Circular Economy in Furniture Design : Lifecycle Strategies for Material Reuse and Waste Reduction in Contemporary Interiors

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Abstract

The circular economy (CE) offers a forward-looking framework for sustainable furniture design, aiming to reduce waste and enhance resource utilization throughout a product's lifecycle. This study investigates how CE principles—such as material reuse, modular construction, and long-term durability—can be effectively embedded in modern furniture systems. A mixed-methods approach is adopted, integrating expert interviews with quantitative findings from Lifecycle Assessment (LCA) applied to selected furniture models. Environmental metrics, including carbon emissions, resource consumption, and end-of-life recyclability, are examined to assess performance. Results indicate that modular configurations, renewable materials, and reverse logistics mechanisms can significantly mitigate environmental impact. The research provides practical guidance for designers and manufacturers seeking to develop circular furniture solutions for residential and commercial interiors.

Keywords: Circular Economy, Sustainable Furniture, Lifecycle Thinking, Modular Design, Renewable Materials.

الاقتصاد الدائري في تصميم الأثاث: استراتيجيات دورة الحياة لإعادة استخدام المواد وتقليل الفاقد في البيئات الداخلية المعاصرة

غيداء علي العمري، قسم المسرح والفنون الأدائية، كليه الثقافة والفنون، جامعه الملك خالد، السعودية.

الملخص

يمثل الاقتصاد الدائري إطاراً متقدماً لتصميم الأثاث المستدام، حيث يهدف إلى تقليل الفاقد وتعزيز كفاءة استخدام الموارد على امتداد دورة حياة المنتج. تساهم هذه الدراسة في الكشف عن كيفية دمج مبادئ الاقتصاد الدائري، مثل إعادة استخدام المواد والأبنية القابلة للتفكيك، والمواد ذات المتانة طويلة الأمد في أنظمة الأثاث المعاصرة. وقد تم اعتماد منهجية مختلطة، تجمع بين مقابلات مع خبراء في التصميم ونتائج كمية مستخلصة من تقييم دورة الحياة (LCA) لعينة مختارة من قطع الأثاث. جرى تحليل مؤشرات بيئية مثل انبعاثات الكربون، واستهلاك الموارد، وقابلية إعادة التدوير في نهاية العمر الافتراضي لتقييم الأداء البيئي. وتشير النتائج إلى أن التصاميم القابلة للتعديل، والمواد المتجددة، وآليات الاسترجاع تُسهم بشكل كبير في تقليل الأثر البيئي. تقدم هذه الدراسة إرشادات عملية للمصممين والمصنعين الراغبين في تطوير حلول أثاث دائري يلائم المساحات الداخلية السكنية والتجارية.

الكلمات المفتاحية: الاقتصاد الدائري، الأثاث المستدام، التفكير بدورة الحياة، التصميم القابل للتعديل، المواد المتجددة، العمارة الداخلية، طول عمر المنتج، تقليل النفايات، المؤشرات البيئية، الأنظمة الدائرية.

Introduction:

1.1 Introduction

Recent global policy shifts, such as the European Green Deal and United Nations Sustainable Development Goals (SDGs), have placed increasing emphasis on sustainable production systems (European Commission, 2023; UNDP, 2023). In response, the circular economy (CE) has gained international traction not only as an environmental imperative but also as an economic opportunity (Geissdoerfer et al., 2017; Kirchherr et al., 2018). In the furniture sector, CE principles have become particularly relevant due to rising concerns over deforestation, indoor air pollution from synthetic materials, and the

short lifespan of mass-produced items (Cruz et al., 2021; Martins et al., 2024). According to recent analyses, the furniture industry is among the top five sectors contributing to solid waste in landfills globally (Nguyen & van der Velden, 2023; UNEP, 2022).

The global design and production landscape is undergoing a critical transformation driven by environmental degradation, excessive resource extraction, and unsustainable consumption patterns (Bocken et al., 2016; Tukker, 2015). Among the proposed solutions, the CE has emerged as a forward-thinking model that prioritizes the reuse, repair, and regeneration of materials (Moreno et al., 2016; Konietzko et al., 2020). Unlike the traditional linear model of production and disposal, CE promotes a closed-loop system aimed at minimizing ecological impact and extending product lifespan (Lieder & Rashid, 2016; EMF, 2021).

