

DIGITALLY ENHANCED DESIGN

Breakthrough tools, processes, and expressive potentials



edited by Maurizio Rossi and Davide Spallazzo



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3. Strengthening knowledge of the transition to a circular economy in the furniture sector

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Abstract

This chapter focuses on thematic areas of the circular economy, reflecting the goals of the European Green Deal and addresses gains made by European furniture companies. The goal is to explore guidelines and assessment criteria for how the design and manufacturing of furniture can contribute to a climate neutral Europe by 2050 with a sustainable economy that leaves no one behind. How are European furniture companies adapting to a circular economy model?

A circular economy aims to preserve the value of products, components, and materials within a larger economic system. It is oriented to achieve more efficient production and consumption systems, thanks to continuous and regenerative cycles. It also focuses on reduction of raw materials and energy consumption, waste, and emissions generation in the production processes. The adoption of the circular economy requires a change of business, territorial, and individual visions, and to rethink ways of producing and consuming.

The authors study evidence of the circular economy values, such as reuse, recycle, remanufacturing in the European furniture sector. By developing the knowledge base for greener and smarter manufacturing processes, it is possible to plan for a sustainable and more democratic European design culture.

3.1 Introduction

This chapter focuses on circular economy (CE) strategies in the furniture sector and offers examples where furniture companies in Europe are responding to the transition. We explore the values of the CE model and identify strategies for European furniture companies to shift to a more socially democratic, healthier, and sustainable future. Which companies are leaders and innovators of CE solutions and strategies? By strengthening the knowledge base for greener solutions and CE manufacturing processes, it is possible to foresee a sustainable and more democratic European design culture achieve the goals outlined in the European Green Deal.

Furniture relies on materials and energy for its manufacturing and distribution to consumers throughout the world. Across the sector, manufacturing utilizes a hybrid of analog and smart digital technologies that result in making innovative solutions, systems, and services. The origin of the word *manufacturing* connects production to a process of making with one's hands using hand tools. The term has Latin origin, a noun, denoting something made by hand; from French, reformed by association with Latin *manu factura* 'made by hand' (Etymonline, 2021). In the past 50 years, there has been an accelerated transition towards technological innovation in how most furniture is made, transitioning away from hands to machines, and more recently, to CAM technologies and digitally programmable robots. How things are made is the basis of manufacturing, but now, more than ever, manufacturing needs to be reconsidered in tandem with an important environmental challenge: Will the world be *made* a better place to live in tomorrow, by how things are made today?

We need to consider sustainable practices in using materials and smart processes that consume less energy in the resource extraction, transport, manufacture, and distribution of furniture products. Manufacturing has a profound impact on the health and welfare of those who make and use furniture, but also impacts the planet and environment regarding the energy consumed in the extraction, use, and reuse of materials and products. We begin by introducing environmental and economic challenges and an innovative program titled the European Green Deal. This is followed by a discussion of what is a circular

economy. We then assess the global furniture industry and highlight European furniture companies adapting to this changing direction.

3.2 Background to the European Green Deal

The world today is facing complex environmental, societal, and economic challenges. The intersectionality of these challenges: climate change, environmental concerns of sustainability, health, and welfare issues, growing populations and urbanization, financial crises, shifts in societal lifestyle and values, and the rise of smart and digital IoT technologies, all contribute to the need to pause and reflect on the influence that manufacturing solutions, systems, and strategies can have on our lives. Manufacturing depends on designers and companies who address these realities and relies on consumer's buy-in to gauge successful outcomes. Smart strategies can serve as a foundation for innovative manufacturing strategies and solutions that benefit society, regional and global economies, and the environment. There is a need to develop further guidelines, and utilize assessment criteria for CE manufacturing, specifically by leading European furniture companies to help achieve climate neutrality with a sustainable economy by 2050. The European Union has begun that process.

On 11 December 2019, the EU Commission announced the European Green Deal (EU, European Commission, Secretariat-General, 2019) to transform the EU into the first climate-neutral continent by 2050. The plan is to improve the EU's economy, by turning climate and environmental challenges into opportunities. It is a growth-strategy to transform the EU into a more sustainable, more environmentally respectful place of production and consumption by adopting the CE model. The Green Deal's goals should result in a competitive circular economy, where there are no net emissions greenhouse gases by 2050, economic growth is decoupled from resource use, and no place is left behind.

