Annals of Warsaw University of Life Sciences – SGGW
Forestry and Wood Technology № 122. 2023: 36-46
(Ann. WULS - SGGW, For. and Wood Technol. 122, 2023: 42-52)
Received: 13.04.23 / Accepted: 07.05.23 / Published: 30.06.23

Smart design upcycling of post-production display panels into new creative materials to support the sustainable development of a circular economy in the furniture industry

MAŁGORZATA GROTOWSKA[1], PIOTR BEER[2]

[1] Okoń Parkiety, Poland
[2] Department of Technology and Entrepreneurship in Wood Industry, Institute of Wood Sciences and Furniture, Warsaw University of Life Sciences WULS-SGGW, Poland

Abstract: *Smart design upcycling of post-production display panels into new creative materials to support the sustainable development of a circular economy in the furniture industry*. The economy is currently transforming from a linear economy to a circular economy. This is increasingly supported by policy, legislation, industry, and academia. A circular economy means more efficient management of renewable natural resources, which has implications for businesses' bioeconomies, as expressed in the sustainable development goals of the United Nations' 2023 Agenda. Our study contributes to solving a research gap by seeking to answer several questions: How can post-production residues be used to improve a company's bioeconomy? Can they bring profit to a company while saving natural wood? Is upcycling using the smart design of post-production a helpful solution for material and cost savings in the bioeconomy? The outcome of our study is twofold. From a creative input perspective, we show the creative possibilities of upcycling production residues. For business models, we refine the conceptualisation of a sustainable SME circular bioeconomy through the profit gained from such a product solution. Based on our research, we present conclusions and suggestions for small and medium-sized enterprises, scientists, designers, and technologists to help the furniture industry transition from a linear economy to a sustainable circular economy. This promotes company profitability and growth and helps to save natural wood.

Keywords: sustainability, upcykling, wood waste, eco design, green product, furniture

INTRODUCTION

As stated in the United Nations (UN) 2023 Agenda and Sustainable Development Goals, a circular economy promotes the efficient management of renewable natural resources, which has implications for the bioeconomy of businesses (UN, 2015). To support the Sustainable Development Goals of the UN's 2030 Agenda and the Paris Agreement, Europe is leading a plan to accelerate the deployment of a sustainable European bioeconomy. This was developed in 2012 and updated in 2018 (European Commission, 2018; De Araujo et al., 2022).

Several stakeholders, such as producers, consumers, and policymakers, must be involved and committed to changing the current economic model from production–consumption–waste to production–consumption–reuse. This will positively impact the social life of communities, the economic viability of businesses, and the natural environment (Hysa et al., 2020). Currently, linear economies are being replaced by circular ones, with growing support from policymakers, regulators, industries, and academics (Anupam et al., 2022). The contemporary economic and environmental situation is forcing the creation of efficient, cost-effective and environmentally friendly products (Zenid, 2009).

This study explores the potential use of wood waste to support the bioeconomy. The protection of forests and the recycling and upcycling of wood is both economically and ecologically important. It is especially vital for countries where the wood industry is central to

the economy. The value of the natural raw material of wood waste is increasing significantly as progress is made towards renewable ecological sources.

Our study solves research gaps by seeking answers to the questions: How can post-production residues be used to improve a company's bioeconomy? Can they bring profit to a company while saving natural wood? Is upcycling using the smart design of post-production a helpful solution for material and cost savings in the bioeconomy? The study seeks to identify whether upcycling through the smart design of post-consumer finished displays will promote material and cost savings in the bioeconomy. What are the business challenges and opportunities associated with operationalising these business models? Telenko et al. (2016) highlights that politicians, consumers, and industry leaders are increasingly concerned about the environmental impact of modern products. Product designers are responding by looking for simple and effective ways to reduce the environmental impact of their design products.

This paper examines products made from wood waste as a viable alternative to new wood raw materials for interior objects in architecture. Such a solution influences the development of the global bioeconomy, where the demand for sustainable solutions is consistently increasing. The study also aims to increase knowledge about design in sustainable development. As design is central to solving the challenges of developing sustainable architecture, it is vital to rethink product development from the beginning, including the types of materials used. This will help to create healthy living and working environments that positively impact customers, users, and the environment.

This study has two aims. First, it highlights the potential for creating new products by upcycling wood production residues. Second, it aims to show the positive impact of upcycling production residues on the bioeconomies of companies. To realise these objectives, the authors conducted a market analysis of the types of production residues, including qualifying possible methods for reprocessing and upcycling management. Furthermore, the authors qualified the post-production residues of display panels for further research because this material is unsuitable for other kinds of secondary processing or upcycling due to its nature and intended function. The smart design method was used to investigate the possibility of using post-production residues as post-exhibition, post-exposure, and post-design panels. This highlights the specificity of the upcycling relationship between secondary waste, raw materials, and new products.

