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Eco-design and Eco-materials: an interactive and collaborative approach

Abstract

Sustainability and recycling have come to be keywords in many consumer products. However, the creative industry still lacks design tools suitable for sustainable development. While different recycled and sidestream materials are available in industry, the relation between sustainability and the use of new composites is still difficult to be evaluated and integrated into the early design phases for the creative area. This paper deals with a collaborative Eco-design approach to support these tasks and overcome traditional limits using an interactive approach. The interaction regards the collaboration between several stake-holders such as designers, manufacturers and suppliers throughout the engineering activities and value stream. The framework of an Eco-design tool is proposed to evaluate secondary raw materials, processes, user's feedback, and best practices for the selection of green and recycled materials.

Keywords: collaborative design; recycling; creative industry.

1 Introduction

Recycling and energy efficiency are two of the most used practices for introducing a new product to the market [1]. Organizations such as the European Union have been implementing a green policy to enhance environmental sustainability focusing on several consumer goods [2]. In this context, while the design of engineering products is well structured to support Eco-design activities, different limits are related to the creative industry for what concerns the selection of environmental-friendly materials and composites to meet design requirements with a low environmental impact [3].

With its potential to make products and services user-friendly and appealing, the creative design closes the innovation loop from initial research to commercially viable innovations [4]. Creative design is a non-linear innovation process which can derive from unforeseeable results of people with different skills, cultural background and education. The non-linearity refers to triggering ideas and the joint cultivation of them. This characteristic differs from strategies based on technology-driven design related to the viewpoint of the manufacturing industry [5].

Nowadays, there is increased consideration of the design concept and material selection concurrently at the early stage of product development [6]. In this context, Eco-design tools are necessary to minimize the environmental impact due to the product's materials and related processes [7]. Creativity approaches have emerged as a driving force to innovation processes. Buzuku and Shnai highlighted that using creativity assessment methods and Eco-design methods facilitates the decision-making process in the early stage of conceptual design for sustainable manufacturing [6].

In engineering design, Design for the Environment (DfE) is one of the most applied design strategies to support the innovation of sustainable products [8]. Another approach to support the eco-innovation is the use of the Life Cycle Assessment (LCA) analysis [9, 10]. Both approaches are valid methods to support an eco-innovation activity to reduce environmental impacts [11] related to the lifecycle of a product [12]. The LCA approach aims to evaluate the environmental impacts in terms of eco-indicators such as the Global Warming Potential (GWP) method [13]. Traditional DfE and Ecodesign tools are used to support the re-design of products. Several OEM manufacturers have been investing in Eco-innovation activities [11] to support the early estimation of product energy performance. However, regarding the industry there is a lack of tools and studies to provide a collection of environmental-friendly materials.

Reducing energy consumption and promoting efficient use of energy are considered key factors in achieving a sustainable business. In fact, companies need to consider the environmental impacts of their products as a competitive and innovative component. One of the risks of environmental analysis is to not produce a result for business evaluation. Moreover, some material can be considered critical for business if it has high price volatility and high supply risk [14]. Generally, as highlighted in [15], companies have to consider three aspects:

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economy, environment, and society. However, the creative industry also needs to consider the aesthetical and functional impact on the final-consumer.

Figure 1 describes a typical design flow related to the creative industry, where the producer interacts whit each player without using collaborative and knowledge sharing strategies. As already known in literature, collaboration and team management activities are suitable to enhance creative processes in a team-based design [16]. A current trend of product design leads to a change in the collaborative working style. To find the most efficient way to exchange information on the digital mock-up of a product, a synchronous co-located collaborative design environment with recent technologies is often necessary [17]. In the creative industry, a typical design workflow for small-medium enterprises (SMEs) is producer-driven. Usually, the manufacturing company interacts with each actor such as material suppliers, research centers, market, service, stakeholders, etc. Some limits can make it difficult to push innovation and integrate the market's feedback into the early design loop. Another limit concerns the integration of the research and development of Eco-materials with design activities.