Following the creation of the European Innovation Council (EIC), the European Commission launched a €1 billion call for research and innovation projects that: respond to the climate crisis; support the European Green Deal initiative; and help protect Europe's unique

ecosystems and biodiversity. These initiatives were conceived before the COVID-19 pandemic. The Horizon 2020-funded European Green Deal call was created to spur Europe's recovery from the COVID-19 pandemic by stimulating transformative "green" challenges into innovation, opportunities, and solutions.

3.3 Overview of the Circular Economy

The CE model is gaining interest as a new industrial paradigm which demonstrates a smarter alternative to the linear economy (Murray, Skene and Haynes, 2017). The primary goal of a CE is to decouple economic growth from natural and limited resource constraints and connect the benefits of multi-use to proven sustainable practices. Therefore, the definition of the CE that best explains this research is:

A sustainable development initiative with the objective of reducing the societal production-consumption systems linear material and energy throughout flows by applying material cycles, renewable and cascade-type energy flows to the linear system (Korhonen *et al.*, 2018).

The CE model is a smart approach to design, production, and consumption. It contrasts with the existing model of production and consumption identified as a linear economy. The linear economy is a process of making, using, and discarding products. It has been the paradigm for most worldwide industrial output, including the manufacturing of furniture. CE is an industrial system of manufacturing, distribution, and consumption that is restorative and regenerative by design. The term *restorative* suggests a closed-loop cycle that encourages more output and utility from products than what is delivered in a linear economy. In a restorative system, technical materials and products are recovered and given new life. In a regenerative system, biological nutrients are reproductive (Ellen MacArthur Foundation, SUN and McKinsey, 2015).

CE is not a new concept, but it has taken time to develop a conceptual framework with obtainable goals. A goal of CE is to extend the life and value of furniture through innovative manufacturing processes

enabling reuse, repair, refurbishment, and remanufacturing cycles in production strategies that respond to environmental challenges outlined in the European Green Deal (2019).

In striving for a holistic and theoretical understanding of circular economy implementation, the authors leverage some of the consequential literature produced thus far (Simmonds, 1862; Ayres and Kneese, 1969; Kenneth E. Boulding, 1966; McDonough and Braungart, 2003; Lewis and Slack, 2014; Ünal, Urbinati and Chiaroni, 2019) and the CE research, publications, and video presentations executed by the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2013). This collective research has helped frame options available to transform many industrial practices currently dependent on exploitation.

The novelty of CE relies upon a system where products are designed and manufactured to be used longer, applying any number of “value cycles” or closed-loop strategies to extend the value of the product beyond its conventional end-of-life (EoL) use (Ellen MacArthur Foundation, 2015). CE is a change in thinking in the approach to how we think about making things. It is a concept that puts [re] in front of use, make, and manufacture, placing value on innovative ways to re-use things. It is valuable and complementary to the Cradle-to-Cradle (C2C) concept (McDonough and Braungart, 2003). C2C has influenced thinking about values in design and manufacturing and has set the stage for today’s discussion on the CE.

Our goal is a delightfully diverse, safe, healthy, and just world, with clean air, water, economically, equitably, ecologically and elegantly enjoyed (McDonough, 2007).

This statement presents a new connection to why we design and make things.

The Ellen MacArthur Foundation developed a diagram that illustrates two intersecting economic systems, (linear and circular). Figure 1 illustrates two closed loop cycles located in distinct sectors: one biological and the other technical. The central vertical axis represents the linear economic model, while the rest of the diagram illustrates the continuous flow of materials and processes referred to as *value cycles*. The furniture sector is concerned with technical cycles. Including both

biological and technical systems remind us that the furniture sector can draw values from both. Any one of these value cycles can extend the life of a product. A combination of value cycles manifests a traceable impact on the economy and the environment. These two models are often defined as cradle-to-grave (linear economy) versus cradle-to-cradle (circular economy) (Ellen MacArthur Foundation, SUN and McKinsey, 2015).

