

Selected Challenges of Closed-Loop Economy in the Furniture Industry

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Abstract: *Selected Challenges of Closed-Loop Economy in the Furniture Industry.* In this work, the subject matter of the reutilization of wood and other wood-derived materials in the field of carpentry was addressed. To begin with, particular emphasis was placed on elucidating the definitions of upcycling. Additionally, a comparative analysis was conducted, juxtaposing the aforementioned upcycling process with the practice commonly referred to as downcycling. Subsequently, an exposition was presented regarding the concept of a closed-loop economy, alongside an exploration of the legal frameworks governing the reuse of waste materials. The final section of the study delved into the intricacies surrounding recycling within the realm of furniture manufacturing, encompassing a comprehensive elucidation of wood biomass and its subsequent utilization, followed by a focused examination of the potentialities offered through the repurposing of, for instance, antiquated furniture items.

Keywords: recycling, upcycling, reuse, circular economy, furniture making

INTRODUCTION

The awakening of the ecological movement and the circumstances necessitate that companies and countries begin to change their business models and operations for the survival of the planet. Both production and consumption contribute to emissions, pollution, and resource scarcity. Among various stakeholders, there is a growing enthusiasm for exploring new ways of consumption and production. Some research streams focus on sustainable production and consumption, which can be achieved through the adoption of new circular business models and product-service systems where businesses shift to providing services and access to products instead of selling physical goods. Other research focuses on innovations related to new materials, specifically how materials can be easily decomposed and biodegradable, as part of transitioning towards a more sustainable and circular industry.

However, sustainable production, consumption, and closed-loop business models have not yet become the norm. The current state of the industry reveals an increase in annual resource consumption. Consumers demanding change and political decisions, such as government engagement in legal and regulatory changes, are driving forces behind sustainable business model transformation. Government regulations in the form of taxes and legal standards that promote environmental improvement are one of the driving forces of sustainable business model change. In an effort to bring about change, the United Nations introduced the 2030 Agenda for Sustainable Development in 2015, consisting of the Sustainable Development Goals (SDGs), a framework of 17 major goals to be pursued or considered by society in order to sustain the planet and its resources for future generations. Furthermore, all these goals aim to achieve sustainable development on three levels: planet, people, and profit, also known as the triple bottom line. This represents a significant step by governments towards regulation for achieving a sustainable society and currently acts as a driving force for business change.

Literature indicates the importance of common standards and terminology to enable the implementation of more sustainable closed-loop business practices. Additionally, standards can provide verification of corporate sustainability efforts in the form of certifications and

demonstrate a company's involvement in various stakeholder coalitions working towards sustainable development. The existence of standards is crucial for all industries to maintain the chance of quality control, which will guide actions in the right direction, fulfilling their aspects.

The aim of this study (defined research problem) was to analyze the potential for optimizing the utilization of materials used in the furniture industry based on available literature data, and to design various scenarios for upcycling materials within the context of closed-loop economy principles.

MATERIAL REUSE

Characterization of the concept of recycling

The most well-known definition of recycling is: "Recovery, by means of which waste materials are reprocessed into products, materials, or substances for their original purpose or other purposes; this includes the recycling of organic material (organic recycling), but does not encompass energy recovery or the processing of materials into fuels or for backfilling purposes." [<https://stat.gov.pl/metainformacje/slownik-pojec/pojecia-stosowane-w-statystyce-publicznej/1182,pojecie.html> -ustawa z dnia 14 grudnia 2012 r. o odpadach]. Resource utilization, process efficiency, and its consequences are inseparably linked to waste generation and management. Recycling is the most preferred method of waste management when waste prevention or preparing for reuse is not feasible [<https://naszesmieci.mos.gov.pl/materialy/artykuly/144-jakie-odpady-do-recyklingu>]. Through recycling, waste can be reused to create raw materials or materials with the same or different purposes. For example, product packaging that becomes waste can be reused to avoid environmental pollution and maintain balance in the ecosystem. Common resources that can be obtained from waste include paper, plastic, glass, metal, and organic waste. The goal of recycling is to reduce the consumption of natural resources and the generation of new waste.