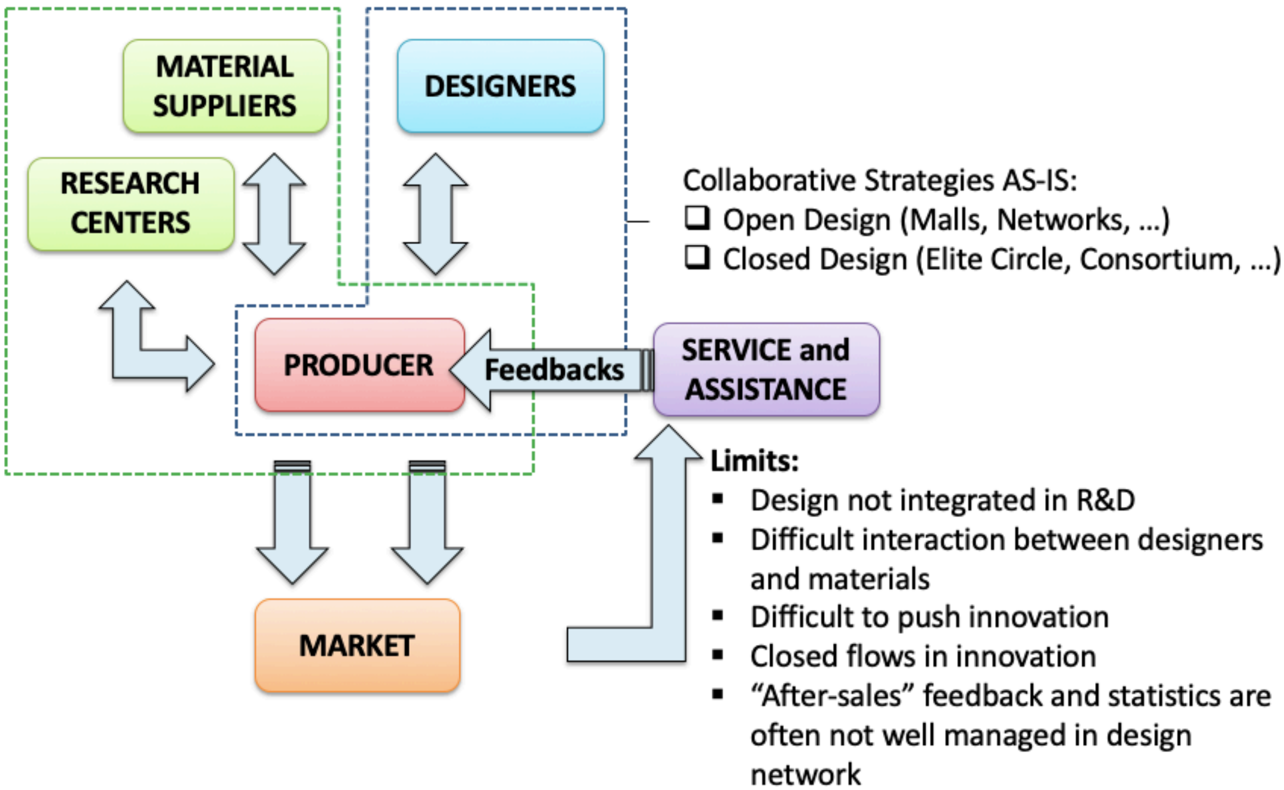

Figure 1 State of the art: a typical design workflow in the creative industry (especially for SMEs).

Guo et al. studied Case-based Reasoning (CBR) applications to support innovation in creative actions for engineering design [18]. In their approach, design tasks have to first be formalized through API (Application Programming Interface) functions in order to be mapped with ontological concepts. Then, a CBR tool searches for the most similar design cases by measuring their similarity with cases in the database. One of the limitations of these systems is the definition of specific functions for the design of a specific product. Eco-design related to the creative industry requires tools to share transdisciplinary knowledge more quickly concerning Eco-materials and their processes. Another Eco-design approach is based on the Theory of Inventive of Problem Solving (TRIZ) and morphological analysis. Some research integrates TRIZ with other methodologies such as Life Cycle Assessment (LCA) and Life Cycle Engineering (LCE), to help design engineers to create, evaluate and select the best solution in order to meet the business' objectives for eco-product and sustainable manufacturing [6].

The integration between environmental aspects and business strategies at the product design stage has been also studied by Chen et al. [15]. Rodrigues et al. researched how Eco-design implementation can potentially affect key corporate performance outcomes [19]. In particular, these studies highlighted a lack of robust decision-making tools to support the development of a business case.

In the context of sustainable design, a recent issue is the interaction between business and Eco-design. As described by Buhl et al., there is a lack of research regarding the application of employee-driven innovation to the development of eco-innovations [20]. This lack is also extended to the evaluation of the potential benefits for the business performance related to Eco-design and Eco-innovation [21].

Recyclable and reusable materials can be recovered at the end of life and re-entered into the industrial flow to become parts of new product chains. This recovering workflow can also support businesses to prevent loss of materials, reduce supply risks and minimize costs for production and disposal. From an environmental point of view, recycling and reusing materials can contribute to reducing the environmental impacts associated with raw material extraction and waste treatment at the end of life [22]. Therefore, an early business model should consider the recyclability and reusability of the Eco-materials involved in the conceptual design.

As highlighted by Pigosso et al., one of the possible Eco-design practices concerns the management of information related to the environmental performance of materials, processes and components in all the product life cycle phases [23]. In fact, the environmental dimension of a product is related to the technicalities of the product such as physical units, materials, energy, efficiency, and environmental load [23]. One of the technical issues of product design is directly related to the material life cycle. The absence of mechanisms to evaluate the potential benefits of Eco-design prior to implementation is a major barrier to wider adoption in manufacturing firms [24]. In fact, most business cases in Eco-design are evaluated with a *posteriori* analysis. The integration of such sustainability-related aspects into product development is considered a complex task, with high interconnectedness among variables over time [25].

Table 1: A list of Eco-design practice related to materials, as described by Pigosso [23]

Minimize material consumption	
	Use as much recyclable material in the process as possible
	Avoid the use of packaging that does not have a specific function
	Design the package to be part (or to become a part) of the product
	Use recyclable, reusable and returnable packaging
Extend the Lifespan of Materials	
	Use recycled materials wherever possible
	Develop considering the use of secondary materials after recycling
	Select materials that easily recover after recycling the original performance characteristics

Table 1 describes the Eco-design practices related to the materials issue as defined by Pigosso et al. [23]. These practices can be applied in the context of creative industry. Focusing on reusable materials, they can be thermoplastics, thermoplastic composites, and non-plastics. Generally, thermoplastics and thermoplastic composites carry an image of cheap to produce, large series products at a low degree of finishing for structural or componential applications or intended for disposal after short use. The re-processability of thermoplastics and vast possibilities to tailor the performance and appearance of composite products offers a huge potential for innovative design in interior and leisure applications. Therefore, grades recycled find typical secondary use as re-extrudates and fibers in automobile parts, appliances, textiles, nonwovens, foams, mulches, films and outdoor construction applications.

Different research deals with the use of recycled materials in the creative industry to create an elevated sense of craftsmanship in order to obtain unique and difficult to copy pieces [26]. The sense of craftsmanship can really turn the mass-produced products to mass-customized [27]. Moreover, due to several actions for increasing public awareness, the consumers expect more and more eco-sustainability products with recycled materials [28]. The complexity of the creative industry concerns the implementation of novel and sustainable material solutions to create unique effects [29]. Industrial designers have to meet sustainability characteristics with other properties such as color, surface appearance, etc. Therefore, new eco-design tools are required along the design process. This paper proposes a collaboration framework to enhance the interaction between consumers, designers and stakeholders inside the value chain.