MATERIALS AND METHODS

Due to increasing economic and population growth, the global need for natural resources is growing. Natural resources are vital to promoting a good quality of life in the built environment and efficient architecture; however, they are being depleted by many industries. Too many products and excessive demand for their production have negatively impacted the state of the planet, damaging its natural resources and the regenerative functions of its ecosystems. Consequently, renewable resources such as forests are being depleted faster than nature can regenerate them. An essential element of the regenerative design process is awareness of the environmental impact of materials used in both architecture and interior design (Attia, 2018).

When products become waste, this can negatively impact human health or the environment. This often occurs if products are poorly designed or of low quality; their negative environmental impact is often not considered during these products' design. This impact can be minimised by appropriate life management of the product during the design stage. Sustainably designing architecture and furnishings reduces the negative impact on the environment. Efficient resource management must be implemented to increase the use of recyclable materials in design and to create architectural and interior design solutions based

on recycling and upcycling of recyclable materials. This solution, alongside design quality, will aid sustainable construction.

The need for a paradigm shift in design stems from architecture's profound socio-ecological challenges, resulting from the historical disregard for its environmental impact. Using wood production residues as a new material for interior design products offers a sustainable way to create architecture that positively impacts the environment. A paradigm shift in design towards regenerative architecture, which can also be achieved using recycled and up-cycled materials in product design, is crucial.

The European Commission is currently undertaking research to address the challenges of introducing a circular economy in building design. An essential element of this work is increasing the life cycle of products used in architecture, interior furnishings, and broader construction. The European Commission promotes circular economy principles in building design, considering access to and use of secondary raw materials. The construction industry plays a vital role in addressing the climate crisis. Therefore, it is essential to address the issue of circularity in the design of architecture, interior furnishings, and construction (Attia et al., 2021).

Secondary raw materials composed of different materials are challenging to recycle. It is often impossible to recycle secondary raw materials with a non-homogeneous structure or when disassembly is costly or too complex. This is due to the requirements of a complex supply chain and the well-organised system of disassembling end-of-life products into similar parts, which is vital for recycling. When classifying products for recycling, their easy disassembly into individual material types enables recycling when grouped. Conversely, in upcycling, the homogeneous secondary raw material is processed into a new material, intermediate product or, preferably, direct product. Furthermore, finance plays a significant role. Financial considerations are central to recycling. It is often claimed that, despite its ecological benefits, recycling is often unprofitable due to high costs, the logistics of collecting the secondary raw materials, the analysis of the processing, and the cost of selling the final material, semi-finished product, or product. The analysis of secondary raw materials suitable for upcycling has considered these aspects, which are an advantage for upcycling due to the smart design methodology involved in upcycling post-production display panels.

UPCYCLING-SPECIFIC ANALYSIS OF THE CONSTRUCTION OF A SECONDARY RAW ATERIAL DISPLAY PANEL

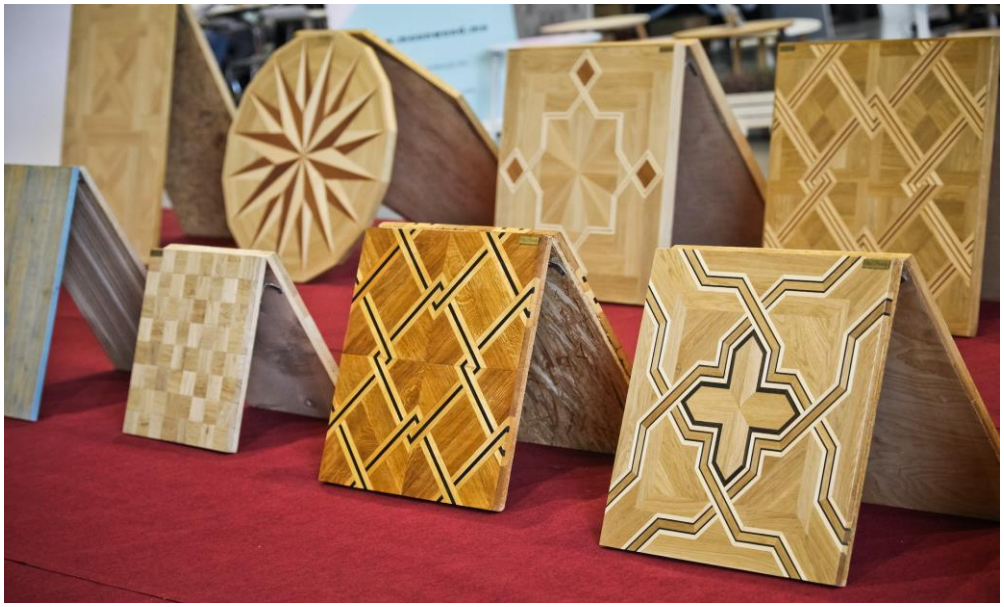

Figure 1. Architectural display panels (authors).