Characterization of the concept of upcycling

Most articles found in the materials science field defined upcycling as a way of recycling, recovering materials and products, or as an enhanced form of recycling. The second most common definition in materials science is that upcycling involves returning materials to their initial state. Another closely related definition associates upcycling with adding value to materials or products that no longer serve any purpose. The concept of added value is often closely related to improving quality and creating new products from residual materials, as depicted in other definitions of upcycling. Finally, the last definition describes upcycling as the use of discarded materials as reinforcement in new products [Coelho 2011].

From the definition, upcycling refers to the recycling or reusing of something in a way that increases the value of the original object. In other words, upcycling involves taking something old and creating something new. The best way to understand upcycling is by comparing it to downcycling. Both are types of recycling. Downcycling is the type of recycling that is commonly thought of, such as recycling paper or plastic. These materials are broken down and reused to create a product that is considered less valuable than the original. For example, most waste paper, like old newspapers, is considered lower-quality paper. Upcycling is the same process of reusing old materials, but it creates something of higher value or quality. Examples of upcycling include using materials from plastic bottles to make new shoes or using reclaimed wood to produce high-quality furniture. Fundamentally, the difference between downcycling and upcycling lies in the fact that downcycling creates a lower-quality version of

the same thing, while upcycling transforms old materials into a new, different high-quality product [Saiter et al., 2011].

Upcycling also supports a closed-loop economy. A closed-loop economy is a system in which goods are used and reused multiple times rather than discarded after a single use. This system is more sustainable as it relies on utilizing what we already have rather than continually creating new products from new materials.

Products in the furniture industry from recycling and upcycling

Under the concept of wood waste, biomass is understood as the byproduct of wood processing in various stages of production. Wood waste and losses occur throughout the wood processing stages, influenced by natural factors such as shape and size inconsistencies with the final product parameters.

Wood waste can be categorized as follows (<https://enerad.pl/aktualnosci/biomasa-w-polsce-wykorzystanie-i-rola/>):

1. Sawmill waste (sawdust, wood chips, shavings), is primarily used in panel production, pellet production, briquette production, etc.
2. Wood obtained from green areas maintenance in parks, forest parks, along railways, etc., is mainly utilized by regional municipal power plants and heating plants as fuel chips, as well as in agriculture and industry, for example, as bedding material ("old wood").
3. Industrial wood waste and used wood products: pallets, furniture, old railway sleepers and posts, formwork, packaging, wood waste from construction works, etc.

In developed countries like Finland, Sweden, Germany, Canada, the USA, etc., wood biomass is not considered waste. On the contrary, wood biomass is seen as a related material that can be used to generate useful products. This approach not only reduces collection costs but also generates additional revenue for companies.

As demonstrated, recycling wood waste has the potential to transform waste into high-value-added products that have market demand. Waste-free production can be implemented in both large wood and wood processing companies, as well as small and medium-sized enterprises specializing in the collection and processing of wood waste [Yakovleva et al., 2021].

Analysis of Upcycled Products

Upcycling is one of the preferred options as it only requires the creativity of individuals, with or without professional knowledge. Unlike recycling, which involves breaking down an object to create something new, upcycling combines reuse, reduction, and recycling while enhancing the unwanted item, preserving its original form and history. However, this effort is often not undertaken by individuals. The term "upcycling" emerged in the 1990s. Upcycling includes the simple act of improving an unwanted item through personal creativity, without requiring professional skills as in recycling. Recycling involves the breakdown of objects like plastics and paper, which can be transformed into new items of varying value.

Within the popular trend of ecological and nature-inspired design based on recycling, there is a noticeable direction known as wood upcycling. Furniture and interior elements are

crafted from wood previously used in other products. This trend primarily focuses on the handmade creation of unique products, but the popularity of such items has transformed "reclaimed" wood materials into a semi-industrial scale raw material.