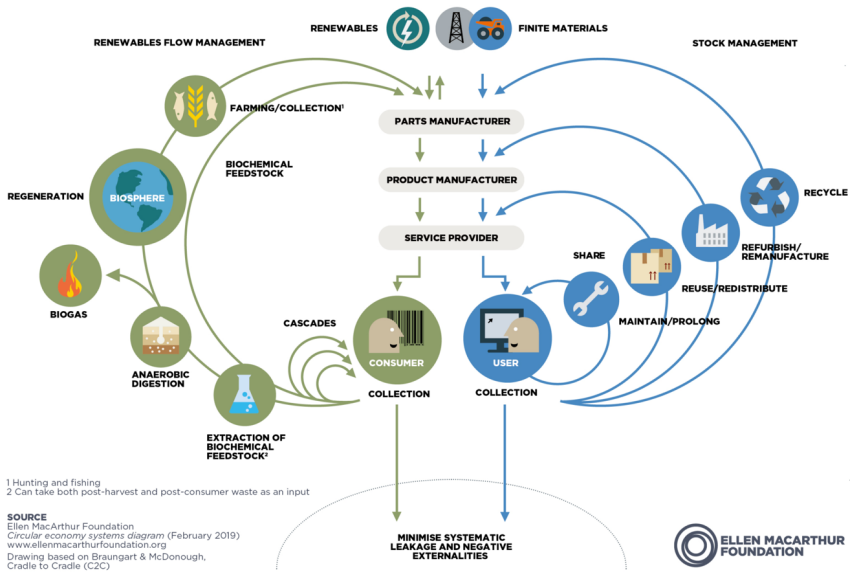


Fig. 3.1 - The Butterfly Diagram for Circular Economy. Circular economy systems diagram. Ellen MacArthur Foundation (2019). Drawing based on Braungart & McDonough, Cradle to Cradle. Copyright © Ellen MacArthur Foundation (2019), www.ellenmacarthurfoundation.org.

Addressing the critical problem of natural global resource depletion, the Ellen MacArthur Foundation (2013) has summarized four principles of the CE as “points of action” to revitalize existing material value throughout one or more stages in the manufacturing of products. The authors see value in the four principles and will later synchronize them to exemplary cases. It is important to note these are complementary, yet distinct from green and sustainable principles. Subcategories

(*) have been added by the authors to the four *points of action* related to the furniture sector:

1. Optimize the use of resources and energy throughout all life cycle stages.
 - * Design for efficiency in the use of material, time, and energy.
2. Maintain production and components in use over a longer time.
 - * Improve furniture design by thinking about modularity, standardization, and compatibility with existing components and assemblies (open platform).
 - * Generate personal attachment to furniture.
 - * Manufacture for self-maintenance and repair.
 - * Consider ease of disassembly and reassembly.
3. Cycle materials through the production system as many times as possible.
 - * Create opportunities for upgrading downgrading, adaptability, re-use and repurpose.
 - * Consider the recyclability of material.
4. Utilize pure materials to improve quality of post-life use.
 - * Use materials that maximize reliability and durability.

CE achieves more efficient production and consumption outcomes by moving products and components through continuous use cycles so that at the product's EoL there is minimum residual of a product that ends up as waste or in a landfill (Rios and Charnley, 2017). CE focuses on ways to re-cycle a product through stages of production to exploit all its reiterations of use. The full adoption of the circular economy within an industry requires a change in how society thinks about value and accepts new ways of consuming products through various cycles.

Cyclical, closed-loop processes allow for a broad range of strategies and actions for furniture such as:

- Refurbishing: remanufacturing a product to optimize its life.
- Restoring: refinishing or re-upholstering to extend the condition of a product.
- Repairing: corrective repair of a product.
- Maintaining: preventative maintenance to maximize product life

- Reusing: redistributing products through a change in ownership.
- Repurposing: changing the functionality of a product, (i.e., a chair becomes a table).
- Recycling: recovering the value of materials and components in products for reuse.
- Regenerative: a process of regrowing (renewing).

A CE is suitable for technological industries to adopt because it opens avenues for smart and innovative ways of using closed-loop processes. Also important is the reduction of raw materials and energy consumption, waste, and emissions generation in the production processes. Adopting the circular economy model does require a change in business practices and consumer behaviors. CE requires everyone to rethink the way products and services are produced and consumed. We examine the CE paradigm by applying the concept to the furniture sector to examine how well a CE can change an existing linear economy.

3.4 Overview of the Global and European Furniture Sectors

The furniture industry today accounts for a considerable portion of regional and global trade with approximately one million workers employed in the EU (EEB, 2017). The global furniture market was estimated at approximately €285 billion in 2019 and is expected to reach approximately €390 billion by 2026. Approximately one-quarter of the world's furniture manufacturing occurs within the EU28 member states, representing a €84 billion market that equates to a EU28 consumption of about 10.5 million tons of furniture per year (EU FURN360, 2017).