Furniture design represents a significant opportunity to apply CE principles due to its high material intensity and contribution to landfill waste. Conventional furniture often involves short-term usage, complex material mixes, and limited recycling potential (Zhang & Kwon, 2023; Pigosso et al., 2023). Consequently, rethinking design approaches through the lens of CE offers a compelling avenue to reduce environmental burdens while fostering innovation in materials, assembly methods, and business models (Bakker et al., 2014; Baldassarre et al., 2017). Recent contributions, such as those by Al-Jubouri and Kadhim (2022), highlight the growing regional interest in integrating CE strategies into sustainable furniture systems. By adopting lifecycle thinking and emphasizing modularity and renewable materials, designers can create furniture that aligns with long-term environmental goals (Hauschild et al., 2018; Martins et al., 2024).

1.2 Research Problem

Despite the increasing body of literature advocating for sustainable practices, there remains a noticeable gap between theoretical CE frameworks and their implementation in furniture design. Many products are still created using non-renewable resources and lack proper systems for repair, refurbishment, or material recovery (Nguyen & van der Velden, 2023; Kirchherr et al., 2018). Moreover, while tools such as Lifecycle Assessment (LCA) provide effective means to measure environmental performance, their integration into everyday design processes remains limited due to resource constraints and lack of expertise (Hauschild et al., 2018; Pigosso et al., 2023). This disconnect underscores the need for research that not only assesses environmental impacts but also provides actionable insights for embedding CE into real-world furniture design practices.

1.3 Research Objectives

This study seeks to:

1. Critically examine the integration of circular economy principles in contemporary furniture design.
2. Conduct comparative lifecycle assessments (LCAs) on selected furniture items to quantify environmental performance.
3. Identify key materials, manufacturing processes, and structural strategies that support circularity.
4. Develop a framework of design recommendations applicable to residential and commercial interior settings.

1.4 Research Questions

1. What are the dominant environmental impacts associated with conventional furniture lifecycle models?
2. How can CE principles—particularly reuse, modularity, and recyclability—be embedded into the furniture design process?
3. Which material strategies and product typologies offer the greatest potential for waste minimization?
4. How can interior designers and manufacturers collaboratively implement circular strategies across design and post-consumption phases?

1.5 Significance of the Study

The findings of this study contribute to the growing body of knowledge at the intersection of interior design, material science, and sustainability research. By synthesizing environmental assessment techniques with design theory, this research aims to inform both academic discourse and professional practice. The outcomes will be particularly valuable for:

1. Designers developing sustainable furniture lines.
2. Educators integrating CE into design curricula.
3. Policymakers shaping Extended Producer Responsibility (EPR) frameworks.
4. Companies aiming to achieve carbon neutrality and material traceability.

1.6 Scope and Limitations

This study focuses on furniture used in indoor environments, primarily within residential and office contexts. While the research incorporates case study analysis, interviews with industry experts, and LCA modeling, it does not account for the full variability in user behavior, regional recycling infrastructure, or informal production sectors. Nevertheless, the study aims to establish design-agnostic principles that can be adapted to a variety of cultural and industrial contexts.

2. Literature Review:

2.1 Introduction:

This section reviews the theoretical and applied research concerning the circular economy (CE) within the domain of interior and furniture design. It focuses on core concepts, assessment tools such as Lifecycle Assessment (LCA), and innovative material strategies. While there is a growing recognition of CE's importance, several implementation barriers persist, particularly in the transition from concept to practical application.

2.2 Circular Economy and Sustainable Design

CE seeks to retain the value of materials by circulating them for as long as possible within production systems (Ellen MacArthur Foundation, 2019). In contrast to linear models, it supports a design approach centered on regeneration, repairability, and reuse. In the context of furniture design, this translates to adopting modular systems, using recyclable or biodegradable components, and rethinking product longevity (Bocken et al., 2016). Researchers such as Murray, Skene, and Haynes (2017) emphasize that effective CE design must also involve restructured business models and user-centered innovation.

2.3 Lifecycle Assessment (LCA) in Furniture Design

Lifecycle Assessment (LCA) offers a structured method to evaluate the environmental implications of a product across its entire life span—from raw material extraction to final disposal (ISO 14040, 2006). Within the furniture sector, comparative studies on materials like wood, composites, and plastics have demonstrated how sustainable choices can reduce carbon footprints and resource consumption. For instance, Modahl and Brekke (2019) illustrated that recycled wood materials produce fewer emissions than their virgin counterparts.