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CIRCULAR ECONOMY

Closed Loop Economy - Concept Overview

"A closed loop economy is an economic model where no waste is created; everything is shared, repaired, reused, or recycled. What would traditionally be considered 'waste' instead becomes a valuable resource for creating something new" [Stahel 2019].

The closed-loop economy is essentially the result of the collaboration between various businesses within the closed-loop supply chain. It requires a reimagining of how products (and packaging) are designed, produced, sold, repaired, and recycled. Currently, most companies operate within a linear economy model, where resources are extracted, delivered to manufacturers for product design and creation, consumed, and then discarded by other companies or individuals. The majority of the material is wasted, with only a small amount being saved. This process repeats itself if there is access to more resources.

Large consumer goods companies are beginning to realize that by developing closed-loop supply chains, they can lower production costs and provide consumers with more sustainable products. Additionally, governments acknowledge how local recycling and closed-loop economies reduce municipal waste budgets, generate revenue, and stimulate the creation of local jobs.

Sustainable Development - Basic Assumptions

The idea of sustainable development is well-captured in the statement from the World Commission on Environment and Development's 1987 report "Our Common Future": "Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [<https://www.gov.pl/web/rozwoj-technologie/zrownowazony-rozwoj>]

According to G.H. Brundtland's proposal, sustainable development is "development that allows for meeting current needs without the concern that the needs of future generations will not be met." Achieving this goal requires joint actions from international institutions, individual governments, businesses, and consumers to ensure that economic growth is not solely linked to rapid and uncontrolled consumption of non-renewable resources but also improves the quality of human life in times of resource depletion [Brzustewicz 2013].

Sustainable development is increasingly discussed in various aspects of life. An example is sustainable construction, which is frequently mentioned nowadays. There are numerous environmental, economic, and practical reasons to promote workplace recycling and strive for environmentally sustainable construction. Construction and demolition waste recycling is one of the most visible commitments a developer can make towards sustainable

construction, visible to every worker on-site and passerby [Lennon 2005], e.g., recycling construction and demolition debris, which always poses challenges in this sector.

Another significant issue is the forestry-wood sector, which can be addressed through the implementation of the cascading use of wood and the 4R principle (Reduce, Reuse, Recycle, Recover). In this sector, wood waste, which can be a valuable resource, is generated during production processes (from wood harvesting to wood-based material processing and final product manufacturing) and during the consumption phase when the product's lifespan ends [Ratajczak et al. 2017].

Product Life Cycle

The term "product life cycle" refers to the time span from when a product is introduced to the market for consumers to when it is removed from store shelves. This concept is utilized by management and marketing professionals as a decisive factor for determining when to increase advertising, lower prices, enter new markets or redesign packaging. The process of planning continuous support and maintenance of a product is called product life cycle management [Stahel 2019].

The product life cycle consists of six phases: product concept phase, project concept phase, product design phase, design verification phase, production phase, and end-of-life phase. Reliability engineering is an effort carried out simultaneously in each of these six phases of the product life cycle. Risk mitigation is a process.

Legal aspects regarding waste and its reuse

The legal aspects related to waste and its reuse are based on the Waste Act of December 14, 2012 (Journal of Laws of 2013, item 21), which requires waste management plans to be updated at least once every 6 years. The Waste Act also aligns with the waste hierarchy established in Directive 2008/98/EC, which prioritizes waste prevention, preparation for reuse, recycling, other recovery operations, and disposal.

The Waste Management Plan for 2022 (KPGO 2022) is part of strategic documents adopted at the EU and national levels. It complies with the EU legislation on waste management and addresses tasks such as protecting the environment and human health, increasing efforts to combat pollution and reduce marine waste, improving waste prevention and management in the EU, transforming waste into resources, limiting energy recovery for non-recyclable materials, phasing out landfills suitable for recycling or recovery, and ensuring high-quality recycling without negative environmental or health effects.