This study investigates post-production display panels. In the furniture industry, these panels are produced as product samples to develop product types. The samples analysed in this paper were from three stages of production. First, the study used samples from product development and prototyping for visual and quality testing when deciding about product implementation. These involve the shortest lifespans of patterns; these patterns are usually used only once. They are typically used for a few hours to a few months, depending on the pace of product development in the company, and are then discarded. The second type of pattern is made to order for property developers, architects, restorers, and construction companies; such patterns serve the specific order of an individual, institutional or investment client. These samples typically last from a few days to about a year. The third sample type is developed to sell the product to distributors and display the type, quality, colour, texture, and pattern of wall coverings, flooring, and furniture. These samples are usually last more than one year and can be used for several years

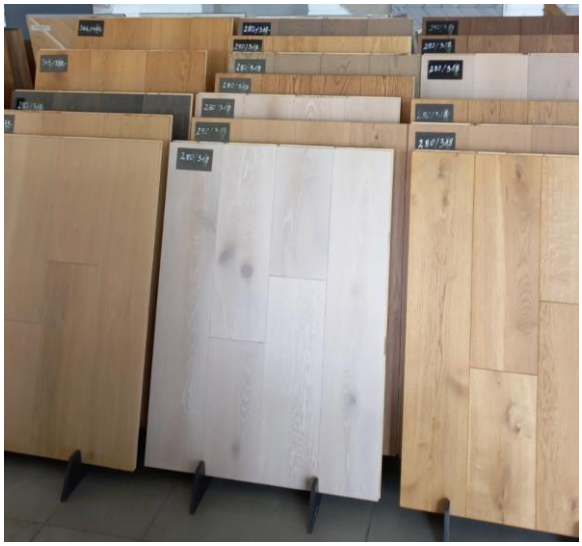

Figure 2 and 3. Store display panels (authors).

These panels ’construction usually involves several layers: a core layer, an adhesive layer, a main layer, and a surface protection layer. Underlay layers are sometimes made of different materials, such as plywood, chipboard, MDF, HDF, OSB, and glulam of various types and sizes. The primer layer is glued to the top layer, usually with a wood adhesive. The construction of the top layer is even more varied than the bottom layer. Due to the intended use of such display panels, the construction of the top layer is generally not reproducible. Consequently, a source of recycled material will typically have many of these panels, each with a different top-layer construction. The construction of the surface layer may use solid wood planks from domestic or exotic species, two-layer and three-layer planks, oil, adhesive, and other materials. The top layer may be made of oil, oil wax, wax, or varnishes using various chemical compositions. These layers often have a high abrasion resistance due to the display boards ’use for advertising purposes and their impact resistance requirements; the boards are often moved around architectural and design offices, building sites, showrooms, and exhibitions. The design methodology assumes the appropriate selection of waste materials to create suitable products that achieve the best possible aesthetic and financial value compared with the secondary raw material from which they were designed. Simultaneously, the products should minimise the use of financial, human, and raw material resources.