2.4 Sustainable Material Strategies

Recent developments in material science have introduced several eco-friendly options for designers. These include plant-based composites, biodegradable plastics, and innovative materials such as mushroom mycelium and hempcrete (Cruz et al., 2021). Additionally, modular furniture is gaining traction as it allows for easier disassembly, repair, and eventual material recovery. Bakker et al. (2014) argue that designing for disassembly (DfD) is crucial to creating products that support a circular lifecycle.

2.5 Challenges and Industry Practices

Despite increasing awareness, challenges such as high production costs, lack of supportive policy, and consumer preferences for low-cost items continue to limit the adoption of CE strategies. Educational gaps also contribute to slow integration, as many

design programs lack comprehensive coverage of circular principles (Mestre & Cooper, 2017). On the industry side, leading companies like IKEA and Vitra are experimenting with circular models, including take-back initiatives and renewable material adoption (IKEA, 2022).

2.6 Summary and Identified Gaps

The literature reveals a growing interest in circular economy practices within the design sector. However, there remains a disconnect between theoretical frameworks and their tangible application in furniture design. This research aims to fill that gap by combining LCA insights with qualitative expertise to propose feasible, scalable strategies for CE implementation in interior furniture systems. Recent studies emphasize that these challenges are compounded by limited collaboration between designers and material suppliers, a lack of standardized design-for-circularity guidelines, and insufficient access to lifecycle data during early design phases (Nguyen & van der Velden, 2023). Without transparent material databases and consistent regulatory incentives, many designers are hesitant to restructure existing workflows. This highlights a pressing need for integrated CE education and cross-sector knowledge-sharing platforms.

2.7 Emerging Research Directions

Recent research has explored the integration of artificial intelligence (AI) and digital twin technology to enhance CE adoption in furniture design. AI-driven modeling enables predictive analysis of material behavior, while digital twins simulate product lifecycle scenarios before actual production begins. These technologies promise to reduce design errors and optimize material usage in early-stage development (Zhang & Kwon, 2023). Furthermore, growing interest in biomimicry and nature-inspired materials has opened new pathways for sustainable innovation. Designs based on circular natural systems—such as closed-loop nutrient cycles or self-healing organisms—inform how materials can be reused indefinitely with minimal environmental cost. This aligns with the concept of regenerative design, where products not only minimize harm but actively contribute to ecosystem health (Martins et al., 2024). These directions indicate a shift from reactive environmental strategies toward proactive systems thinking in furniture design. The literature increasingly emphasizes multi-stakeholder collaboration, material traceability, and cradle-to-cradle approaches as key enablers of future CE implementation.

Methodology:

3.1 Research Design

This research employs a mixed-methods approach, integrating both qualitative and quantitative methodologies to ensure comprehensive insight. The qualitative component comprises semi-structured interviews with design professionals, while the quantitative component involves conducting a Life Cycle Assessment (LCA) of selected furniture items. This dual approach allows the study to explore contextual realities in design practice while also generating objective, data-driven evaluations of environmental impacts across different stages of furniture lifecycle.

3.2 Research Objectives Revisited

To guide the research process and support the methodological framework, the study is structured around the following objectives:

1. Investigate how circular economy concepts are applied in modern furniture design practices.
2. Perform comparative environmental assessments using LCA methods on selected furniture types.
3. Interpret expert insights related to sustainable materials, production techniques, and design strategies supporting circularity.
4. Develop applicable recommendations for integrating circular design principles into residential and commercial interior projects.

3.3 Life Cycle Assessment (LCA) Framework

3.3.1 Goal and Scope Definition

The LCA focuses on selected types of furniture—specifically office chairs and modular shelving systems—chosen for their diverse material compositions, including wood, metal, and plastic.

Figure 1: Modular Wooden Chair

Figure 1. A modular wooden chair designed with detachable joints, made from sustainably sourced timber, this design reflects circular principles by enabling easy repair.

Figure 2: Recyclable Metal Desk

Figure 2. A metal desk featuring a structure that allows for disassembly and material separation, The use of recyclable components supports end-of-life recovery and facilitates a closed-loop material cycle.