Focusing on the demand for plastic materials in Europe, about 50 Mt is the current demand for plastic on the EU market with a turnover close to 300 billion euro [30]. While about 40% of the total plastic demand is represented by packaging applications, 60% is related to building, automotive, electrical devices, household appliances, furniture and medical products. However, about 27% of plastic waste is still landfilled in Europe [30]. Therefore, much energy and the processed raw material is lost instead of being recycled into new products. As an answer, the Waste Framework Directive [31] regulates the plastic waste collection to achieve 50% household waste collection target by 2020 in Europe. In this scenario, the end-of-life products and the production of sidestream materials are considered as potential secondary raw materials for second applications due to the incurred recycling costs and improved recycling systems. One of these second applications is represented by the creative industry, where the designers can adapt to the effect of new sustainable materials to create shapes with original effects such as craftsmanship.

The reusing of plastic and non-plastic materials is already described in the literature. For example, the thermoplastic shaping processes offer possibilities to optimally combine recycled materials of various types [32] such

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as different plastic matrices with by-products and derivatives from e.g. the wood, minerals, metals, glass, paper, textile, leather and resins converting industry [33]. Thereby, effects such as visual reinforcement fibers and fillers, non-plastic appearance, and optical effects can be achieved. The reuse of non-plastic materials with shaping and surface finishing technologies can compose manufacturing concepts that can be adapted to the functional and aesthetic needs that appeal to the customer [34].

This paper shows an approach for promoting new collaborative innovation strategies and practices throughout the value chain by reducing the gap between the material developers, designers, manufacturers and consumers. A user-centered orientation is applied integrating design into research and development, considering new eco-composites with recycled materials to increase product sustainability. The remainder of the paper proposes the methodological approach analyzing the architecture of a collaborative network. The design platform considers Eco-materials, processes, feedbacks, simulations, and users' interactions along the value chain for the development of creative products. A scheme of a visual chart is proposed to describe the business model related to the proposed approach. Finally, two test cases are described as an example of applications.

2 Methodological approach

Considering the context of the creative industry, this section describes the proposed method to support the employment of Eco-materials using an interactive and collaborative approach. The interactive approach regards the collaboration between different stakeholders throughout the engineering activities and the value stream (Figure 2). This methodology is focused on new business opportunities boosting innovation by knowledge sharing and enabling the transformation of industry through creativity. The research background concerns the integration of between user-centred design, Eco-design and product customisation. This collaborative approach aims at supporting the design of new manufacturing concepts such as composites with recycled materials in thermoplastics processing.

The main objective is the development of a collaboration network to innovate material solutions for the creative industry such as furniture, lightings and leisure. As described in Figure 2, the collaborative environment connects user-centred design, research, manufacture and suppliers to reach an interactive value chain. The integration of consumer perception is a trigger to innovative material solutions. The approach enhances the development of a collaborative web platform, called *Co-Working Interface*, where tools and data are shared between different users from industrial designers to consumers. The collaborative platform consists of two modules called as *Material Selection Tool* and *Interaction Interface*.

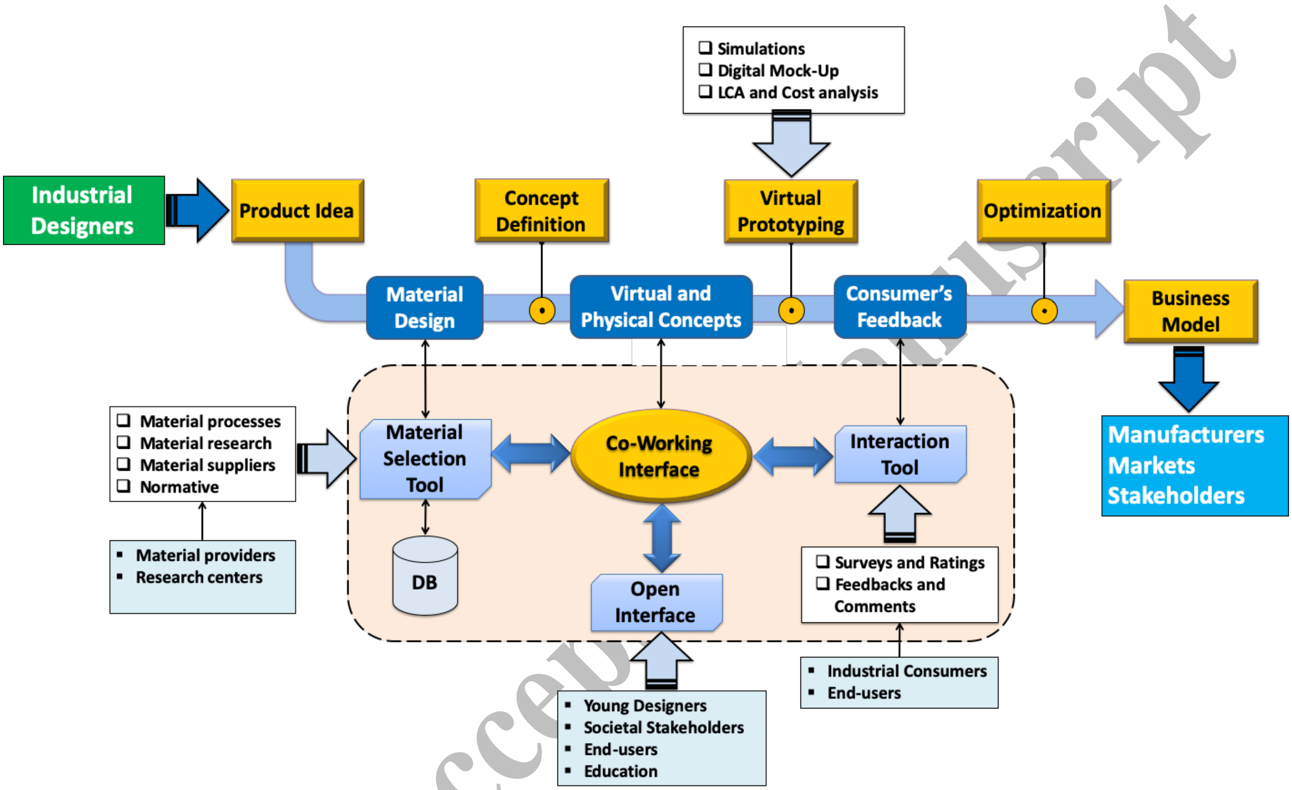

Figure 2 The interaction between the creative design workflow and the collaborative platform which involves different actors throughout the value chain.