KPGO 2022 incorporates regulations and requirements derived from various EU directives, including those on environmental protection, packaging and packaging waste, landfilling, end-of-life vehicles, waste from extractive industries, and batteries. The Waste Directive 2008/98/EC is a key EU legislation aiming to create a recycling society that avoids waste generation and utilizes waste as a resource.

The National Waste Prevention Program, which was adopted in 2014 and subsequently integrated into KPGO 2022, focuses on breaking the link between economic growth and environmentally impacting waste generation.

In summary, the important legal aspects concerning waste and its reuse include the Waste Act, the waste hierarchy, the Waste Management Plan, EU directives on waste management, and the goal of creating a recycling society while preventing waste generation.

RECYCLING IN THE FURNITURE INDUSTRY

Wood biomass

Woody biomass has been defined as a potential resource for improvement through thermochemical or chemical processes. Thermochemical processing of woody biomass is preferred over other biomass sources. This renewable resource has certain advantages related to easy handling, high energy content, and relatively high fixed carbon content [<https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52004DC0038>].

Lignin is considered the most important renewable source of aromatics worldwide. Furthermore, this biopolymer can be transformed into a range of value-added products (e.g., vanillin, benzene, toluene, xylenes, quinones, and eugenol) that can be used in the chemical, pharmaceutical, cosmetic, and textile industries. Lignin isolation can be carried out through various methods such as mechanical, chemical, physical, and enzymatic. However, the most common methods used at the industrial level involve the use of chemical agents. The extracted lignins can be divided into sulfonated lignins and sulfite-free lignins, depending on the chemical agents used for lignin isolation [Fresner 1998].

Recycling of old wooden furniture

Currently, the circulation of used furniture in the market can be broadly divided into three categories: traditional solid wood furniture, removable structural furniture, and furniture made from various materials. Traditional solid wood furniture primarily includes mortise and tenon construction, which is the most valuable furniture sold as a single piece. Currently, this type of furniture is just beginning to enter the secondary market for further resale and uptake. Removable structural furniture mainly consists of panel furniture, which is easy to produce, sell, dismantle, and assemble. This type of furniture aligns with the currently promoted concept and popular trend and is easy to reproduce after recycling. It is characterized by a high degree of reuse. Furniture made from mixed materials is primarily designed and manufactured in combination with other materials such as metal, resin, glass, etc., and is not suitable for separation. Such furniture has a high processing cost and may pose difficulties and hazards during processing [Galka 2005].

Discarded furniture leads to resource waste and can cause environmental pollution. Furniture entering the secondary market is inexpensive, mainly attracting renters or those with temporary needs, such as for filming purposes, etc. Many products accumulate dust, and the entire market is gradually being ignored. However, burning used furniture as fuel would cause serious environmental pollution. Thus, a new social problem has emerged on how to deal with the issues arising from the current consumption pattern and how to make this vast resource suitable for reuse.

Currently, recycling primarily involves used furniture substrates and utilizes four main methods: energy utilization, refurbishment and restoration, recycling, and other specialized approaches. Energy utilization refers to its direct use as fuel or processing into new fuels, such as the production and utilization of charcoal. Refurbishment and restoration involve its reuse

after simple repairs or mechanical treatments. This method allows for the continued use of good furniture after decontamination, repair, and other procedures. Similarly, it can be used to reduce and thin out large, heavy furniture materials so that they can still be used. Additionally, they can be processed into specific board specifications and reused in furniture production.

Recycling refers to the classification of waste wood substrates, their decomposition or crushing into chips, wood fibers, etc., followed by further processing into particle boards, fiberboards, and other artificial boards for use in various furniture production processes. In the field of wood processing, wood-plastic composite materials have been produced and processed. Discarded wooden furniture can also realize its intrinsic value through this approach. Other specialized methods include the production of controlled-release fertilizer shells from wood residues, which can regulate the rate of fertilizer release, and the production of crude wood vinegar, which has bactericidal and antibacterial properties and can be used in agriculture, fisheries, and other aquaculture production [Kotovicová and Božek 2004].