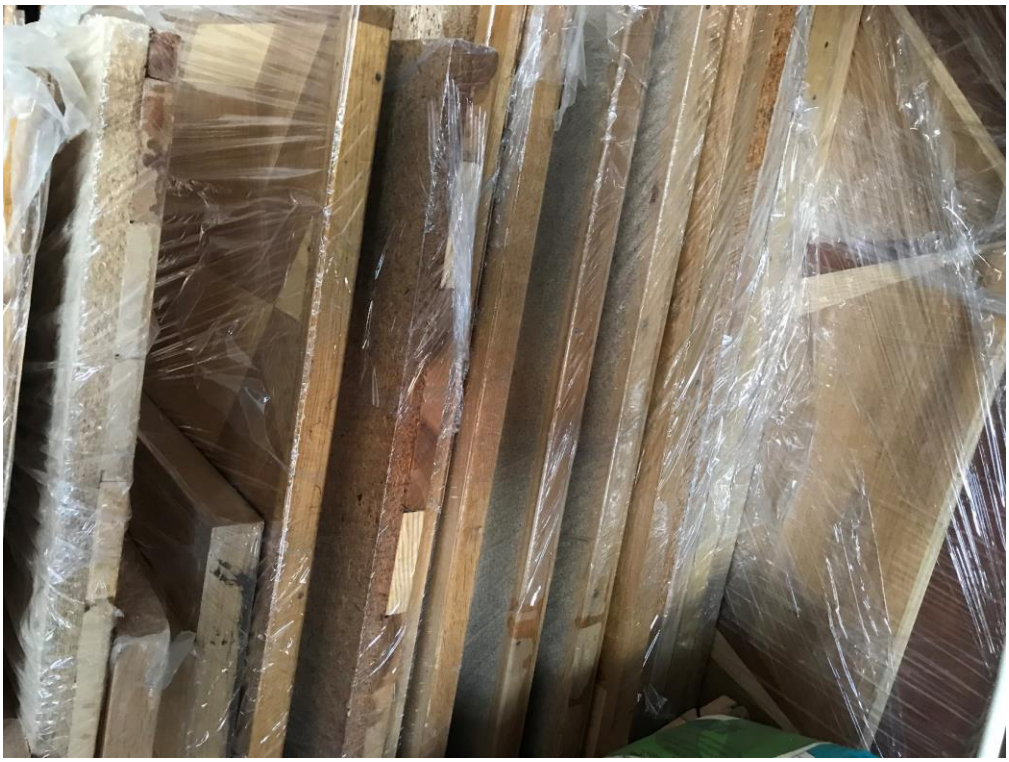

Figure 4. Architectural display panels as a waste (authors).

Figure 5. Store display panels as a waste (authors).

The design concept also assumes the application of the European Commission guidelines for the New European Bauhaus, which are based on the principles of beauty, sustainability, and inclusivity. An essential aspect of upcycling design methodology is developing a methodology that combines the characteristics of the secondary raw material with those of the new product. The disadvantages of the secondary raw material should become advantages for the new product. In this case, non-homogeneous construction, components made of different materials in different shapes, robust construction, and the preservatives and refining chemicals that interfere with recycling are advantages for the new product. The bio-economy combines the production of renewable bio-resources and their conversion into bio-based products (European Commission, 2012). Byggeth et al. (2007) highlight the importance of a sustainable product development methodology to integrate social and environmental aspects of sustainability with a strategic business perspective. Furthermore, Klöpffer (2002) highlights that researchers involved in design in sustainable development must provide appropriate design instruments. The Life Cycle Assessment tool is an internationally standardised environmental tool that helps to measure a product's environmental impact.

RESULTS

This study has two outcomes. From a creative input perspective, it highlights the creative possibilities of upcycling production residues. This supports SMEs' sustainable closed-loop bioeconomy business model because they can profit from a sustainable product made from production waste. Appropriately using this waste improves a company's financial position rather than adding an additional cost burden, as it would if it remained waste. The broader waste management process is based on the cascade principle, where natural raw material remains used for as long as possible. Cascading promotes the efficient use of wood: producing wood materials, reuse, recycling, bioenergy and disposal. (European Commission, 2013). Vis et al. (2016) emphasises the critical role of cascading in sustainable wood processing and indicates that various obstacles must be overcome for cascading to be fully implemented. It is vital to develop sustainable design methods to enable and facilitate the cascaded processing of wood secondary raw materials.

