ANALYSIS OF THE DEVELOPMENT OF MATERIALS AND TECHNOLOGIES USED IN THE PRODUCTION OF ICONIC SINGLE-SEATING INTERIOR PIECES FROM THE EARLY 20TH CENTURY TO THE PRESENT

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Abstract
This article examines the role of materials and technologies in product design, focusing on iconic chairs from the early 20th century to the present. It explores the impact of ground-breaking materials, such as bent steel and plastics, on aesthetics, ergonomics, and industrial production transformations. The analysis extends beyond the design, highlighting the application of traditional and modern materials. The article traces historical milestones where design responded to emerging technological possibilities. Additionally, it investigates current challenges designers face in addressing sustainability and resource efficiency. The concluding section emphasizes how these factors increasingly shape not only the aesthetic but also the functional and ethical dimensions of contemporary design, with potential implications for its future evolution.

Keywords: interior, design, chair, armchair, materials, plastic, steel, leather, plywood, aluminium

INTRODUCTION
The turn of the 19th and 20th centuries in product and interior design was characterized more by nostalgia than by embracing the new opportunities brought by the Industrial Revolution. Although the Art Nouveau (Belle Époque) style was historically inspired, it began incorporating machinery and modern materials, such as iron and steel in architecture and new chemical compounds in glass and ceramics production [1].

The early 20th century brought revolutionary changes in furniture design, enabled by new materials and production technologies. Chairs and armchairs played a pivotal role in shaping the modern interior design aesthetic. The introduction of tubular steel, molded plywood, and plastics profoundly influenced seating furniture design, particularly the shift from craft-based to mass production [1].

Today, over a century of intense development in these products has been shaped by innovations in materials and technologies. These changes have reflected the spirit of their respective eras and addressed their challenges and priorities, such as creating the Navy Chair during World War II for the US Navy [2].

This article focuses on how new materials and technologies have influenced the design of iconic single-seating pieces and their societal and aesthetic impacts across different periods. Often, the most ground-breaking transformations occur during crises. For example, chromium, initially used in projectile heads during World War I, was later employed in Functionalist furniture for finishing bent tubular steel. Similarly, polyethylene, developed as insulation for electrical cables, found applications in furniture design among traditional materials like metal and rubber, which were in short supply [1].

The present era represents another turning point. On one hand, traditional materials are well understood but often environmentally unsustainable. On the other hand, emerging materials and technologies offer novel ways to adapt or improve existing resources. Based on the analysis of a selected group of iconic seating pieces, this article maps the current state and future possibilities.

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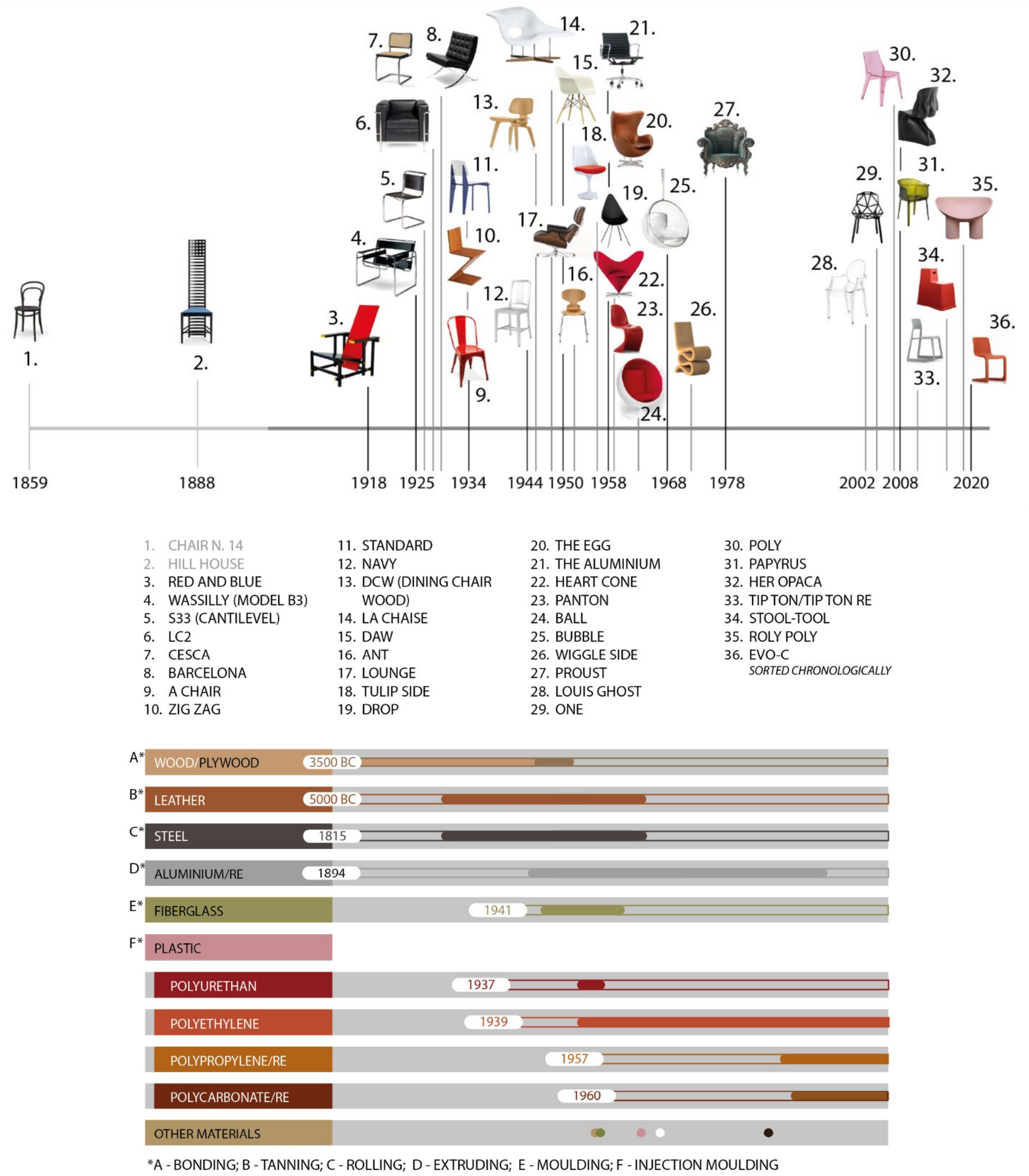
Research Questions:

1. How has the development of materials and manufacturing technologies influenced the design of iconic single-seating furniture in the 20th century?
2. What key material and technological innovations have shaped contemporary furniture design?
3. How has the focus on sustainability and environmental responsibility impacted the evolution of modern seating furniture?

METHODOLOGY

This study employs a qualitative research methodology based on primary and secondary sources, including historical records and specialized design and materials engineering literature.

Iconic single-seating pieces, such as the *Barcelona Chair* by Ludwig Mies van der Rohe, the *Eames Lounge Chair* by Ray and Charles Eames, the *Panton Chair* by Verner Panton, and the *Louis Ghost Chair* by Philippe Starck, were selected for analysis [11][20][26][31]. A historical timeline was compiled for these iconic products (Fig. 1). The timeline highlights



1: *Timeline of iconic seating elements and materials used for them [4–39][40, 41, 45, 50, 52, 58–62, 66–68]* the primary materials used, which are subsequently examined in terms of their material composition, manufacturing techniques, and design aesthetics. The analysis also incorporates the approach of contemporary designers and reviews literature focusing on sustainable design practices.

Five representative material groups (plus related materials) for seating furniture were selected (for their historical significance and innovations in materials and manufacturing technologies. The selection criteria included design iconicity, material innovation, technological advancements, influence on design history, and application in modern interiors.

These groups were analyzed regarding the materials used, production processes, and design philosophy. The analytical parameters included material composition, manufacturing technology, aesthetics and design philosophy, sustainability, historical impact, and relevance.

RESULTS

Wood, a foundational material, was succeeded by molded plywood in the mid-20th century.

The Finnish architect and designer Alvar Aalto pioneered using bent plywood, creating iconic furniture pieces in the 1930s. Following the war, Charles and Ray Eames designed a collection of plywood furniture—the *Plywood Group*—which achieved mass production. (In contrast to these simple forms, the upholstered *Lounge Chair*, which design theorist Zdeno Kolesár likened to a sculptural work, was later introduced.) These designers experimented with the spatial shaping of plywood through pressing techniques to create comfortable, ergonomic, lightweight, and durable forms [1][40].

Plywood became a favored material due to its strength, flexibility, and ease of processing. An additional advantage is its relatively low manufacturing cost, facilitating broader industrial furniture production [40].

Plywood chairs have a relatively low carbon footprint compared to materials such as metal or plastic, mainly when made from certified wood (eliminating risks associated with unsustainable resource extraction) and eco-friendly adhesives (as conventional adhesives often contain harmful substances) [40].