The creative design has been here described as a 5-step process: product idea, concept definition, virtual prototyping, business model, and final prototypes with testing. Following, the description of the design phases highlighted throughout the value chain:

Product idea: it is the early conceptual study of the product. Designers elaborate ideas analyzing the requirements from markets, stakeholder's analysis and so on. This phase is the synthesis of market needs, consumer customizations, normative and suggestions;

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Concept definition: designers develop embodiment concepts including environmental-friendly materials. At this phase, the product specifications in terms of functionalities, appearance and innovation are synthesized. The designers complete the concept definition using the *Material Selection Tool* to define the employment of Eco-materials and their processes;

Virtual prototyping: Virtual and physical prototyping are included into the design platform. While physical concepts are necessary to demonstrate processability and performance of recycled materials, the employment of virtual tools includes studies based on simulations, and calculation such as LCA and cost-benefit analysis. Therefore, the use of virtual tools includes analysis based on conceptual mock-up regarding the evaluation of environmental impact, cost estimation, and product performance in terms of functionalities, usability, and appearance. Digital mock-up methods are also used to support the design-driven practices during the demonstration of concepts, in order to enhance the collaboration practices and user activities. At this level, designers can involve directly end-users, in order to obtain an early feedback. Finally, prototyping is the phase where concepts are manufactured, tested and presented. Results from virtual and physical analysis are collected into the repository *of Co-Working Interface* and visible only to the closed flat network (inner network) constituted of designers, manufacturers, and suppliers;

Optimization: the employment of new composites can require an optimization analysis based on virtual studies, testing of physical concepts, and feedback from consumers' analysis. The optimization phase enhances the development of new products with innovative functionalities and solutions. Customization and user-centered analysis are considered in this analysis;

Business model: this phase regards the definition of the details with the economic analysis to produce a business model for creativity products. Thus, revenue streams, values, channels, customer segments and cost structures are considered;

Final prototypes with testing: the final design phase regards the development of final prototypes with testing. The next step is the business plan and the presentation to market.

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Into the proposed networking, the designers have a central position in the transdisciplinary processes and interactions between creativity and innovation, materials and consumers, technology and business. The influences from the societal stakeholders to the collaborative design are related to normative (safety and environment policies), financing (investments), education activity and markets (sales, statistics, and competition). Particularly, industrial designers can be considered as interpreters of the user-centered design for presenting products with added value and Eco-materials to the end-users. In this scenario, the role of research centers is to enable valorization of waste and by-product materials into creative composites by developing their processing technologies as well as elevating the public awareness of possibilities in innovative recycled utilization.

The improving of the collaboration possibilities for design, materials research, materials recycling, manufacturing and firms is considered as crucial for a sustainable innovation into creative industry. The proposed network between these parties aims to contaminate innovation ideas in the meeting of different skills and knowledge, cultural assets and business models. In this paper, the design for the creativity industry is described as a technology-driven approach which includes research and best practices focused on the employment of Eco-materials and sustainable processes.

The *Co-Working Interface* is a web platform for promoting the collaboration design activities throughout the value chain. This application interacts with two different tools (Figure 2). A *Material Selection Tool* is proposed to support the selection of Eco-materials. The designer can choose composites structures with advanced functionalities and new appearance. Data collection also includes 3D model, datasheets, project sheet and reports. A shared database also collects data related to testing and analysis of virtual and physical prototypes.

Material data and processes are collected into a database. This information is shared on-line between the actors of the inner network (which are designers, manufacturers, suppliers, end-users, etc.), using the functionalities of the *Co-Working Interface*.

An *Interaction Interface* has been defined to improve the collaboration between internal and external actors along the value chain. External actors are final consumers, students, young designers, societal stakeholders, etc. Through logged account, each user can visit the virtual showroom, read open-document, view videos, have experience with digital mock-up, do surveys, rating solutions, leave feedback related to virtual and physical

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experiences, and attend in virtual workshops. Therefore, this interface allows different stakeholders to have experiences with design strategies and best practices.

Recycled materials are considered as secondary raw materials with potential to reach high-end composite products and reduce the manufacturing costs with gains in terms of environmental impacts. Material solutions, based on the valorization of waste in new composite solutions, give added value over secondary bulk products and energy use. For example, combinations of non-plastic recycled items with recycled plastics offer creative tailoring and shaping possibilities. However, these processes sometimes require refining and compounding processes to be optimally implemented. Recycled and environmental-friendly materials are here called as Eco-materials. In the context of the creative industry, there is the possibility to create visual, haptic, and functional effects by the selection and mix of recycled composites. Innovation in processes can also enlarge the materials performance in terms of lifetime and durability. Therefore, the introduction of a collaborative design platform has been proposed to enhance the widespread of new design and business solutions.

2.1 Material Selection Tool

This tool is a technical interface that supports the designer in the selection of Eco-materials and new composites including secondary raw materials (Figure 3). *Material Selection Tool* is a set of materials, processes and solutions to support collaborative innovations. This tool interacts with a Material Knowledge Base which collects information, data, and rules related to past projects and processes for using green and recycled materials. Industrial designers and materials suppliers are involved in this framework in order to increase the valorization of the recycled materials using sustainable manufacturing processes. The resultant solutions are novel material compositions for creativity products. Materials and processes data are collected into a database repository which is connected with Material Knowledge Base.