So often the case, after furniture no longer serves its primary purpose, if not sold to another user or repurposed for another use, it is discarded for any number of reasons into a landfill. According to the European Environment Bureau (EEB), 10 million tons of furniture are discarded by businesses and households as waste every year (EEB, 2017). This accounts for over 4% of the total Municipal Solid Waste (MSW) stream in the EU. Sadly, 80 to 90% of EU furniture waste in MSW was incinerated or sent to landfill with only 10% recycled (EU

FURN360, 2017). Waste arising from commercial sources is assumed to contribute 18% of total furniture waste generation across the sector. These numbers represent a cradle-to-grave life cycle: an unsustainable ecosystem.

In 2017, most of the EU furniture companies in the sector were small and medium-sized enterprises (SMEs). Italy (€17.5 billion), Germany (€14.5 billion), and UK (€8.8 billion) were the most significant furniture producers by value (EEB, 2017). The most significant exporters were Germany (€9.5 billion), Italy (€9.2 billion) and Poland (€8.7 billion). The largest importers were Germany (€11.8 billion), UK (€6.6 billion) and France (€6.0 billion). European member states are major consumers of furniture with a considerable proportion from wooden furniture, kitchen units, and mattresses.

The statistics on EOL production and waste are not limited to the EU. Historically, the furniture sector has utilized a traditional business model that follows a linear process: one of harvesting materials, making, using, then discarding products as waste. Waste is often burned or ends up in landfills, characteristic of the cradle-to-grave model. Additionally, this sector is known to use virgin raw materials (wood, stone, textiles) for production and uses adhesives, dyes, and coating materials to finish and protect furniture, which can result in emission of volatile organic compounds (VOCs). Regardless of the material consumed and technology used in the manufacturing of furniture, companies that focus on CE methods are reimagining the value of furniture by incorporating closed-loop cycles. We now explore tools and resources that provide opportunity and evidence of transition from a linear to the circular economic model.

3.5 CE Resources and Tools Available for the Furniture Sector

Resources and tools are available to advance sustainable furniture design, serving to build adoptable strategies and strengthen knowledge in the sector. Annotated projects also help benchmark sustainability. One project was coordinated by Centro Legno Arredo Cantù (CLAC) Ecomind (Centro Legno Arredo, Material Connexion and Istituto

Europeo di Design, 2006). It was the result of collaborative work that highlights ecological furniture solutions and material strategies. A second is Eco-Design (Fuad-Luke, 2010), cataloging a broad range of product and furniture solutions designed for a sustainable future. Both sources strengthen knowledge about sustainable and eco-sensitive strategies that benefit the environment and argue that eco-sustainability criteria should receive the same weight as technical, functional, aesthetic, ergonomic and economic considerations in the design process. Surveys and assessments serve as measurements of practice and attitudes that assist the adoption of a sustainable, methodological, design approach for innovative solutions in the various stages of the product life cycle is the adoption of the Life Cycle Assessment (LCA) (Ceschin and Gaziulusoy, 2016). The Ecodesign Directive by the European Commission (EU, 2005) provides directions for companies to use LCA to evaluate their productive processes and products. This self-evaluation tool helps identify CE practices being used and suggests others to incorporate in practice. This is a CE approach that many companies in the wood furniture sector can adopt to raise quality standards and be more competitive in a market that is increasingly attentive to the use of energy, materials, and certifications. The link between sustainability and innovation, in fact, is becoming increasingly intertwined.

A report from Federlegno Arredo (FederlegnoArredo, Symbola, 2016) highlights latest trends in the production of the furniture sector among leaders in the European market. It reports on low energy consumption, reduction of emissions, waste reduction, and recycling of materials. Furniture enterprises are identified by their green practices.

In recent years legislation at the European and international level has defined rules for the certification of raw materials from responsibly managed and environmentally sustainable sources. Among the most important are the Programme for Endorsement of Forest Certification (PEFC) schemes and the Forest Stewardship Council (FSC). These programs guarantee that the raw material used in the manufacture of furniture comes from controlled cultivation of plants, guarantees protocols that avoid deforestation, (the consequent increase of CO₂), and commits to maintain biodiversity in the areas of origin. According to the directives of the European Regulation 995/2010 (EU,

2010), materials are verified and certified, defining their origin and adherence to the standards provided. Furniture manufacturers and designers who source certified raw materials can add the endorsement programs to their marketing materials.

