content and edit it, verify if applicable to the role assigned;
- defining the information architecture of the user interface of an interactive system to allow efficient access to interaction objects: overall integration and implementation.

As the result of the design process and input gained during the software testing and refinement phase, the implemented features have been defined to face specific objectives of the software with respect to its purpose and FiberEUse co-design scope. Continuous testing and refinement of the software interfaces improves functionality and usability of the tool, e.g. registration system, submission of new content, and feedbacks.

3.2 The Functional Features of the Idea Manager

The IM provides a collaborative environment for sharing ideas on innovative products by means of publishing ideas and collecting reactions and comments on these submitted ideas. In the process of co-design, the aim of the tool is to provide qualitative and quantitative feedbacks from a target community.

The protection of IPRs (Intellectual Property Rights) must have priority. In order to support the protection of IPRs, the IM provides the option of restricted access to a company, an organization, or individual initiators. In that case, ideas can be shared only with a specific audience, for instance a certain group of designers. If restricted access is preferred, contributors—which can be end-users, designers, entrepreneurs—may see and contribute to the concepts of other designers, but results are not open to the wide public.

In any case, the IM always provides clear information about the type of publication (generally accessible or restricted) and asks its users during the registration process to agree to the publication mode when accepting the general terms and conditions.

In the FiberEUse project, the IM supported an open-access co-design following the open innovation principle, encouraging a wide public audience to take part in the development processes.

In general, collected feedbacks along the co-design process can be used to determine future refinements of the proposed design solutions and the selection of the most attractive and feasible design product concepts.

The IM enables the following stakeholders to participate in co-design.

- Organizations (‘drivers’) looking for innovative ideas, the most promising directions, informed decisions, and strategic solutions for product design and development.
- Idea creators (‘contributors’) proposing, sharing, and elaborating new ideas and solutions for design products.

- Moderators ('content managing users') who can decide on the appropriateness of ideas that can be shared within the community, whose members in turn generate ideas and provides feedback in the form of comments, votes, and further elaborations; moderators can also create surveys and polls, access statistics, and aggregate ideas into concepts.
- Evaluators ('viewers') participate in co-creation; they can directly express their appreciation and opinions by voting and commenting ideas or answering to surveys and polls.

The implemented functional features of the IM [7] are:

- Creation, search, and editing of ideas
- Management of ideas: approval of publication and removal from publication list
- Visualization of ideas statistics
- Creation of voting mechanisms.

Web-based software tools such as the IM need to be functionally and graphically designed to achieve two of the main objectives of a project:

- stimulating the (co-)creation and evaluation of ideas about new products from re-cycled materials, as well as
- enhancing people's awareness of how materials, e.g. fiberglass reinforced composites, can be used to give life to new objects.

The interfaces of the online tool need to be designed and implemented to provide information about the project and offer the necessary information to guide the stakeholders involved through the idea creation and evaluation phases. The graphic appearance of the site was adopted to FiberEUse's visual identity to provide visual brand recognition.

4 Creative Product Concepts Embedding Recycled Fibers

4.1 Production Technologies

The starting point of the selection of creative product concepts in the FiberEUse project is the identification of production methods for prototype production incorporating recycled fibers. Ten production methods are currently being used and/or tested:

1. open-mold casting
2. closed-mold casting
3. compression molding
4. vacuum casting
5. continuous lamination
6. continuous extrusion

Table 3 Technology in relation to recycled content of selected prototypes

Technology	rGFRP content wt%	Prototype
Open-mold casting	41%	Variously colored cylinder-shaped tests
Closed-mold casting	37% because fresh glass is added (to be confirmed during preliminary test)	Swing
Compression molding	37% because fresh glass is added (2×600 g/m^2 biaxial) for improved mechanical resistance 38.7% because fresh glass is added (1×375 g/m^2 CFM) for improved mechanical resistance	Yellow (stool) Lamp

7. 3D printing
8. rotomolding
9. centrifugal molding
10. filament winding.

Several prototypes and concepts of creative design products following the aforementioned design brief and demonstrating the manifold possibilities of applications of recycled fiber reinforced composites are described in detail in Chap. 15 'Use Case 1: Mechanical Recycling of Short Fibers' of this book.

4.2 Manufacturing Results

Table 3 sums up the production technologies for the prototypes and indicates the achieved percentage of recycled content per design product prototype. All of the rates have exceeded the initially targeted 30%.