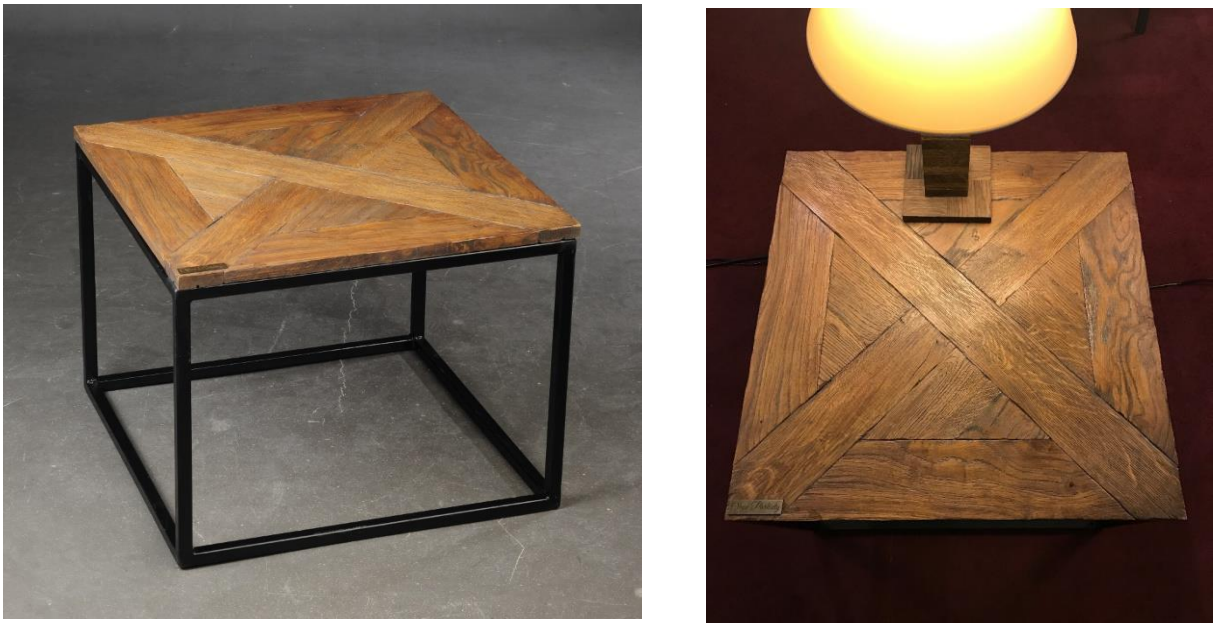

Figure 6a, 6b. Architectural display panels upcycled into coffee table (authors).

This approach will help create furniture that can be used in domestic and commercial interiors. The products will be high-quality, have pleasing aesthetics, and be useful. It will meet eco-design guidelines and involve minimal energy and human resources during production. This could include dining tabletops, coffee tables, desktops, bed headrests, cupboard fronts, seats, seat backs, and wall coverings. This research resulted in creating tables and coffee tables of various shapes and sizes. The researchers strived to make the best use of the waste; therefore, the study was based on adapting the waste's shape, form, and aesthetic qualities for the final product.