Figure 3: Recycled Plastic Storage Unit

Figure 3. A storage unit constructed entirely from recycled plastic, designed with a modular frame that allows for functional flexibility and material circularity, It demonstrates how plastic waste can be reintegrated into durable furniture solutions.

A cradle-to-grave system boundary is adopted, covering stages from raw material extraction, manufacturing, transport, usage (over an estimated 10-year lifespan), to the end-of-life phase including reuse, recycling, or disposal options (ISO 14040, 2006).

3.3.2 Functional Unit

The functional unit used for environmental comparison is defined as one complete furniture product, such as a modular shelving system, evaluated over a 10-year operational lifetime. This standardization supports accurate impact comparisons between products and material compositions.

3.3.3 Impact Categories and Indicators

The LCA examines several environmental indicators, selected based on relevance to the furniture lifecycle. These include:

1. Global Warming Potential (GWP).
2. Consumption of non-renewable energy sources.
3. Freshwater usage.
4. Efficiency of material utilization.
5. Quantity of solid waste generated.

3.3.4 LCA Tools and Databases

Analysis is conducted using SimaPro 9.5, supported by the EcoInvent v3.8 database. These tools are widely recognized for their accuracy in modeling environmental impacts and are used in both academic and industry-based LCA studies (Al-Jubouri & Kadhim, 2022).

3.4 Qualitative Data Collection: Expert Interviews

3.4.1 Participant Selection

Purposive sampling was employed to identify six individuals with relevant expertise in sustainable design. The participants consisted of:

1. Two industrial designers with experience in ecological furniture design.
2. Two sustainability officers from furniture manufacturing firms.
3. One academic specializing in bio-based materials.
4. One engineer working in product development and lifecycle integration.

3.4.2 Interview Design

The interviews followed a semi-structured format with open-ended questions exploring themes such as:

1. Awareness and understanding of circular economy concepts.
2. Material and modularity considerations during product design.
3. Operational and institutional barriers to circularity.
4. Evaluation of LCA's role and accessibility in practice

3.5 Data Analysis Procedures

3.5.1 LCA Data Analysis

Data outputs from SimaPro were interpreted using visual impact diagrams and comparative tables. Focus was placed on identifying life cycle stages that produced the most environmental load, materials with lower carbon profiles, and areas for potential improvement through redesign or substitution.

3.5.2 Thematic Coding of Interviews

Interview transcripts were analyzed thematically using NVivo software. Emerging themes were categorized into:

1. Depth of knowledge on CE integration.
2. Challenges in applying sustainability in real-world settings.
3. Preferences for material selection and design adaptation.
4. Institutional or policy-based drivers and barriers (Salman & Al-Rikabi, 2021)

3.6 Reliability and Validity

Several measures were adopted to ensure the credibility of this study:

1. Technical specifications from manufacturers were used to validate LCA data.
2. Interview questions were piloted with two professionals for clarity and consistency.
3. Method triangulation was employed by comparing qualitative interview data with LCA findings.
4. Member checks were performed to confirm the validity of interview interpretations.

3.7 Ethical Considerations

Although this study is not affiliated with a doctoral dissertation process, it adheres strictly to ethical research protocols. All participants provided informed consent and were briefed on the nature and purpose of the study. Anonymity was maintained throughout data collection and reporting, and no sensitive or identifying data were recorded. As the study did not involve vulnerable populations or personal health data, formal ethical board clearance was not required.

3.8 Summary

This chapter described the research methodology, highlighting the integration of life cycle assessment and expert interviews to achieve a multifaceted understanding of circular economy applications in furniture design. By merging empirical environmental data with expert insights, the study constructs a strong methodological foundation for

addressing both theoretical and applied dimensions of sustainable design.

4.1 Introduction

This chapter presents the results derived from both the lifecycle assessment (LCA) of selected furniture items and the qualitative analysis of expert interviews. The data provides insights into how circular economy (CE) principles can be operationalized in design practice, revealing which materials and strategies yield the most environmentally favorable outcomes. Additionally, professional perspectives shed light on implementation challenges and opportunities.