Early 20th Century: Steel Tubes and Modernism

The introduction of tubular steel in furniture design at the beginning of the 20th century revolutionized seating furniture. Dutch architect Mart Stam created the concept of the metal two-legged chair (*S33*) [8][1]. Alongside Stam, Ludwig Mies van der Rohe *(Barcelona Chair)* and Marcel Breuer (*Cesca*) explored tubular steel construction. Their designs represented a modernist ideal of “form follows function” [9][11].

In 1925, Marcel Breuer created the iconic Wassily Chair (*B3*), one of the first chairs to feature chrome-plated tubular steel [7]. Inspired by bicycle frames, Breuer experimented with bending steel tubing to produce lightweight, structurally strong, and industrially manufacturable furniture pieces [1][49]. Tubular steel utilization introduced elegance and lightness, contrasting the heavy, traditional wooden furniture of the time [1].

While steel is a non-renewable material, it is the most recycled industrial material globally. Annually, up to 630 million tonnes of steel re-enter the supply chain, with typical recycling rates ranging from 70% to over 90% [46][47]. Recycling chrome-plated materials, however, is more challenging due to removing the chemical coating, which requires additional energy-intensive processes. To enhance sustainability, emphasis should be placed on green energy sources, recycled materials, surface treatment innovations, and efficient recycling at the end of the product lifecycle [48].

Elegance and Quality of Leather

Leather is one of the oldest materials processed by mankind, together with stone and wood. People have extensive historical experience with leather and excellent knowledge of its material characteristics [41]. It remains unrivaled as an upholstery material, offering exceptional durability, adaptability to body temperature, and resistance to staining. Over time, leather develops a patina, becoming more aesthetically pleasing as it ages.

Although leather is a renewable material, its production is associated with significant environmental and ethical challenges, such as greenhouse gas emissions and biodiversity loss linked to livestock farming. Additionally, tanning and dyeing processes often involve harmful chemicals that harm ecosystems. Companies are now exploring alternative plant-based processes to mitigate these impacts [41][42][43].

There is a growing effort to replace leather with alternative materials, such as mycelium-based products [44]. However, due to entrenched consumer expectations, these substitutes often fail to replicate the full range of leather's desirable properties.

Aluminium and Recycled Aluminium

Aluminum is widely used in product design due to its low weight and favorable mechanical characteristics. While non-renewable, aluminum is fully recyclable without quality loss, with approximately 40% of global aluminum currently recycled [53]. However, primary aluminum production is energy-intensive, accounting for 2% of global human-induced emissions. It also generates toxic by-products and pollution during the chemical processing of bauxite [54][55].

Due to high demand and the long lifespan of many aluminium products, the volume of primary aluminium will remain significantly larger than that of recycled aluminium in the foreseeable future [56].

Plastics and the Post-War Era

Alongside moulded plywood, plastics began showcasing their potential. Derived from non-renewable fossil sources, early plastics like Bakelite were introduced [57]. Injection moulding technology propelled plastics into prominence, enabling designers like Verner Panton to create fluid, organic shapes, exemplified by the *Panton Chair*. These new materials catered to the post-war consumer culture, prioritizing comfort, accessibility, and innovation [1].

In the United States, furniture manufacturers Herman Miller and Knoll spearheaded the adoption of plastics in furniture production [1]. Various plastics are used in the furniture industry, including PVC, polyester, and polyethylene. For this analysis, polyethylene (PE) was selected, as it has been a key material in furniture manufacturing since the latter half of the 20th century, notably in components such as glides and guide rails, exemplified by the glides of the *TipTon Chair* [36].

The production of plastics has surged significantly, from 100 million tonnes annually in the early 1990s to 390 million tonnes in 2021, primarily driven by their use in packaging [64].

Furniture companies are now exploring innovative approaches to plastic use and recycled material options. For instance, Vitra employs long-lasting virgin plastics (e.g., the *EVO-C Chair*) as well as recycled variants (e.g., the *Eames Plastic Chair RE*). Vitra avoids practices like those of Kartell, which incorporates additives like finely milled wood chips into recycled plastics, rendering further recycling impossible and ending the material's lifecycle. Instead, Vitra uses technical fillers such as glass fibers. All recycled plastics used by Vitra can be 100% recycled at the end of the product's life [65][69].

SUMMARY

This study analysed the material characteristics and manufacturing technologies employed in the 20th century, examining their impact on product design. The materials selected for this analysis were evaluated based on several key criteria: recyclability, depletion of primary resources, energy intensity of production, processability, and future potential (Fig. 2). The assessment was conducted using a 1–3 scale, where 1 represents a low value, while 3 indicates a high value.