From the circular economy perspective, designers can use an eco-sustainable approach to design using strategies that consider varied factors in product development (Pigozzo, McAloone and Rozenfeld, 2015). Not only by focusing on the formal and material characteristics of a sustainable product, but also considering the link between the product to other product processes such as packaging, distribution, marketing, and social performance. This business solution at the design phase can impact waste issues in localized markets. Chiu and Kremer (2011) provide an exhaustive analysis of Design for X guidelines and a toolkit, where X stands for any attitude in the design process (Manufacturing, Assembly, Disassembly, Logistics, ...) to supply practitioners with an index for each DfX concept and method. In summary, a variety of resources and tools have been developed to strengthen CE knowledge in the furniture sector. Undoubtedly, there will be more to come. The next section explores the *Points of Action* outlined in the Overview of CE section and synchronizes them to innovative case studies.

3.6 Case studies and practices: innovative CE solutions and strategies

There is growing evidence of furniture designers and companies adopting CE values to improve furniture design and manufacturing processes. In this section, we provide examples which align with the previously identified four *points of action* that were discussed in 3.3 Overview of the Circular Economy. These furniture solutions and manufacturing companies exhibit substantial effort to commit to the CE value system. Following are six examples of innovative CE solutions and strategies that represent changes the furniture industry is making to extend material value and reduce consumption of energy throughout one or more stages in the manufacturing of furniture products.

3.6.1 Optimize the use of resources and energy throughout all life cycle stages

Companies in the furniture sector are seeking opportunities to optimize the use of resources and energy. The examples that follow were selected because they demonstrate forward thinking solutions for the management of resources and energy in manufacturing and distribution.

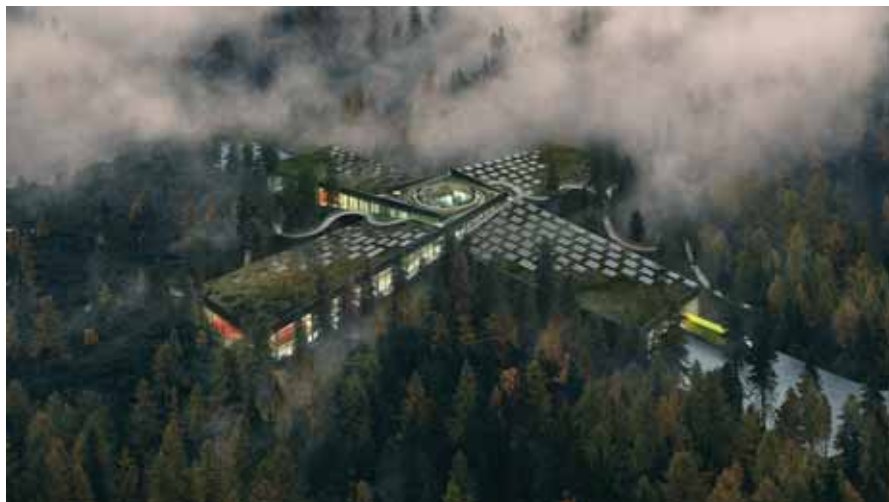


Fig. 3.2 - The Plus has been designed by BIG - Bjarke Ingels Group (2021) based on sustainable and CE values. The Plus Aerial Image credit: Lucian R.

Vestre is a Norwegian furniture manufacturer that commits to long term sustainability, a prerequisite in all parts of their operations, their design of furniture solutions, procurement of materials, and their manufacturing to distribution processes. Using innovative robotic technology, their new manufacturing plant “The Plus” (designed by BIG - Bjarke Ingels Group and scheduled for completion in Autumn 2021), will be carbon zero. The new factory will be the first industrial building in the Nordic region to achieve the highest environmental certification, BREEAM Outstanding, by using solid wood and ensuring a fossil-free and emission-free construction site. The Plus will employ several Industry 4.0 solutions, such as smart robots and self-driving

trucks, and the whole factory can be run from a tablet device. Every aspect of the factory will be based on principles of renewable and clean energy to ensure eco-friendly production. The Plus will produce 50% lower greenhouse gas emissions than similar conventional factories.

Additive manufacturing is a straightforward process of making that can impact the production of furniture components from a three-dimensional model adding material layer by layer in filament, liquid, or powder through a digital-driven technological process that can replace or complement traditional fabrication methods. Fields of applications in additive manufacturing, range from prototyping to actual production, and given the widespread use of this tool, an assessment of the environmental dimensions concerning the production phase and the entire life cycle of the components produced is needed (Kellens *et al.*, 2017).