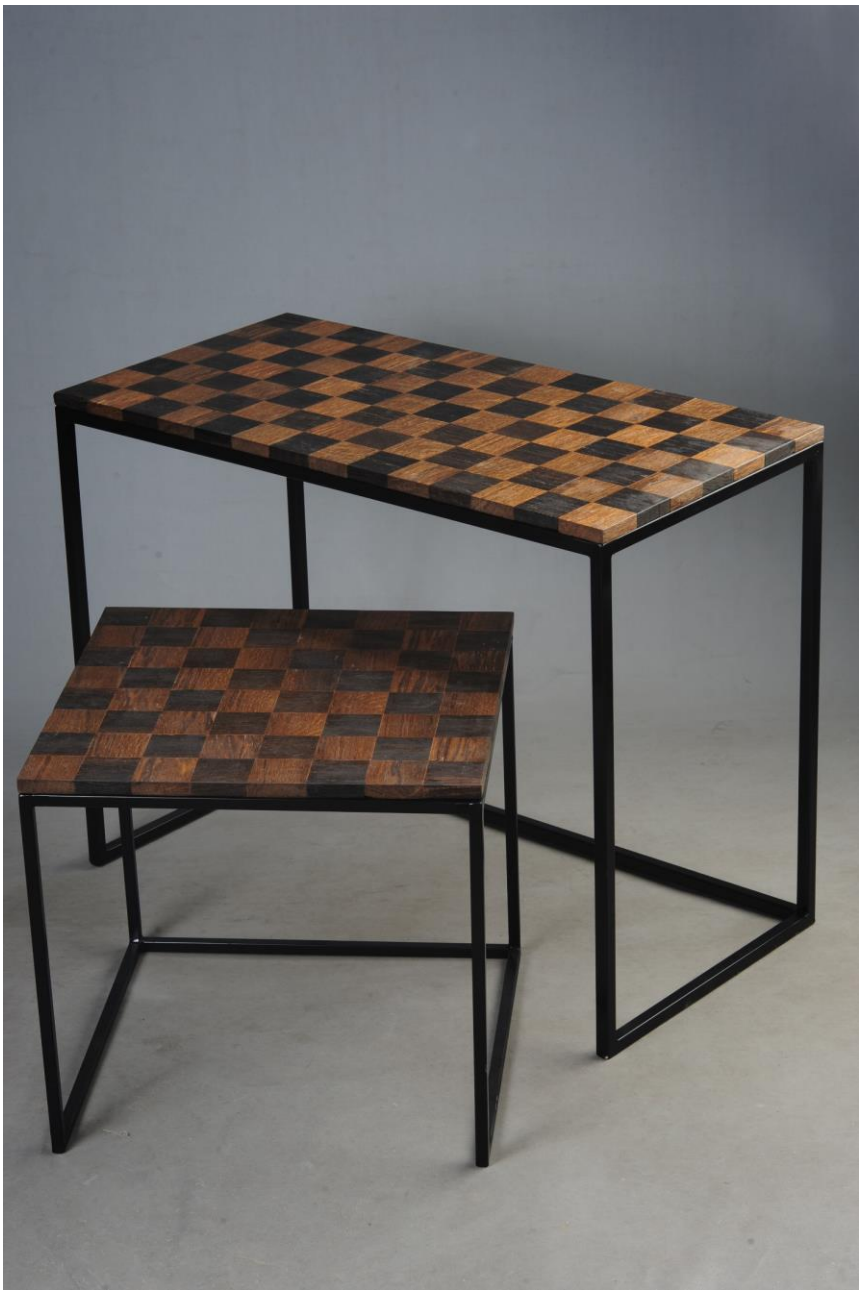

Figure 7. Architectural display panels upcycled into tables set (authors).

If the frames are also made from recycled materials, the products will meet eco-design requirements and have a minimal negative environmental impact. This is because the raw materials are of secondary origin, and the production process is environmentally friendly. Supplying such products in-house by companies, factories, and distributors will save energy

and human resource costs. This study used a design phase emphasising eco-design principles as this is the most critical component of the upcycling methodology.

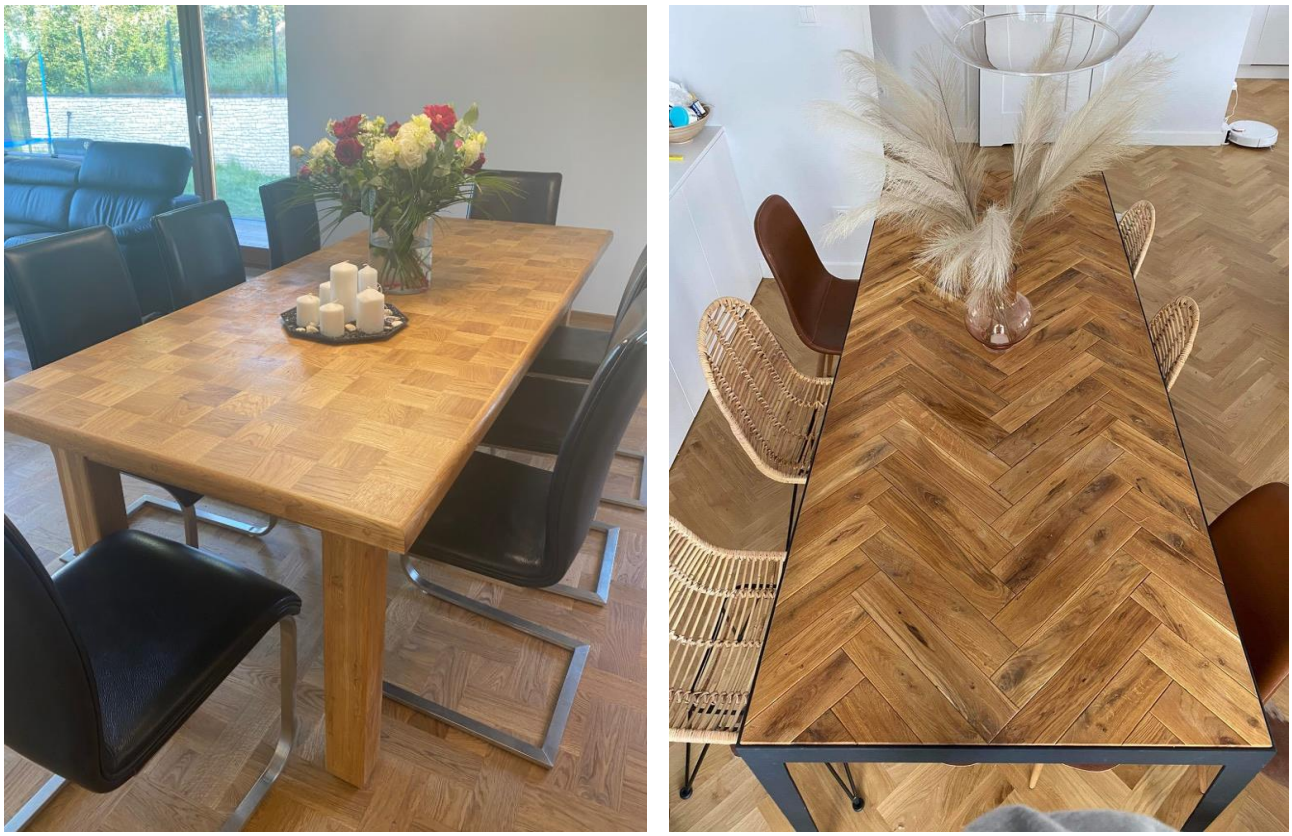

Figure 8,9. Store display panels upcycled into dining tables (authors).