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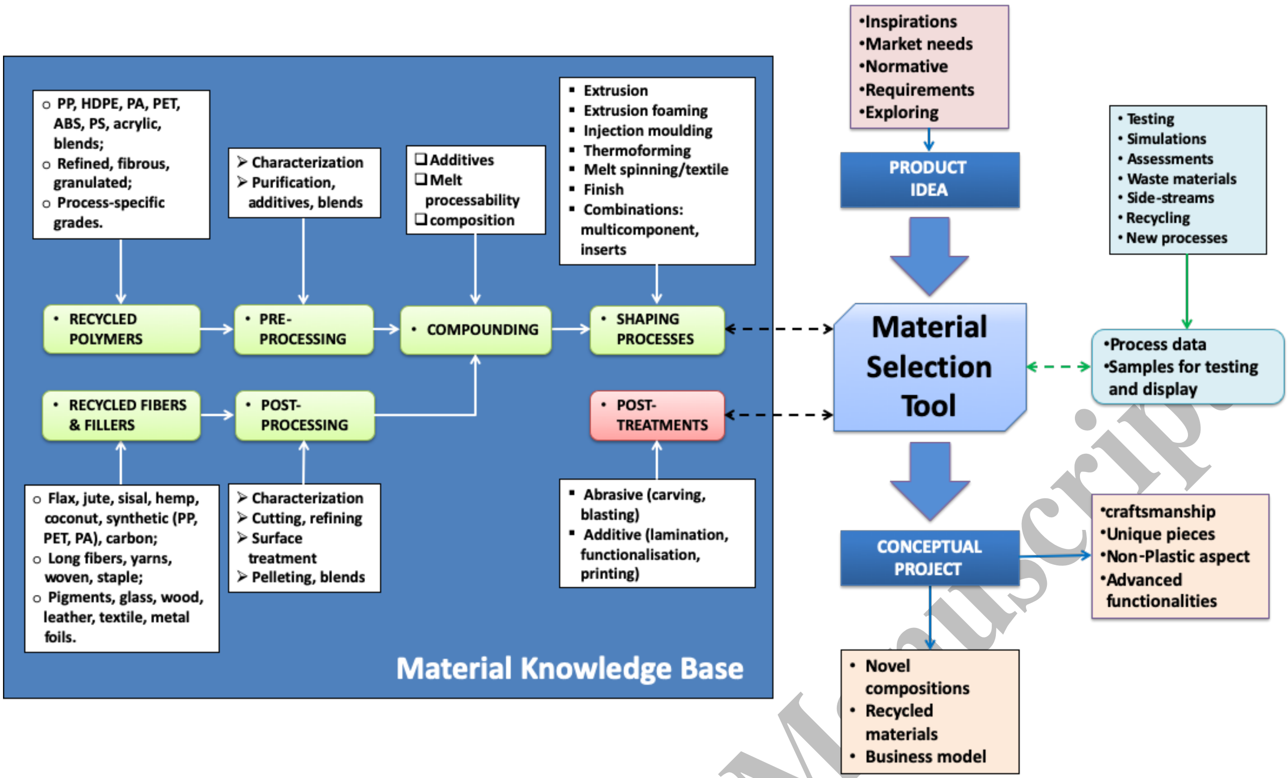

Figure 3 The architecture of the *Material Selection Tool* and the related Knowledge Base.

As highlighted in Figure 3, this paper considers the employment of Eco-materials to be involved in shaping processes such as extrusion, foaming, injection, thermoforming, melt spinning for textile applications, etc. Example of Eco-materials for creative industry can be the use of polymers, fibers and fillers from the recycling industry. In this context, pre-processing and post-processing treatments are necessary before to obtain a processable compound from recycling.

Generally, the recycling industry sorts and processes waste materials from manufacturing industries and urban areas. Pre-processing phases for recycled polymers require to add additives for the material purification. Concerning fibers and fillers, they come from the natural and synthetic origin and are screened after the recycling phase (post-processing) in terms of technical performance and characterization.

The designer interacts with *Material Selection Tool* to search possible Eco-materials and processes to be applied for the creative products. *Material Selection Tool* concerns information related to the development of composite concepts, including phases such as recycled sourcing and screening for properties and possibilities, their pre-processability and compounding development and shaping process development with optional post-treatment methods (Figure 3). Rules, tests, and past projects are updated into the Material Knowledge Base.

Using this tool, a product "idea" can be elaborated into a concept with an early material definition. A conceptual project can also include a novel composition of materials. Therefore, a business model is proposed to support the employment of recycled materials from an economic point of view. As highlighted in a lot of research, the business model related to the recycled materials is necessary to support the development of these practices.

2.2 Value chain

Figure 4 shows the players related to the development of products in the context of the creative industry. For each player the main activities and tasks are highlighted to understand "what they do or require" throughout the related value chain. The difficult question to answer is: who proposes innovation in this collaboration network? Designers are directly involved because they also collect needs and suggestions from markets and customers, of course. However, using a collaborative network the proposal of innovative solutions can be shared between different actors including the material researchers.