The findings provide a comprehensive insight into how material and technological innovations influenced the design of iconic single-seating furniture pieces in the 20th century. They also highlight the environmental sustainability of contemporary design using these materials and technologies. The evolution of these innovations significantly shaped aesthetics, manufacturing processes, and sustainability in the global context of furniture design. Leading designers of their time successfully integrated these changes into their creations, inspiring subsequent generations of designers and manufacturers.

The study emphasizes that the environmental impact of furniture design is closely linked to material selection and technological processes. Achieving genuine sustainability requires re-evaluating traditional and modern materials and optimizing their life cycles.

For designers who traditionally prioritized furniture's visual and functional aspects, this entails a shift towards careful aesthetic consideration and a deeper understanding of the environmental impacts associated with material choices. Sustainability must be embedded from the beginning of the design process, necessitating close collaboration between designers, material specialists, and environmental experts.

DISCUSSION

Selected iconic furniture pieces represent specific time periods and aesthetic movements, but do not encompass the full breadth of material and technological innovations in furniture design. Another limitation is that some environmental and

	recyclability	threats to primary raw materials	energy requirements for production	shaping energy	the potential for future use
WOOD	●●●	●●	●	●	●●
PLYWOOD	●●	●●	●●	●	●●
LEATHER	●	●●	●	●	●
STEEL	●●●	●	●●	●●	●●●
ALUMINIUM	●●●	●●	●●●	●●	●●
RE ALUMINUM	●●●	●	●●	●●	●●●
POLYETHYLENE	●●●	●●	●○	●	●●
RE POLYETHYLENE	●●	●●	●	●	●●●

● Low value
●● Average value
●●● High value

2: *Parameters of selected used materials [40, 41, 45, 50, 51, 58, 59, 62, 63, 77–83]* technological data were obtained from secondary sources, which may impact the accuracy and timeliness of the findings.

The analysis showed that materials with low energy processing requirements, particularly those from sustainable sources such as certified forests (FSC, PEFC, EUTR) and recycled material, ranked highest. The study suggests gradually replacing certain traditional materials, such as reducing the use of leather and virgin plastic. Sustainable alternatives include materials with a lower environmental impact, such as substituting MDF with carbon-negative materials like HONEXT [70].

Despite efforts to reduce its use, plastic remains the most suitable material for industrial furniture production, and it has been utilized extensively since the 1960s with increasing intensity. The projected compound annual growth rate (CAGR). for plastic furniture sales from 2023 to 2033 is 5.9% [71]. However, excessive use of plastics, including furniture, results in "spread" of microplastics within the environment, impacting human health. While their presence and potential risks have been confirmed, the exact exposure from furniture contact or inhalation in indoor environments remains unclear. Little is known about which chemicals may adhere to these microplastics and nano-plastics indoors [72][73][76].

These findings underscore the importance for designers and manufacturers of maintaining an updated critical approach to material selection and addressing environmental impacts when creating new products.

Hemp-based materials could be a viable alternative to plastics and wood, offering excellent mechanical features. Hemp requires less water to grow and is harvested in shorter cycles than traditional wood cultivation [74].

Another aspect closely linked to material selection is the manufacturing technologies that vary in energy intensity. Materials with high energy demands during production were rated negatively, with one pathway to improvement being the adoption of renewable energy sources in the manufacturing process [48].

Design can no longer be judged solely on aesthetic grounds; it must incorporate sustainability and ethical considerations in material engineering. In this context, it is essential to design products based on circular economy principles, where product recyclability should be a standard and clear choice, not merely an option.

An innovative approach to the circular economy is demonstrated by Dutch designer Ineke Hans with her deposit-based chair, REX. This model is built on the concept that furniture is often replaced not due to wear but because of a desire for change. Her Circuform project enables customers to return furniture for resale, either in its original form or with replaced components [75].

CONCLUSION

The analysis reveals that the development of materials and manufacturing technologies in single-seating furniture reflects broader trends in design, culture, and technological innovation. From the use of tubular steel in modernist designs to the introduction of molded plywood and the mid-20th-century rise of plastics, each technological breakthrough has enabled designers to push the boundaries of form, comfort, and functionality.

Contemporary technologies now facilitate unconventional designs using single-material constructions that can be easily recycled at the end of their lifecycle. A notable example is the impressive advancements in processing recycled plastics.