5 Co-Creation | Co-Design: Creative Methodologies and Their Challenges

Co-creation and co-design as specific instance of co-creation in collaboration with designers [8], have always been tools used by design practitioners and have even become increasingly popular among wider groups over the past decades. The idea of co-creation differs in perception from a strongly rational to a spontaneous and almost playful approach [9]. Co-creation methodologies provide the possibility to engage entire stakeholder communities in developing activities to benefit from various user contributions and perspectives.

However, among the manifold advantages of co-creation and/or co-design, such as creating a better fit between the product or service offer and customers' or users' needs [10], the risk of negative impacts is evident: companies or institutions may abuse these approaches to exploit valuable ideas and insights supplied by customers and/or users spending time and energy in collaborating with these companies and institutions while companies may also violate the IPR of designers and co-creators. This danger can never be entirely prevented when concepts are (publicly) shared. Facilitators and users—if being aware of their IPRs—may be willing to share and exchange ideas in order to support the optimization of products and services when benefitting from solutions in their professional or private lives. It remains the responsibility of a co-creation and/or co-design initiator to point out those benefits and risks before participation in joint actions. Thus, it is of great importance to keep co-creation and co-design as open processes that allow the involvement of many groups and to ensure at the same time that those having the power to use this process are provided with enough incentives, such as potential market opportunities, to keep the process fair and sustainable.

It is necessary to question the strategy and method of co-design. Utilizing a co-design process is a preferable approach and a solution for a specific problem, question, or project (like FiberEUse) with respect to the necessity of:

- gaining information about some innovative recycled material (which can only come from the stakeholders involved);
- convincing designers and companies to use this material, provided its performance is satisfactory;
- changing mindsets of people/users to use (these/other) recycled materials: and
- building on awareness for circular economy.

The design profession is a problem-solving profession involving various disciplines (not only product and industrial design, but also communication design, social design, information design, interface design, etc.). Designers are also able to change the user behavior and to facilitate changes (e.g. social change) by means of their work. Questions and problems concerning our society and environment are increasingly posed to designers, who are able to not only improve and change a product or the usage of a product, but also a service and/or system. It is not only designers working on solving a problem, though. In order to minimize clients' risks and funds invested, and in order to influence customers'/users' attitudes and acceptance, more and more people (in organizations, companies, etc.) need to work from different sides and with stakeholder groups.

Hence, the profession of a designer has developed rapidly from problem-solver to consultant (who is expected to have more and more expertise in various disciplines like mechanics, engineering, computer science, packaging, logistics, etc.). Designers now may find themselves as leaders of processes, such as the design thinking approach, checking multiple possible solutions to a problem as to their feasibility and acceptance on the side of clients/users [11].

Going beyond feedback collection, one needs to ask: Has co-design really become increasingly relevant? Or is it just used more because clients/companies want to exploit various means and methods when creating a new product?

Two aspects of a company's behavior help understand the popularity of co-design methods even if sufficient copyright protection is at stake:

- Co-design contributes to finding out if a product/service really meets customers' and end-users' needs.
- Companies want to have guarantees before investing in/spending money on innovation.

Co-design methodologies are definitely a possibility to start influencing and changing mindsets, raise awareness, and move faster in the direction of a circular economy approach, as all stakeholder groups can be involved in the process and be made responsible for the outcomes. Still, their will and wish to bring about change and their positive attitude are required, as is, on the companies' side, a willingness to invest.

If…

- a designer as creator,
- a company as producer, and
- a client as user.

…act in a visionary way and feel responsible for our future, health, environment etc., they might already be very much aware of using recycled materials and/or products resulting from a circular economy approach. The methodology proposed is one of truly involving all stakeholder groups—in order to gain insight in all their aspirations and needs.

Still, it is necessary to keep in mind that IPR rights are involved and that they should be considered and protected by all means; the more people and stakeholders are involved, the more important this becomes.

6 Conclusions and Prospects

For FiberEUse the process of co-design and feedback collection of creative products embedding recycled composites utilizes analog and digital means aiming to involve stakeholders, in particular product designers and the community of end users. Their cooperation is essential for accomplishing a circular-oriented design of products including a dismantling and return systems for product recycling.

Analog (personal) knowledge transfer and IT-based feedback collection tools based on the example of FiberEUse's online tool Idea Manager as part of a strategically oriented communication is crucial for long-term success in co-design for circular economic transition. The advantages of co-creation and co-design for end users and production companies are pointed out and potential risks of copyright violations are discussed.

Future steps include the integration of data and knowledge of essential European stakeholders in cloud-based platform(s) for value chain integration to reach a wider number of potential users of recycled composites.

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