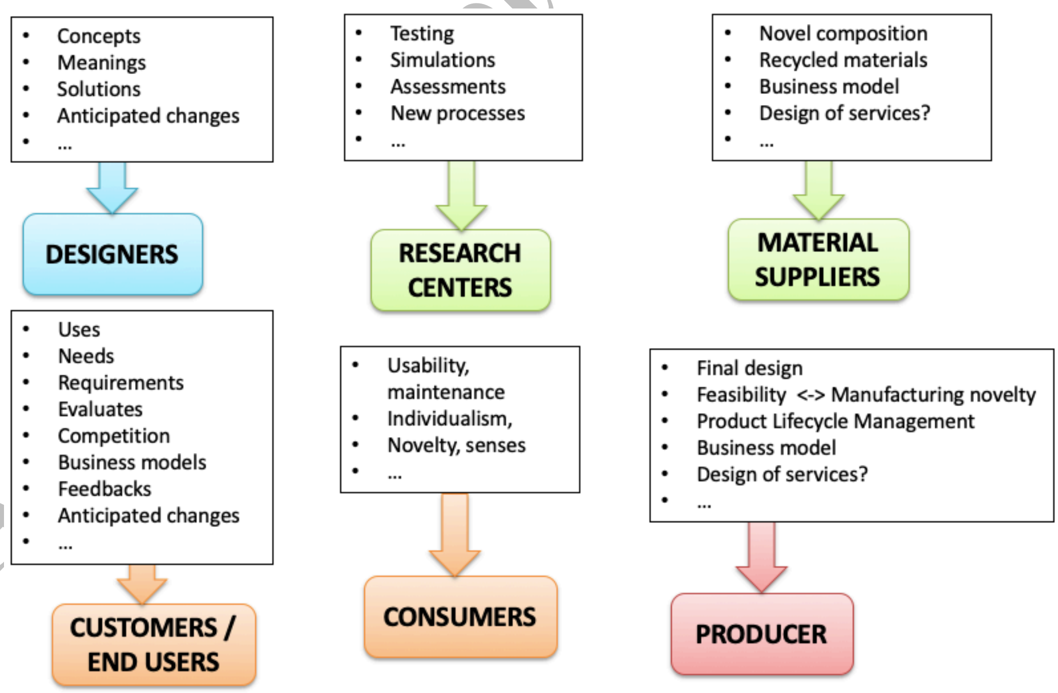

Figure 4 Players for the creative industry.

The techno-economic feasibility of such production naturally depends on the availability of usable recycled materials and industry acceptance of the new resource (traceable sourcing, possible process adjustments involved). Promoting technological advances in recycling and ensuring continuity of recycled utilisation in manufacturing are important drivers for the proposed design activities. In keeping up to the social responsibilities of the actions, sourcing of recycled raw materials conformed to waste regulations and safety issues need to be identified in their selection. The developed concepts are based on established recycling, pre-processing and shaping processes and are evaluated for feasibility in terms of eco-design and scalability to guide decisions towards minimised environmental footprint and commercial relevance.

A business model is proposed to describe how value can be created and delivered. This analysis is focused on a generic company that produces creative products following the proposed collaboration approach. Figure 5 describes the business model related to the collaborative design workflow proposed for creative industry. A Business Model Canvas template has been used to illustrate players, activities, relationships, revenue streams, and potential trade-offs. In this visual chart, arrows describe the main interactions between each area. Figure 5 includes the classical nine areas of a business model: customer segments, customer relationships, channels, value propositions, key activities, key resources, key partners, cost structure, and revenue streams.

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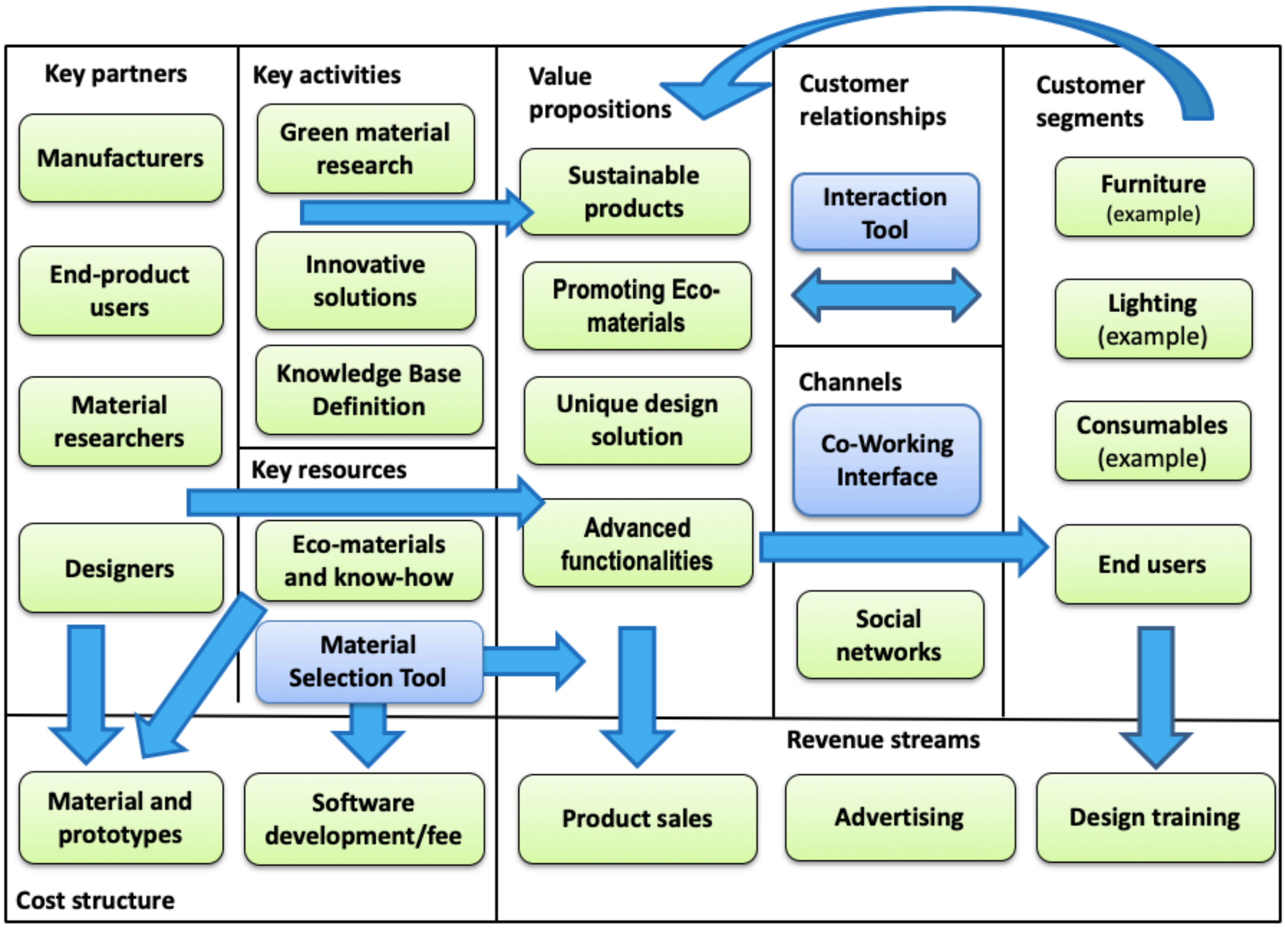

Figure 5 Visual chart of the proposed business model for Eco-design in creative industry considering Eco-materials and the collaborative design platform.