This study makes two vital contributions. Creatively, we show the possibilities of using ready-made materials. Second, we highlight the possibility of incorporating this solution into a company's bioeconomy business model through the profit derived from such a product solution. Furthermore, we demonstrate the possibility of up-cycling production residues for trial, demonstration, and sales displays.

CONCLUSIONS

This study has addressed how post-production residues can improve a company's bioeconomy. Post-production waste can improve a company's bio-economy through smart design and an upcycling methodology. This involves minimum energy and costs and creates new, high-quality interior design products. This approach produces sustainable goods, creates forestry opportunities, and can stimulate a green recovery in times of crisis (Sen and Singer, 2020).

Based on our research, we present conclusions and suggestions for SMEs, designers, and technologists to help the furniture industry transition from a linear economy to a sustainable circular economy. These promote company profitability and growth and save natural wood raw materials. It is essential to develop eco-design and sustainable production to promote eco-products, encouraging both producers and consumers to care about a sustainable future (Hossain et al., 2020).

Resource efficiency can minimise environmental and climate impacts by using wood to produce higher value-added outputs in a cascade approach (European Commission, 2013). Bioeconomy policies are critical in countries where forestry is a crucial industry (Teitelbaum et al., 2020). The value of the post-production residue is much higher than that of secondary raw material due to lower cost and effort requirements. The shift from a linear economy to a bio-economy is an essential response to all the critical issues facing humanity (Biancolillo et al., 2020). It is central to the future of architecture and construction.

The industry must promote eco-products with low-impact operations that use recycled residual resources. Public authorities must also engage in sustainable procurement and use products with fewer harmful environmental effects (Sönnichsen and Clement, 2020). Although some products using bio-based solutions already exist, more must be developed. Therefore, further research should focus on developing policies for research, consumer involvement, and governments. Many changes will have to take place in the field of sustainable architecture around the world to improve quality of life (De Araujo et al., 2022).

"It is possible to use the forest without its destruction, creating work and income" (De Araujo et al., 2016). This highlights the value of upcycling and ecological design, both of which require further research.

REFERENCES

1. ANUPAM KHAJURIA, VELLA A. ATIENZA, SUCHANA CHAVANICH, WILTS HENNING, ISHRAT ISLAM, ULRICH KRAL, MENG LIU, XIAO LIU, INDU K. MURTHY, TEMITOPE D. TIMOTHY OYEDOTUN, PRABHAT VERMA, GUOCHANG XU, XIANLAI ZENG, JINHUI LI, Accelerating circular economy solutions to achieve the 2030 agenda for sustainable development goals, Circular Economy, Volume 1, Issue 1, 2022, 100001, ISSN 2773-1677, https://doi.org/10.1016/j.cec.2022.100001.

2. BIANCOLILLO, I., PALETTO, A., BERSIER, J., KELLER, M., ROMAGNOLI, M. 2020.A literature review on forest bioeconomy with a bibliometric network analysis. In Journal of Forest Science 66, 265-279.

3. BYGGETH S., BROMAN G., ROBÈRT K.H.,A method for sustainable product development based on a modular system of guiding questions, Journal of Cleaner Production, Volume 15, Issue 1, 2007, Pages 1-11, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2006.02.007.

4. DE ARAUJO, VICTOR & VASCONCELOS, JULIANO & ROCCO LAHR, FRANCISCO & CHRISTOFORO, ANDRE. (2022). Timber forest products: a way to intensify global bioeconomy from bio-materials. Acta Facultatis Xylologiae. 64. 99-111. 10.17423/afx.2022.64.1.09.

5. DE ARAUJO, VICTOR & VASCONCELOS, JULIANO & BARBOSA, JULIANA & MORALES, ELEN & GAVA, MARISTELA & SAVI, ANTONIO & GARCIA, JOSE. (2016). Wooden Residential Buildings – A Sustainable Approach. Bulletin of the Transilvania University of Brasov. 9. 53-62.

6. EUROPEAN COMMISSION. 2013. A new EU forest strategy: for forests and the forest-based sector. Brussels: European Commission. pp.1-17.

7. EUROPABIO 2012. Building a bio-based economy for Europe in 2020. Brussels: EuropaBio.

8. EUROPEAN COMMISSION. 2018. Bioeconomy: the European way to use our natural resources: action plan 2018. Brussels: European Commission. pp.1-23.

9. HOSSAIN, M.U., THOMAS NG, S., ANTWI-AFARI, P., AMOR, B. 2020. Circular economy and the construction industry: existing trends, challenges and prospective framework for sustainable construction. In Renewable and Sustainable Energy Reviews 130, 1-15.