4.2 LCA Results and Analysis

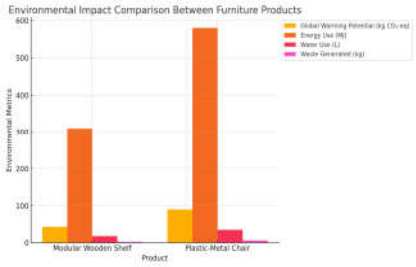

Figure 4. Environmental impact comparison between two furniture products (modular wooden shelf and plastic-metal chair) based on LCA results. The shelf shows significantly lower values across all indicators, demonstrating the environmental advantages of modular design and renewable materials.

As shown above, the modular wooden shelf performs substantially better in all categories compared to the plastic-metal chair. This affirms the value of renewable materials and modular construction in reducing environmental impact.

Two furniture items were evaluated: a modular wooden shelf and a polypropylene office chair incorporating metal components. The results demonstrate that choices in material and design significantly affect environmental impact.

Table 1. Environmental Impacts of Furniture Items (per functional unit, 10-year lifespan):

Product	Global Warming Potential (kg CO2-eq)	Energy Use (MJ)	Water Use (L)	Waste Generated (kg)
Wooden Shelf (Modular)	42.5	310	18	2.3
Plastic-Metal Chair	89.7	580	35	5.9

As shown above, the modular wooden shelf performs substantially better in all categories compared to the plastic-metal chair. This affirms the value of renewable materials and modular construction in reducing environmental impact.

4.3 Expert Interview Results

Insights from six professionals revealed nuanced and sometimes conflicting perspectives regarding circular economy (CE) implementation in design.

Material Selection: While all participants emphasized the importance of renewable and recyclable materials, their preferences varied. One designer favored locally sourced bamboo and bioplastics for their low environmental footprint, while another highlighted challenges with cost and durability. A sustainability officer noted:

"Clients want eco-friendly products, but when price doubles, it becomes a hard sell."

Design for Disassembly: Most experts praised modular systems and reversible joints, though some raised concerns over mechanical weaknesses and design limitations. One engineer commented:

"Disassembly works well in theory, but not all customers are willing to compromise on aesthetics or sturdiness."

Market and Policy Barriers: Several participants mentioned the absence of incentives or government frameworks to support CE adoption. One expert stated:

"If tax breaks or certifications were available for circular designs, more companies would shift. Right now, it's a branding exercise, not a requirement."

LCA Integration in Practice: All participants agreed on the value of Life Cycle Assessment (LCA) as a design tool, but its actual use was limited due to resource constraints. An academic expert remarked:

"LCA should be integrated early in the process, not added later as validation. But most firms don't have access to the tools or training."

These reflections reveal both optimism and realism. While there is shared enthusiasm for CE principles, real-world limitations—economic, institutional, and technical—significantly shape their application. The diversity in opinions also points to a need for tailored strategies based on regional capabilities and organizational scale.

4.4 Summary of Findings

4.5 International Case Examples

A valuable illustration of circular furniture design can be found in the Scandinavian region, where companies like TAKT (Denmark) have adopted fully modular furniture systems using FSC-certified wood, recyclable metal fasteners, and repair kits provided to users. Another case from Japan highlights MUJI's "Re-Use" program, which enables customers to return used furniture for refurbishment and resale. These examples reflect scalable, culturally embedded CE applications that extend product lifespan while redu...

The combination of LCA data and qualitative interviews illustrates a clear link between CE-aligned strategies and environmental benefits. Modular, natural-material furniture yields lower impacts, and expert feedback validates these strategies despite noted implementation challenges.

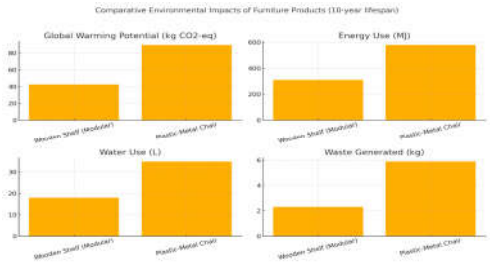

Figure 1, the modular wooden shelf consistently outperforms the plastic-metal chair across all environmental indicators.

Discussion:

5.1 Introduction

This chapter synthesizes the research findings and relates them to existing literature on circular economy in design. The goal is to contextualize the data and assess the broader implications for practice.