The customer segments concern different categories from manufactures to the final end-users. The customer relationships are regulated by the proposed *Interaction Tool* and the main channel is represented by the collaborative web-portal (*Co-Working Interface*). Other channels could be represented by social networks. The value propositions regard the development of sustainable products with unique design solutions, possible advanced functionalities, and the promoting of Eco-materials. The development of such products can create new marketplaces for creative products, recycled materials and related processes. Here, the main key activities are the research about green materials, the definition of a material knowledge base, and the study of innovative design solutions. The key resources are the know-how about Eco-materials (recycled and processes), and the proposed *Material Selection Tool*. The cost structure is represented by the cost related to materials, prototypes and testing. Moreover, software development is another cost item to be considered in this scenario. This cost item could be also defined as a fee to be paid per each industrial user. Key partners can be material researchers, designers, and stakeholders such as manufacturers and consumers.

2.3 Applications

As example, this section describes some possible test cases which can consider the employment of secondary raw materials and related processes into the design workflow. Possible applications concern the fields of furniture, lamps, fabrics, linings, paddings, clothing, leisure products, household objects, etc. As described in the *Material Selection Tool* section (Figure 3), the processes which can be involved with sustainable composites are melt spinning/textile, foam extrusion, injection molding with composites, extrusion-thermoforming, etc. In particular, the employment of recycled textiles and foams can be used in sustainable fashion and personal objects for fabrics and linings. On the other hand, recycled composites with injection molding can be used for developing sustainable leisure products. Following, two test cases are described with the description of materials and processes for furniture and lighting.

Considering a test case on furniture, the collection of secondary raw materials to be used can include recycled of PP, HDPE, PET, natural and synthetic fibers, fillers, etc. A possible application can be the design of seat frame and legs (Figure 6). In this context, the related processes to be investigated and applied could be profile extrusion and injection molding. Another example could involve the seat upholstery where the manufacturing processes to be considered can be foam extrusion and melt spinning/textile. New seat upholstery solutions can be also evaluated considering recycled textile and extrusion foamed sheets. Combining different composite solutions with Eco-materials, designers can create new customization aspects, visual and haptic effects based on the development of recycled.

Considering the seat application, the end user can evaluate the concepts in terms of visual, haptic and comfort performance. Using virtual prototyping tools, users and stakeholders can have experience with digital mock-up and give feedback. New solutions for sofas and armchairs can be analyzed implementing the re-use of recycled polymers for frame and legs. Therefore, new product structures can be also expected with innovations in internal structure and exterior details. A good product dismantling should be analyzed in the design of these

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products. An easy disassembly can be guaranteed by a modular design, which consists of assembling different functional groups such as extrusion profiles frame and soft blocks. In the design of sofas and seats, the main functional requirements concern: comfort, visual aspects, haptic, and structural behavior. The seat comfort can be improved integrating bionic design-driven approaches with early feedback from users who have experience with virtual and physical prototypes.

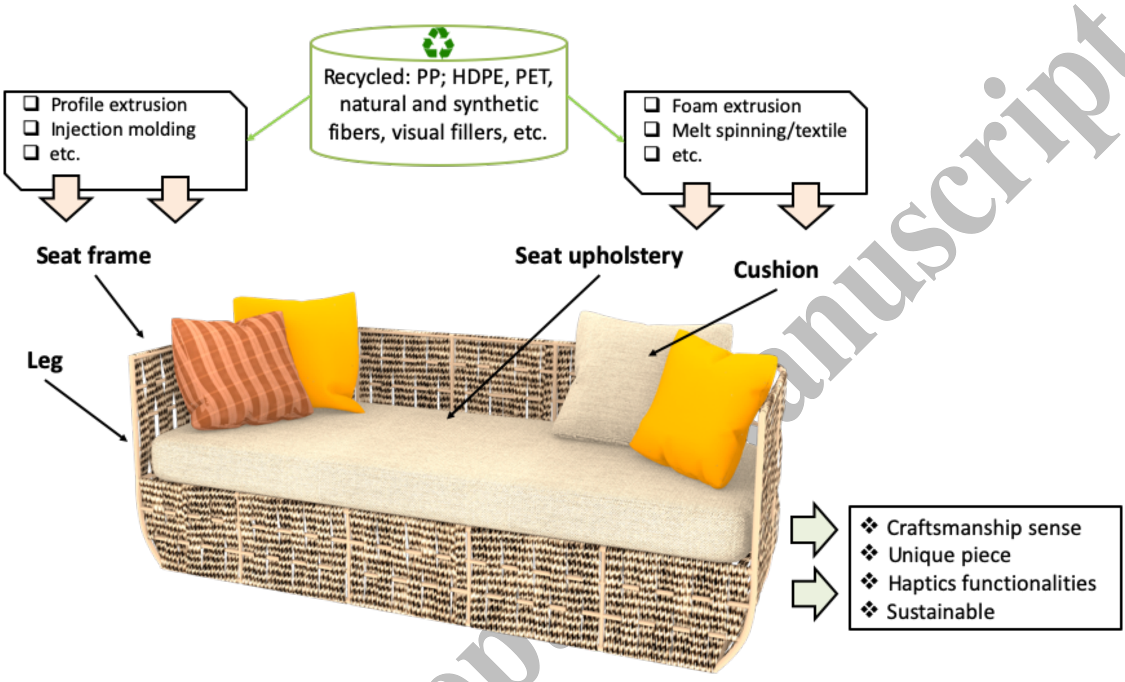

Figure 6 Example of furniture test case with eco-materials and processes available in *Material Selection Tool* to obtain a creative and sustainable concept.