The analysis underscores that designers are primarily responsible for improving material usage today. Just as some designers historically shaped new trends, those who adapt their approaches and embrace emerging technologies will lead the way today. The role of the designer continues to evolve. One hundred fifty years ago, Michael Thonet introduced innovations that enabled the mass production of chairs in shorter timeframes. Seventy years ago, Verner Panton sought to realize his visions by pioneering the technologies needed to achieve them. At the end of the 20th century, Bořek Šípek became a designer-artist, defying ergonomic norms with his glass chairs while expanding the creative possibilities of design processes.

Today, Ineke Hans focuses not only on product design but also on the social dimensions of design and architecture, including the processes that accompany them. Contemporary designers must consider the growing potential of new materials and the adoption of more environmentally friendly manufacturing techniques. Trends suggest that the future of the furniture industry will continue to be shaped by technological progress with a strong emphasis on sustainability.

REFERENCES

[1] KOLESÁR, Zdeno; MÁLKOVÁ, Kateřina. 2004. *Kapitoly z dějin designu.* Praha: Vysoká škola umělecko-průmyslová. ISBN 80-868-6303-4

[2] EMECO. 2024. *Emeco for US Navy.* EMECO. [Accessed: 2024-11-04] https://www.emeco.net/about/design/how-it-started-emeco-alcoa-for-us-navy..

[3] RIPPLE, William, J.; WOLF, Christopher; NEWSOME, Thomas M.; BARNARD, Phoebe; MOOMAW, William R., 2020. World Scientists' Warning of a Climate Emergency. Online. *BioScience.* 70(1), 8–12. https://doi.org/10.1093/biosci/biz152

[4] TON. 2024. *Chair n.14* [in Czech: *Židle 14: Nadčasová ikona*] TON [Accessed: 2024-11-04] https://www.ton.eu/zidle-14-nadcasova-ikona

[5] M H FURNITURE HOLDINGS LTD. 2024. *The Hill House Chair.* Iconic Interiors. [Accessed: 2024-11-04] https://www.iconicinteriors.com/designer_furniture/category/chairs/hill_house_chair

[6] M H FURNITURE HOLDINGS LTD. 2024. *The Red and Blue Chair.* Iconic Interiors. [Accessed: 2024-11-04] https://www.iconicinteriors.com/designer_furniture/category/chairs/red_and_blue_chair#photo-1

[7] DESIGNPROPAGANDA. 2024. KNOLL *Wassily Chair* [in Czech: *KNOLL křesla Wassily Chair, přirodní tkanina*]. Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produktv/knoll-kresla-wassily-chair-prirodni-tkanina

[8] CLASSICFACTORY24. 2024. *S33: Cantilever.* ClassicFactory24. [Accessed: 2024-11-04] https://www.classicfactory24.com/en/Chairs/Mart-Stam-Cantilever-Chair-S33.html

[9] BAUHAUS 2 YOUR HOUSE. *Marcel Breuer Cesca Cane Side Chair.* 2024. bauhaus2yourhouse [Accessed: 2024-11-04] https://www.bauhaus2yourhouse.com/products/marcel-breuer-cesca-cane-chair

[10] M H FURNITURE HOLDINGS LTD. 2024. *Le Petit Confort Armchair LC2.* Iconic Interiors. [Accessed: 2024-11-04] https://www.iconicinteriors.com/designer_furniture/category/chairs/le_petit_confort_armchair

[11] DESIGNPROPAGANDA. 2024. *KNOLL Barcelona Chair.* 2024. Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produktv/knoll-kresla-barcelona-chair-kuze-kategorie-y

[12] DESIGNPROPAGANDA. 2024. *TOLIX Chaise A.* Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produkt2/designove-zahradni-zidle-tolix-chaise-a

[13] AMBIENTE DIRECT. 2024. *ZigZag Chair.* Ambiente Direct. [Accessed: 2024-11-04] https://www.ambientedirect.com/en/cassina/zigzag-rietveld-chair_pid_38124.html

[14] DESIGNPROPAGANDA. 2024. *Vitra Standard Chair SP.* 2024. Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produkt/vitra-zidle-standard-chair-sp-designove-zidle/?utm_source=biano.cz&utm_medium=cpc-biano&utm_content=202021579&utm_campaign=biano%2Bjidelni-zidle&utm_term=11ef9a9f-584a-cb70-9b15-4a5703672a53

[15] DESINGBUY. 2024. *EMECO 1006 Navy Chair.* Deingbuy. [Accessed: 2024-11-04] https://www.designbuy.cz/emeco-zidle-1006-navy-chair-matna