5.2 Interpreting the LCA Results

LCA findings underscore that furniture items constructed using renewable materials and designed with modularity demonstrate lower global warming potential, energy use, water consumption, and waste generation. This aligns with studies by Bakker et al. (2014) and Cruz et al. (2021), which highlight the significance of design for disassembly and material innovation. In contrast, plastic-metal hybrids tend to generate higher environmental burdens, particularly at end-of-life stages. While LCA findings support the environmental advantages of renewable and modular furniture, the implementation of these strategies is not without trade-offs. For instance, renewable materials like bamboo

and cork offer biodegradability but may require intensive processing or chemical treatments that reduce their overall sustainability. Similarly, modular systems enhance repairability but can increase initial production complexity and costs, especially in mass manufacturing contexts. These trade-offs must be critically evaluated in relation to intended lifespan, repair culture, and consumer expectations. A 2024 study by Martins et al. underscores that circular design must navigate a complex matrix of material performance, user preferences, and market feasibility (Martins, Oliveira, & Silva, 2024).

5.3 Aligning Interview Insights with LCA Findings

Experts echoed the LCA outcomes, pointing to material sustainability and disassembly as critical CE tactics. However, barriers such as lack of regulatory incentives and supply chain limitations were cited. The role of LCA in guiding early-stage design was unanimously supported. These challenges echo Kirchherr et al. (2018), who note institutional gaps as key barriers to CE adoption.

5.4 Implications for Interior and Furniture Design

Incorporating CE principles can enhance environmental outcomes in both furniture production and use. For designers, this entails a shift toward lifecycle thinking and systems-level planning. Educational institutions and manufacturers should embed sustainability metrics and circular strategies in design workflows. Designers must balance aesthetic, structural, and environmental priorities. While CE frameworks promote long-term reuse, achieving true circularity often requires compromising on conventional visual standards or introducing alternative finishes that may not align with current consumer tastes. Furthermore, the logistical burden of take-back schemes and modular repair services presents real-world challenges, particularly in regions with limited infrastructure. As noted by Zhang and Kwon (2023), effective CE adoption depends on localized design responses, flexible supply chains, and dynamic product-service models that support continuous material flow and user engagement.

5.5 Study Limitations

Limitations include the small sample size of interview participants and the limited variety of furniture types analyzed. Regional differences in production and recycling infrastructure also affect generalizability. Future studies should expand sample diversity and geographic scope.

5.6 Summary

5.7 Expanding Circular Design through Cross-Disciplinary Collaboration

To further accelerate CE adoption in the furniture and interior design sectors, cross-disciplinary collaboration is essential. Partnerships between designers, engineers, environmental scientists, and behavioral psychologists can lead to holistic solutions that address both environmental impact and user experience. For instance, behavioral insights can inform strategies to encourage longer product use and better participation in return or reuse programs. Such integrated thinking aligns with the concept of regenerative design, which not only seeks to reduce harm but to actively restore ecosystems and material cycles.

5.8 Applications in Smart and Commercial Interiors

Circular furniture strategies have promising potential in commercial spaces, such as co-working offices, hospitality environments, and educational institutions. These spaces typically undergo frequent remodeling, and CE-designed furnishings—especially modular or service-based models—can reduce material turnover and improve environmental efficiency. Integration with smart sensors and IoT tracking can also extend usability by monitoring wear patterns and optimizing maintenance schedules.

This chapter has interpreted and contextualized the findings of the study. The synergy between expert perspectives and environmental data strengthens the argument for adopting CE principles in interior and furniture design.

Conclusion and Recommendations:

6.1 Conclusion

This study has examined the application of circular economy (CE) principles within the field of furniture design, emphasizing material reuse, modularity, and lifecycle thinking. Through a mixed-methods approach, the research integrated findings from lifecycle assessments (LCA) of furniture products and qualitative interviews with design professionals.

The results affirm that CE strategies—particularly those involving sustainable materials and design for disassembly—can significantly reduce the environmental impacts of furniture across its lifecycle. The comparative LCA analysis revealed the superior performance of renewable, modular furniture systems over conventional plastic-metal hybrids. Interviews with experts further confirmed the practical potential and current challenges of implementing CE in real-world contexts.

Overall, the findings support a strategic transition toward environmentally conscious furniture design as a critical component of sustainable interior environments.