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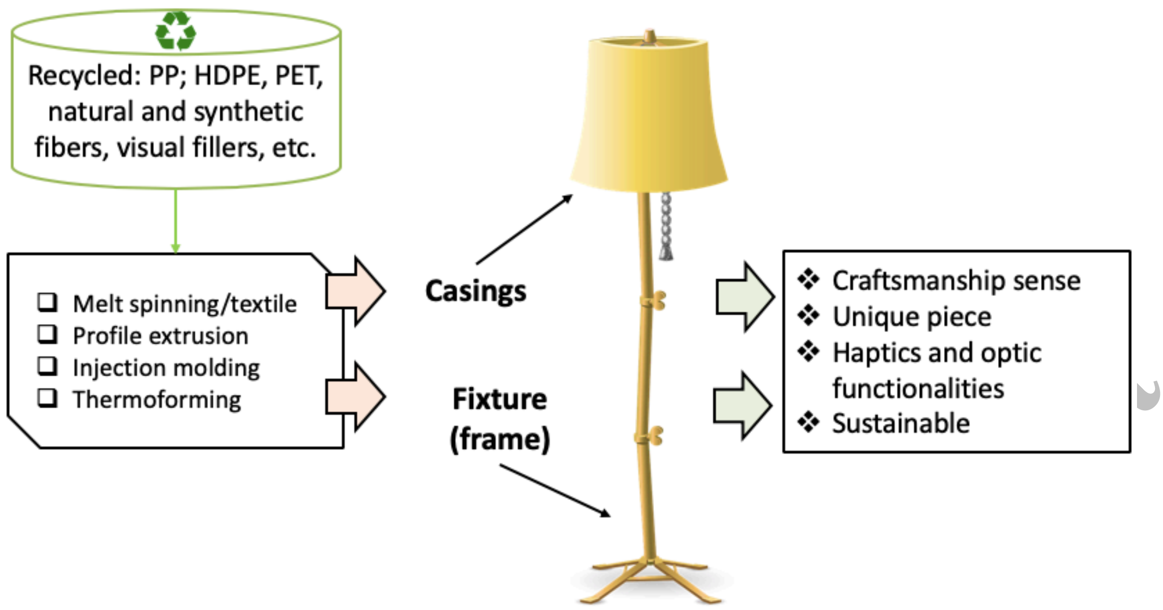

Figure 7 Example of a lighting test case with eco-materials and processes available in *Material Selection Tool* to obtain a creative and sustainable concept.

The same recycled materials, analyzed in the case of furniture, can be applied in the lighting design for lamp shade, fixture, and frame (Figure 7). For a lamp frame, materials solutions can include processes such as extrusion and thermoforming.

In each possible test case, a materials demonstrator should be always produced in laboratory for testing and design reviewing. The use of a collaborative interface such as *Material Selection Tool* allows data and knowledge, related to design concepts, to be collected into a repository. This knowledge base constitutes a set of solutions to be screened and analyzed for future product innovations.

3 Discussion

The scope of this research is to support the use of Eco-materials in the Eco-design activities related to the field of creative industry. The approach shows a method for supporting the design of cost-efficient and environmentally sustainable solutions. The proposed approach enhances the sharing of knowledge and best practices between different players and stakeholders throughout the value chain, including also the possibility of dissemination activities. By integrating parties of the value chain into the design-driven actions, the research method can support the innovation in the creative industry. Valorisation of recycled materials and advanced processing can open possibilities for cost-effective manufacturing, value added products, new markets and business opportunities.

The approach also considers the dissemination of best practices and results in educational activities. Developing the proposed *Interaction Tool*, students and young designers can read open-documents and do actions giving feedback, comments, and suggestions. Virtual showrooms and e-documents can support the educational activity in courses and training. This contamination about Eco-material practices can improve the results of the design-driven approach in the creative industry.

Even if several recycled and sidestream materials are available in industry; their application in creative industry is still difficult. This paper aims at presenting the architecture of a collaborative web-tool to promote recycled materials in creative applications. The possibility to achieve a lower production cost with a simultaneous reduction of environmental footprint can create a tangible gain in this sector. Moreover, the demonstration of sustainable composites' possibilities for the creative industry can improve business around waste collection and converting. A continue use of recycled materials in mass-production can increase the competitive position of Eco-materials on the market and reduce the overall environmental footprint in creative industry. In this scenario, the use of an accessible knowledge base for developing manufacturing concepts can fertilize future product innovations. A limit of this approach could be the intellectual property related to materials, knowledge, and applications. To overcome this limit, the collaborative network should provide different level of access, in order to select the shared information.

Limits and risks related to the widespread employment of Eco-materials in the creative industry are the availability of recycles and the cost-efficiency of the recycling processes and post-processes. A higher and constant demand of recycled materials could reduce the price of these practices and consolidate the market.

4 Conclusions

This paper proposes a collaborative environment that allows designers to be better involved in the research activities. The research is focused on the creative industry and it aims at increasing the understanding of practices and knowledge sharing about the use of recycled materials.

A collaborative platform tool has been described to support the design phases in the creative industry. The design workflow is based on the development of a *Material Selection Tool* which reduces the gap between research, development, and innovation using a design-driven approach. The *Material Selection Tool* collects knowledge regarding recycled material, research stage, process development, and manufacturing concepts to be used for creative products. The selection of materials is driven by the design needs related to the specific case study. Throughout the design platform, physical and virtual demonstrators of materials and products can be evaluated with testing, simulations and digital mock-up. The collaborative environment with disciplines of industrial designers, materials, engineering, and manufacturing opens up possibilities to renew the in-house practices of companies towards an interactive innovation strategy.

Another objective of the proposed approach is to enhance the increasing awareness of sustainable materials, using activities such as dissemination of results, and virtual and physical user-experiences with prototypes and concepts. Some case studies have been described in the Section 2.3 to understand the possible applications for the described collaborative design approach. As a future work, different test cases will be analyzed, and different composites will be tested in the design of creative products.

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