10. HYSA E, KRUJA A, REHMAN NU, LAURENTI R. Circular Economy Innovation and Environmental Sustainability Impact on Economic Growth: An Integrated Model for Sustainable Development. *Sustainability*. 2020; 12(12):4831. https://doi.org/10.3390/su12124831

11. KLÖPFFER, W. (2002). Life-Cycle Based Methods for Sustainable Product Development. The International Journal of Life Cycle Assessment. 8. 157-159. 10.1007/BF02978462.

12. SEN, M., SINGER, B. 2020. Forests: at the heart of a green recovery from the COVID-19 pandemic. Geneva, Switzerland: UN. pp.1-4.

13. SÖNNICHSEN, S.D., CLEMENT, J. 2020. Review of green and sustainable public procurement: Towards circular public procurement. In Journal of Cleaner Production, 245, 118901.

14. TELENKO, C., O'ROURKE, J. M., CONNER SEEPERSAD, C., AND WEBBER, M. E. (January 13, 2016). "A Compilation of Design for Environment Guidelines." ASME. *J. Mech. Des*. March 2016; 138(3): 031102. https://doi.org/10.1115/1.4032095

15. TEITELBAUM, L., BOLDT, C., PATERMANN, C. 2020. Global Bioeconomy Policy Report (IV): A decade of bioeconomy policy development around the world. Berlin: IACGB. pp.1-165.

16. SHADY, A.,MUHEEB, A. (2021). Design criteria for circular buildings. Sustainable Building Design Lab, Dept. UEE, Faculty of Applied Science, University of Liege, 4000, Belgium

17. Shady, A. 2018. Regenerative and Positive Impact Architecture, SpringerBriefs in Energy, https://doi.org/10.1007/978-3-319-66718-8_2

18. UN Agenda 2030, United Nations Sustainable Development Summit on 25 September 2015. https://sdgs.un.org/2030agenda. access: 08.04.2023

19. Vis M., U. Mantau, B. Allen (Eds.) (2016) Study on the optimised cascading use of wood. No 394/PP/ENT/RCH/14/7689. Final report. Brussels 2016. 337 pages

20. ZENID, G.J., 2009. Madeira: usosustentável na construção civil. (inPortuguese). IPT, 99 p

Streszczenie: *Upcykling metodą smart design powystawowych paneli ekspozycyjnych jako wsparcie rozwoju zrównoważonego gospodarki obiegu zamkniętego w przemyśle drzewnym*. Gospodarka przekształca się obecnie z gospodarki liniowej w gospodarkę o obiegu zamkniętym. Jest to coraz bardziej wspierane przez politykę, ustawodawstwo, przemysł i środowisko akademickie. Gospodarka o obiegu zamkniętym oznacza bardziej efektywne zarządzanie odnawialnymi zasobami naturalnymi, co ma wpływ na biogospodarkę przedsiębiorstw, zgodnie z celami zrównoważonego rozwoju zawartymi w Agendzie 2030 Organizacji Narodów Zjednoczonych. Nasze badanie przyczynia się do wypełnienia luki badawczej, starając się odpowiedzieć na kilka pytań: W jaki sposób można wykorzystać pozostałości poprodukcyjne do poprawy bioekonomii firmy? Czy mogą one przynosić zyski firmie, jednocześnie oszczędzając naturalne drewno? Czy upcykling z wykorzystaniem smart desig jest pomocnym rozwiązaniem w zakresie oszczędności materiałów i kosztów w biogospodarce? Wyniki naszego badania maja dwa aspekty. Z perspektywy projektowej pokazujemy kreatywne możliwości upcyklingu pozostałości produkcyjnych. W przypadku modeli biznesowych udoskonalamy konceptualizację zrównoważonej biogospodarki o obiegu zamkniętym dla MŚP poprzez zysk uzyskany z takiego rozwiązania produktowego. Na podstawie naszych badań przedstawiamy wnioski i sugestie dla małych i średnich przedsiębiorstw, naukowców, projektantów i technologów, aby pomóc przemysłowi meblarskiemu w przejściu od gospodarki liniowej do zrównoważonej gospodarki o obiegu zamkniętym. Promuje to rentowność i rozwój firmy oraz pomaga oszczędzać naturalne drewno.

Corresponding author:
Małgorzata Grotowska
Warsaw University of Life Sciences– SGGW
Institute of Wood Sciences and Furniture
Department of Technology and Entrepreneurship in Wood Industry
Nowoursynowska St. 159
02-776 Warsaw
Poland
Okoń Parkiety, Poland
malgorzata_grotowska@sggw.edu.pl