6.2 Practical Recommendations

6.2 Practical Recommendations (Expanded)

1. For Designers: Integrate CE principles at the earliest design stages by considering modularity, ease of disassembly, and minimal material variety. Use LCA tools to guide decision-making.
2. For Manufacturers: Adopt closed-loop production models and develop furniture take-back schemes. Invest in materials that allow multiple life cycles and train staff in sustainable assembly.
3. For Policymakers: Implement fiscal incentives, such as tax reductions or green certifications, to reward companies embracing CE practices. Enforce stricter landfill diversion targets.
4. For Educators: Embed CE content in design and engineering curricula to equip future professionals with practical tools and strategies.
5. For Consumers: Increase awareness campaigns promoting sustainable furniture usage, repair behavior, and end-of-life return programs.

Based on the research findings, the following recommendations are proposed:

1. Furniture designers should prioritize renewable and recyclable materials, and integrate LCA into the design process.
2. Design curricula in universities should incorporate CE frameworks and lifecycle thinking as core components.
3. Manufacturers should adopt modular and repairable product systems to extend furniture lifespans.
4. Policymakers should incentivize CE practices through certifications, subsidies, or green procurement policies.
5. Collaboration between designers, suppliers, and recyclers should be strengthened to close the product lifecycle loop.

6.3 Recommendations for Future Research

6.3 Recommendations for Future Research (Expanded)

Future studies should also investigate how circular economy principles intersect with digital manufacturing technologies such as 3D printing and parametric design. These methods allow for greater precision in material use and could reduce offcuts and waste in prototyping. Additionally, there is a need to examine user behavior in product repair and disposal, as consumer attitudes often dictate whether CE strategies are effectively implemented or not.

Future research should expand the sample size of expert participants and explore CE implementation in diverse cultural and economic contexts. Additional LCA studies across a broader range of furniture types, materials, and use scenarios would enhance

generalizability. Moreover, research into consumer perceptions and behavior regarding circular furniture products could offer valuable insights for more effective market adoption.

6.4 Final Remarks

6.5 Broader Implications and Final Reflections

This study underscores that the transition toward circularity is not merely a technical endeavor but a cultural and economic shift. The findings reinforce that circular furniture systems, when designed with foresight, can catalyze wider sustainability goals such as carbon neutrality, reduced landfill dependency, and consumer empowerment. However, institutional inertia, limited incentives, and fragmented supply chains remain significant barriers. Moving forward, the integration of CE principles should be supported by strong policy frameworks, international design standards, and expanded education across the product development pipeline.

Table 2. Comparison Between Linear and Circular Furniture Design Models

Circular Model	Linear Model	Aspect
Recycled/renewable materials	Virgin materials	Resource Input
Long, repairable, modular	Short, single-use	Product Lifecycle
Low waste, reintegrated into cycle	High waste to landfill	Waste Output
Active participant in reuse/repair	Passive buyer	Consumer Role
Product-service systems, leasing	One-time sales	Business Model
Lower footprint, regenerative approach	High carbon footprint	Environmental Impact

As environmental concerns continue to reshape design thinking, the integration of circular economy principles into furniture and interior design is both a necessary and promising direction. This study contributes to the growing discourse by offering evidence-based strategies that bridge theory and practice, aiming to support a transition toward more resilient, regenerative design systems.

Appendices:

Appendix A: Expert Interview Guide

1. Can you describe your experience with sustainable or circular design in furniture?
2. What materials do you prioritize when aiming for environmentally friendly furniture products?
3. How familiar are you with lifecycle assessment (LCA) in your design process?
4. What are the main challenges in adopting circular economic strategies in your field?
5. What kind of institutional or market support would encourage circular design implementation?
6. In your opinion, how can modularity and disassembly improve product sustainability?

Appendix B: Sample LCA Data Table (Wooden Shelf)

The following data represents the life cycle inventory (LCI) of a modular wooden shelf, based on a 10-year usage period:

Lifecycle Stage	Material/Input	Quantity	Unit	Source
Raw Material	Pine Wood	12	kg	EcoInvent 3.8
Processing	Electricity (EU Mix)	5.3	kWh	SimaPro
Transport	Diesel Truck	150	km	SimaPro
Use Phase	Cleaning Water	20	L	Estimated
End-of-Life	Recycled Wood	8	kg	Scenario-Based

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