[16] DESIGNPROPAGANDA. 2024. *VITRA DCW chair.* Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produkt/vitra-zidle-dcw-designove-zidle

[17] DESIGNPROPAGANDA. 2024. *VITRA La Chaise.* Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produkt2/designova-kresla-vitra-la-chaise

[18] DESIGNVILLE. 2024. *Eames DAW chair.* Designville [Accessed: 2024-11-04] https://www.designville.cz/zidle-eames-daw?gad_source=1

[19] BEUT. 2024. *Fritz Hansen The Ant chair.* Beut. [Accessed: 2024-11-04] https://www.beut.co.uk/fritz-hansen-the-ant-chair-clear-lacquer.html

[20] DESIGNPROPAGANDA. 2024. *Lounge chair & Ottoman.* Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/skupina/vitra-designova-kresla-lounge-chair-ottoman

[21] DSIGNHAUS. 2024. *Tulip Side Chair.* Dsignhaus. [Accessed: 2024-11-04] https://dsignhaus.com/TULIP-SIDE-CHAIR

[22] M H FURNITURE HOLDINGS LTD. 2024. *The Egg Chair.* Iconic Interiors. [Accessed: 2024-11-04] https://www.iconicinteriors.com/designer_furniture/category/chairs/egg_chair

[23] PRUNELLE. 2024. *The Drop Chair.* Prunelle [Accessed: 2024-11-04] https://prunelle.ca/en/products/chaise-drop-chair-arne-jacobsen?variant=23183601223

[24] DESIGNPROPAGANDA. 2024. *VITRA Aluminium Chair EA 117.* Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produkt/vitra-kancelarske-zidle-alu-group-ea-117

[25] VITRA INTERNATIONAL AG. 2024. *Heart Cone Chair.* Vitra. [Accessed: 2024-11-04] https://www.vitra.com/en-cz/product/details/heart-cone-chair

[26] DESIGNPROPAGANDA. 2024. *VITRA Panton Chair.* Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produktv/vitra-designove-zidle-panton-chair-leskla-cervena

[27] M H FURNITURE HOLDINGS LTD. *2024. The Ball Chair.* Iconic Interiors. [Accessed: 2024-11-04] https://www.iconicinteriors.com/designer_furniture/category/chairs/the_ball_chair

[28] MUEBLE DESIGN. 2024. *The Bubble Chair.* Nestmobel. [Accessed: 2024-11-04] https://www.nestmobel.de/cs/start/moderni-kreslo/zavesna-zidle-bubble-chair-vyrobena-z-pruhledneho-akryloveho-plastu

[29] DESIGNPROPAGANDA. 2024. *Vitra Wiggle Side Chair.* Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produkt/vitra-zidle-wiggle-side-chair

[30] DESIGNPROPAGANDA. 2024. *Magis Proust Chair*. Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produkt/designove-zahradni-kresla-magis-kreslo-proust

[31] DESIGNPROPAGANDA. 2024. *Kartell Louis Ghost Chair.* Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produkt/kartell-zidle-louis-ghost-designove-zidle

[32] DESIGNPROPAGANDA. 2024. *Magis Chair One*. 2024. Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produktv/magis-designove-zidle-chair-one-cerna

[33] MUEBLES. 2024. *Poly. Karim Rashid de Bonaldo*. 2024. Muebles. [Accessed: 2024-11-04] https://www.muebles.com/silla-poly-karim-rashid/

[34] DESIGNPROPAGANDA. 2024. *Kartell Papyrus*. Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produkt/kartell-zidle-papyrus-designove-zidle

[35] CASAMANIA. 2024. *Her Matt.* Casamania [Accessed: 2024-11-04] https://www.casamania.it/en/design-furniture/him-her-outdoor-chair/

[36] KONSEPTI. 2024. *TipTon/TipoTonRE*. Konsepti. [Accessed: 2024-11-04] https://www.konsepti.com/tip-ton-re/

[37] DESIGNPROPAGANDA. 2024. *Vitra Stool-Tool*. 2024. Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produkt/vitra-designove-zidle-stool-tool

[38] DESIGNPROPAGANDA. 2024. *DRIADE Roly Poly Armchair*. Designpropaganda. [Accessed: 2024-11-04] https://www.designpropaganda.cz/produkt2/designova-kresla-driade-roly-poly-armchair

[39] BIANO. 2024. *Vitra EVO-C*. Biano. [Accessed: 2024-11-04] https://www.biano.cz/produkt/v/103942225-vitra-designove-zidle-evo-c