Drawing on the perspective of contemporary design, the author analyzes the degree of wood damage resulting from recycling and classifies and compares used wooden furniture based on their properties, colour, modelling, etc., primarily reflecting aesthetic and functional aspects. By transforming simple reuse into a systematic product design based on waste substrates, the recycling design of discarded wooden furniture creates a specific system compared to sporadic and independent approaches [Rocha et al., 2020].

One of the key factors influencing the utilization of wood waste in the current market is its acceptance by society. Therefore, meeting the various requirements of different consumers regarding the texture, colour, and shape of recycled products needs to align with the level of acceptance among current users. Additionally, other factors such as ergonomics and psychological design considerations, particularly in terms of functional implementation of recycled wooden furniture, should be taken into account [Rocha et al., 2020].

The interaction between people and furniture often carries emotional interpretations. Discarded wooden furniture usually has a certain "connection" with the user, preserving a certain amount of emotional attachment. This emotional connection is strongest with the original furniture, and in the era of consumption, nostalgia has become one of the most emotionally sensitive responses to consumer content. To increase potential demand, markets should pay attention to the emotional resonance that can be found in a product. Moreover, value-added design can be personalized for users by introducing innovations and reimagining discarded furniture according to user needs, preserving memories from the past and compensating for emotional regrets [Rocha et al., 2020].

Technology and design complement each other, allowing for the full utilization of different properties of materials derived from recycling used wooden furniture, including wood-plastic composites and laminated technology. This, combined with current consumer demand and cognitive research findings, enables various degrees of integration and reconstruction to meet the preferences of different groups of people and introduce new concepts of life and cultural connotations. Thus, technology and design collaborate in the realm of eco-friendly products to realize the added value of innovation and reuse of discarded wooden furniture in the ecological era [Kazancoglu et al., 2021].

Young people highly appreciate innovation and the reconstruction of used furniture, highlighting the need for attention to numerous innovations in appearance, design, and

functionality. Middle-aged and older age groups focus on practicality and emotional preservation, avoiding additional value through additional decoration and painting. Therefore, market research and positioning based on consumer groups, dividing them into multi-level user groups, are necessary to understand the preferences of different users in various aspects, such as expanding product recognition groups and consumer groups and extending the service life cycle with added value [Ormazabal et al., 2016].

Based on the required concept, function, style, etc., key elements of the design should be extracted to break the limitations of the original modelling, reorganize different types of furniture elements, emphasize the theme of redesign, and ensure serialization and richness. Additionally, wood-plastic composites, lamination, and other panel production technologies contribute to the recycling of discarded wooden furniture, fostering innovation and modernization by creating furniture with better design and production parameters compared to wood, presenting a new style while reducing maintenance costs in the later stages [Araujo et al., 2018].

Recycled used wooden furniture encompasses a wide range of base materials that can be targeted to retain their own colour or undergo appropriate colour treatment to highlight the texture of the used wood. Furthermore, colour can be added to the original substrate through coating, decorative paper reconstruction, etc. [Kazancoglu et al., 2021].

Multiple fusion in the form of used wooden furniture as the primary material, incorporating other materials such as metal, glass, stone, etc., serves to break the "old" and enrich the decorative effect and structural durability.

Waste as Artistic Creations

It is worth noting that artists are fascinated by waste, seeing in it more than just rubbish but the potential to create something new. The precursor to art utilizing waste was the concept of found objects (French: objets trouvés), which gained popularity during the Dadaist movement [Izdebska 2017].

The primary objective is to use unconventional artistic methods to create artwork from waste rather than traditional materials, utilizing readily available resources. Therefore, the ultimate fate of objects does not have to be the trash bin; they are given new lives. Re-design and upcycling worldwide align with pro-ecological trends, reflecting the growing societal awareness of environmental threats [Izdebska 2017]. Various types of waste items can be repurposed to create functional spaces. For instance, wooden pallets can be transformed into beds, tables, swings, shelves, or benches, distinguishing them from mass-produced products. It all depends on the designer's creativity and ideas.