An example of AM utilized in the furniture sector is The Endless Chair by Dirk van der Mooij (2011). It was designed using CAD technologies and digital scripts and manufactured using robotic CAM tools. AM processes are efficient, and waste is minimized. The Endless Chair illustrates the potential in digital CAD / CAM technology to transform the furniture sector.



Fig. 3.3 - The Endless Chair, manufactured utilizing AM technologies. Dirk van der Kooij for Studio Kooij (2011).

High-technological processes are pathways toward achieving sustainability goals and adopting the circular economy model's values. Research suggests that this path can become more circular and needs further study.

3.6.2 Maintain production and components in use over a longer time

The concept of maintaining production of components is critically important in extending the life cycle cost (LCC) of manufactured furniture. Here are a couple of examples demonstrating practices that already extend the life of furniture through the manufacture of modular and standardized components and the accessibility to the components by consumers.

IKEA has a global presence with global markets and distribution aligned with CE principles. Much of their furniture embodies modularity and standardization of components which allows for replacement and repair of its furniture products. IKEA created a material recovery program for home furniture, a take-back campaign for recycling furniture and is pursuing the use of waste from production as a resource for new products which reduces landfills. The company places significant value on democratic design, a concept of making clever design available to everyone. IKEA expands the concept of democratic design into five dimensions, which are: function, form, quality, sustainability, and low price. When there is a balance between all five dimensions, IKEA considers the design “democratic” (*IKEA.com*, 2021).

Re-manufacturing is a feasible alternative to reusing furniture where processes of checking, resurfacing and redeployment apply to the long-life components and assemblies, like steel frames or structural parts. Rype Office, a London-based company, remanufactures brand name office furniture back to as-new condition and creates sustainable furniture from potential waste materials. The result looks and performs as new, but at a significant cost savings, economically and environmentally. Remanufacturing is a strategy that commits to a zero-landfill goal by repurposing old furniture for other uses and/or

recycling them into new usable products. Key sustainable factors in the process are eco-sustainability, reducing raw resources, energy, and water, and being in position to sell functioning furniture at a reduced price.

3.6.3 Cycle materials through the production system as many times as possible

The furniture sector is a potential leader for the action of cycling materials through the manufacturing process as many times as possible. Following are examples of how recycling and upcycling can be used to reduce single-use materials.



Fig. 3.4 - Recycled Grey Babila XL by Odo Fioravanti, Pedrali (2020).

Pedrali, an Italian furniture company active in sustainable design, aims to design and manufacture products able to last through time for style and performance. Their collection titled “Recycled Grey” is made of 100% recycled plastic composed of 50% post-consumer and 50% industrial plastic waste. Post-consumer plastic waste comes from

products previously used by consumers, such as plastic bottles or food packaging, while the industrial waste comes from industrial processing. The Recycled Grey collection represents a theme already pursued by Pedrali, who has always reinserted in the productive process the byproduct of internal waste of its factories: plastic material scraps, containers, and plastic films. The 50% of post-consumer waste represents the limit that allows this material to guarantee the product's exacting standards regarding durability for the contract sector, their primary activity sector, known for its heavy and prolonged use.

Upcycling describes the process of increasing the value of waste materials through the recycling process, creating a product with a longer lifespan than the original. Lendager UP is a Danish company working in upcycle product development. An agreement between Lendager Group designers, world-renowned flooring manufacturer Dinesen, and Danish kitchen manufacturer Reform results in UP kitchen cabinets which are created from solid wood, post-production cutouts that would otherwise have ended up in the landfill as waste. UP kitchen cabinets are examples of value gained by upcycling.



Fig. 3.5 - Sacco's Green Limited Edition of the iconic chair by Zanotta (2019).

3.6.4 Utilize pure materials to improve the quality of post-life use

Utilizing pure materials can impact the furniture sector by extending the EoL and improving durability and utility of products. These examples identify calculated and conscious decisions to create sustainable furniture options.

Caimi is a leading Italian company in the production of furnishing accessories. Caimi's *Snowsound technology* acoustic panels are composed of 100% recyclable polyester with variable density, which achieve selective absorption at different frequencies to optimize their acoustic performance. Plastic and metal components are easily detachable and recyclable.