[40] APA – THE ENGINEERED WOOD ASSOCIATION. 2024. *History of APA, Plywood, and Engineered Wood.* APA. [Accessed: 2024-11-04] https://www.apawood.org. https://www.apawood.org/apas-history

[41] GILLAN, Kevin; MURRAY, Jason. 2019. *Comprehensive Guide to Leather Repair and Restoration: Leather Repair Training Manual*. Advanced Leather Solutions. [Accessed: 2024-11-04] https://books.google.cz/books?id=SSOsDwAAQBAJ&hl=cs&source=gbs_navlinks_s

[42] VITRA. 2024. *Leather*. Vitra. [Accessed: 2024-11-04] https://www.vitra.com/en-cz/about-vitra/sustainability/leather

[43] VITRA. 2024. *Vegetable-Tanned Leather*. Vitra. [Accessed: 2024-11-04] https://www.vitra.com/en-gb/about-vitra/sustainability/vegetable-tanning

[44] JONES, Mitchell *et al*. 2021. Leather-like material biofabrication using fungi. *Nature Sustainability*. 4, 9–16. https://doi.org/10.1038/s41893-020-00606-1

[45] HEAVY METAL & TUBES LTD. 2016. The First Methods for Producing Steel Pipe were introduced in the early 1800s. *Medium.* Jul 23, 2016. [Accessed: 2024-11-04] https://medium.com/@hmtl.social/the-first-methods-for-producing-steel-pipe-were-introduced-in-the-early-1800s-16fb48c979c9

[46] Bureau of International Recycling. 2019. *World Steel Recycling in Figures 2015 – 2019.* [Accessed: 2024-11-04] https://www.bir.org/images/BIR-pdf/Bi2001_05a-Ferrous-report-2019.pdf

[47] GRAEDEL, T. E.; ALLWOOD, Julian; BIRAT, Jean-Pierre; BUCHERT, Matthias; HAGELUKEN, Christian *et al*. 2011. *Recycling rates of Metal – A status report*. UNEP. ISBN 978-92-807-3161-3. [Accessed: 2024-11-04] https://www.resourcepanel.org/sites/default/files/documents/document/media/e-book_metals_report2_recycling_130920.pdf

[48] DE LEEUW, Georgia; VOGL, Valentin. 2024. Scrutinising commodity hype in imaginaries of the Swedish green steel transition. *Environment and Planning E: Nature and Space*. 7(4), 1844–1867. ISSN 2514-8486. https://doi.org/10.1177/25148486241238398

[49] SLUNEČKOVÁ, Eva. 2022. Legandární design: Stam vs. Breuer a velký spor o konzolovou židli. Kdo byl první a kdo kopíroval? *Earch.cz* [Accessed: 2024-11-04] https://www.earch.cz/design/clanek/velky-spor-o-konzolovou-zidli-stam-vs-breuer-kdo-byl-prvni-a-kdo-kopiroval

[50] VITRA. 2024. *Aluminium*. Vitra. [Accessed: 2024-11-04] https://www.vitra.com/en-cz/about-vitra/sustainability/aluminium

[51] A LINE AUTOMATION. 2024. *A Brief History and Future Potential of Aluminum Extrusions*. Online. www.alineautomation.com. [Accessed: 2024-11-04] https://www.alineautomation.com/a-brief-history-and-future-potential-of-aluminum-extrusions/

[52] PRINCE, Sharma. 2022. A brief account of man, material and manufacturing: On the timeline. Online. *ScienceDirect*. 66(8), 3572–3577. https://doi.org/https://doi.org/10.1016/j.matpr.2022.07.016. [accessed 2024-11-11].

[53] GRAEDEL, T. E.; ALLWOOD, Julian; BIRAT, Jean-Pierre; BUCHERT, Matthias; HAGELUKEN, Christian *et al*. 2011. *Recycling rates of Metal: A status report.* ISBN 978-92-807-3161-3. https://wedocs.unep.org/bitstream/handle/20.500.11822/8702/Recycling_Metals.pdf

[54] VAN HEUSDEN, Renée; HARRY, Morrison; PULEO, Mary. 2020. *Why addressing the aluminium industry's carbon footprint is key to climate action*. World Economic Forum.