SUMMARY

With improving living standards and the diverse aspirations of individuals, the disposal of furniture has been replaced by more popular and innovative products, leading to an increasing amount of discarded wooden furniture each year. Wood is an important material in furniture production.

Research has shown that utilizing 100% waste wood is more sustainable, and recycling, as the final stage of the product life cycle, must play a crucial role. In Europe, recycling wood

from products to improve the utilization of forest biomass is considered one of the key strategic goals and research areas. Every year, 35 to 40 million tons of wood waste reach the end of their useful life throughout Europe.

Furniture, being durable goods, can last for centuries with proper care, and their disposal is not fully explained by wear and decay. Extending the lifespan of products primarily involves durability, repairability, material modularity, etc., while the influence of lifestyle habits, family structure, and emotional attachment to products remains largely hidden, posing a significant challenge.

Through a review of relevant literature, the author found that regeneration has developed in various industries. It fosters innovation to some extent and has the potential to expand markets and increase profits. In the production and design of furniture, sustainable design concepts and the life cycle design of office furniture are widely applied, indicating that applying the principles of a circular economy to refurbishing and upgrading used furniture contributes to the creation of new businesses and enhances the adaptive capabilities of products. In this sector, opportunities associated with the circular economy model are mostly related to eco-design, the use of renewable materials, emission reduction, and the utilization of environmental certifications.

In recent years, many researchers have also focused on recycling and reprocessing wood waste to fully utilize and realize value-added products. For example, recycling wood waste for the production of wood-based panels and sawdust for thermoplasticity through the benzoin process. Exploring the possibilities of regenerating wooden furniture not only addresses resource gaps and reduces waste but also contributes to building national ecological awareness.

One possible scenario could involve utilizing waste elements generated by carpenters and furniture companies, such as creating plywood patterns from waste that can be used to create new boards or as decorative elements for furniture. Another scenario could be the establishment of a system for companies that allows for the collection of all old furniture and the creation of new ones with different designs or applications. They don't have to be composed of the same elements. The system would involve collecting old furniture, materials, and panels that are discarded or given away for free by owners in good condition and suitable for reuse. The company would process the material and reuse it to create new furniture with a unique appearance, which would be divided into three segments: standard, luxury, and premium, allowing everyone to choose something according to their budget for furniture purchases. Another example is the use of plastics that can be used for 3D printing. Plastic materials, such as plastic bottles, can be used to create filament and print furniture using a 3D printer. The filament for 3D printing is created through the extrusion process. Melted plastic is fed through a small opening called a die to create filament, which is then cooled and wound onto a spool [<https://3d.edu.pl/system-recyklingu-butelek-pet-petalot-blizsze-spojrzzenie/>]. The Ocke series is a set of 3D-printed furniture, consisting of a chair and a sofa. Both the chair and the sofa were designed by Beatrice Müller, an industrial designer at BigRep. BigRep is a German company specializing in large-scale FDM 3D printers [<https://3d.edu.pl/meble-drukowane-w-3d-stan-techniki-w-2020-r/>]. 3D printing,

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Streszczenie: *Wybrane problemy gospodarki o obiegu zamkniętym w meblarstwie.* W pracy poruszono zagadnienia związane z ponownym wykorzystaniem drewna i innych materiałów drewnopochodnych w drzewnictwie. Na wstępie zwrócono uwagę na definicje upcydlingu. Dokonane jest także jego porównanie z procesem określanym jako downcycling. Kolejno przedstawiono czym jest gospodarka z obiegiem zamkniętym, a także jakie są uwarunkowania prawne ponownego wykorzystania odpadów. Rozdział ostatni porusza zagadnienia związane z recyklingiem w meblarstwie - przedstawiono czym jest biomasa drzewna i w jaki sposób się ją wykorzystuje, następnie skupiono się na możliwościach, jakie daje ponowne wykorzystanie np. starych mebli.

Słowa kluczowe: recycling, upcycling, ponowne wykorzystanie, gospodarka z obiegiem zamkniętym, meblarstwo

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