Zanotta's remake of the 1969 Sacco has "*gone green*" and is now made of ECONYL®, a regenerated nylon thread made entirely from fishing nets collected from the seabed, scraps of fabric, and industrial plastic. The new material maintains the same qualities and performance as nylon made from petroleum but can be regenerated, recreated, and remodeled indefinitely without using other natural resources. In addition, the padding of the original project, made of high strength expanded polystyrene (EPS) balls, has been replaced with BEWI's BioFoam® microspheres, a biodegradable and compostable bioplastic (PLA) obtained from sugar cane that has the same characteristics of EPS in terms of structure, properties, and technical performance.

3.7 Discussion

The points of action highlighted in the case studies point to concepts and values that matter in the furniture sector. They point to opportunities that the furniture sector can lead with. Across the furniture sector, there appears to be scattered adoption of CE models despite broad knowledge and support for the goals and values of CE models. Why the gap?

Designers, educators, business directors, and the press are all in position to influence consumer perceptions and consumer patterns that can encourage industry to transition away from unnecessary resource

depletion, but to do so, attitudes and paradigms must change, and design must demonstrate that it can result in more than superficial changes to products (Andrews, 2015). Change must be systemic on several levels and embrace core aspects in the manufacture of furniture to be consequential.

It was valuable to discover a patchwork of CE criteria adopted by European furniture companies, however, quantitative measure is difficult and complex to obtain. Therefore, it would be desirable to have an agreed upon common set of criteria for the furniture sector, complementary to the Circular Indicators Project developed by the Ellen MacArthur Foundation, and related to the ‘Green Furniture Mark’ (GFM). Doing so would provide consumers and procurers a simple means of assessing product circularity. Potentially, a GFM could be deployed alongside other existing EU instruments, such as the EU Ecolabel and GPP criteria.

There are many potential benefits to transition and adopt CE models in the furniture sector. Benefits of a higher level of CE in the EU Furniture Sector (EEB, 2017) could result in: 160,000 extra jobs, 3.3-5.7 million tons of additional reused/recycled materials (Improving carbon footprint), and €4.9 billion increase in EU’s Gross Value Added (GVA) statistics.

Sustainability and circularity drivers will continue to impact manufacturing processes as well as new business models and new ways of production. This is essential to ensure the European industry’s mid and long-term competitiveness with implications for workers and their safety. A circular economy approach in an environmental context could drive innovative strategies to prevent and minimize resource consumption, build into the continual product maintenance of materials in time-based cycles, and recycle potential waste into new uses. In addition to the environmental advantages, the adoption of circular practices results in financial savings.

By developing the knowledge base for greener and smarter manufacturing processes, the authors believe it is possible to achieve a sustainable and more democratic European design culture. Long term sustainable and green designs are embracing smart and innovative CE values involving social, economic, ecological, systems and require a process-based and multi-scale systemic approach to planning and

realizing sustainability guided by a target vision (Bagheri and Hjorth, 2007). It is up to us all, designers, industry, institutions, and consumers, to consider sustainable furniture design strategies and consider circular economy models and scenarios in manufacturing when making decisions and placing value in furniture design.

3.8 Conclusions

Our research on CE solutions and strategies has focused on the knowledge gap in the furniture sector. We believe that guidelines and assessment criteria will encourage the adoption of CE models for the manufacturing of furniture in Europe and can help the sector achieve social, economic, and environmental sustainability, and contribute towards reaching the environmental goal of carbon-neutrality outlined in the EU Green Deal. By developing the knowledge base for greener manufacturing processes, it is possible to plan for a sustainable and more socially democratic European furniture design culture.

The furniture industry needs to be encouraged to adopt a systemic transition from a linear economy to a circular economy because it is a more responsible model for achieving the sustainability goals aspired by many European institutional entities. To transition across the industry, designers and companies must adapt to new economic rules of engagement. Additionally, the public sector actors (influencers, media, teachers, customers) need to be further educated about the value of the CE model. With an educated public who expresses interest in C2C products, designers and companies can confidently push the existing boundaries of what is defined as sustainable furniture. But this should not stall any progress each company identifies for itself to be part of a circular economy.

In short, designers and manufacturers need to shift their thinking, by adding [re] into all aspects of making. The takeaway is that there appears to be a gap between the positive attitude towards CE systems and implementation strategies, which suggests potential growth for both institutions and managers involved in sustainable development processes. In this context, there is a clear need to study the impact of

legislative and voluntary actions in the next decade, forecasting how a more sustainable CE will affect and transform the EU furniture sector.

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