[55] HAVEL,Adam;PHAM,Huy.2022.*Towardssustainability:Designanábytek+Elektronika.*Nov3,2022 10:22 Prague Bratislava [ZOOM Meeting]. https://us02web.zoom.us/rec/play/ZURUcDlynTIQM64emUp-c8a0BIiAoTH1StODe9JBEQ8AggTCjF6Ko5niBAFa0iNvMXXdpWSCH1ERQLOI9.5kkh6C2reTh-WxXyn?hasValidToken=false&canPlayFromShare=true&from=share_recording_detail&continueMode=true&componentName=rec-play&originRequestUrl=https%3A%2F%2Fus02web.zoom.us%2Frec%2Fshare%2FFxncLsvb7Zr1OFFt-CZ85ViDuuN05otcygNrfGYuCLaf5fbJvz45b-CIdIYqWWB-j.NWzB6t_3jzC0P_Uu

[56] VAN HEUSDEN, Renée; HARRY, Morrison; PULEO, Mary. 2020. *Why addressing the aluminium industry's carbon footprint is key to climate action*. World Economic Forum.

[57] ACS CHEMISTRY FOR LIFE. 1993. *Leo Hendrick Baekeland and the Invention of Bakelite®*. 2024. [Accessed: 2024-11-04] https://www.acs.org/education/whatischemistry/landmarks/bakelite.html

[58] NÁBYTKÁŘSKÝ INFORMAČNÍ SERVER. 2013. *Rozdělení plastů.* NIS. [Accessed: 2024-11-04] https://www.n-i-s.cz/cz/rozdeleni-plastu/page/324/

[59] VAN HEUSDEN, Renée; SANDSTRÖM, Jörgen; CHAU, Shaun; PULEO, Mary. 2021. *The answer to the aluminium industry's emissions issue? Aluminium's infinite recyclability*. World Economic Forum. [Accessed: 2024-11-04] https://www.weforum.org/stories/2021/12/aluminium-emissions-recycling-circular-economy/

[60] BUUR, Stine Liv. 2019. *Fiberglass A Materials Exploration*. [Accessed: 2024-11-04] https://www.vitra.com/en-cz/magazine/details/fiberglass

[61] PU FOAM: 2024. *The history of polyurethane*. PO foam. [Accessed: 2024-11-04] https://www.pu-schaum.center/en/facts-worth-knowing/the-history-of-polyurethane

[62] ENCYCLOPEDIA BRITANICA. 2024. Polyethylene. In: *Britanica*. [Accessed: 2024-11-04] https://www.britannica.com/science/polyethylene

[63] LI, Xiaomeng; MAHADAS, Nagarjuna A.; ZHANG, Mengxue; DEPODESTA, Jacquelyn; STEFIK, Morgan *et al*. 2024. Sustainable high-density polyethylene via chemical recycling: From modification to polymerization methods. *Polymer*. 295(1), 126698. https://doi.org/10.1016/j.polymer.2024.126698

[64] STATISTA. 2024. Annual production of plastics worldwide from 1950 to 2023. In: *Statista*. https://www.statista.com/statistics/282732/global-production-of-plastics-since-1950

[65] VITRA. 2024. *Recycled Plastics*. VITRA. [Accessed: 2024-11-04] https://www.vitra.com/en-cz/about-vitra/sustainability/recycled-plastic

[66] HINDLE, Colin. 2024. *Polypropylen.* Online. www.bpf.co.uk. https://www.bpf.co.uk/plastipedia/polymers/PP.aspx. [accessed 2024-11-11].

[67] BRITISH PLASTIC FEDERATION. 2024. *Polycarbonate.* BPF.[Accessed: 2024-11-04] https://www.bpf.co.uk/plastipedia/polymers/Polycarbonate.aspx

[68] KULA, Daniel; TERNAUX, Elodie; HIRSINGER, Quentin. 2012. *Materiology: průvodce světem materiálů a technologií pro architekty a designéry*. Praha: Happy Materials. ISBN 978-80-260-0538-4

[69] KARTELL. 2024. *Sustainable Growth And Development in View of the Agenda for 2030 Kartell*. [Accessed: 2024-11-04] https://www.kartell.com/dk/en/ktdk/corporate/kartell-loves-the-planet

[70] HONEXT. 2024. *Circulat by Desing.* HONEXT. [Accessed: 2024-11-04] https://honextmaterial.com/circularbydesign/

[71] FACT.MR. 2024. Plastic Furniture Market Outlook (2023 to 2033). *Fact MR*. [Accessed: 2024-11-04] https://www.factmr.com/report/3574/plastic-furniture-market

[72] CAMPEN, Matthew; NIHART, Alexander; GARCIA, Marcus a spol. 2024. Bioaccumulation of Microplastics in Decedent Human Brains Assessed by Pyrolysis Gas Chromatography-Mass Spectrometry. *ResearchSquare*. https://doi.org/https://doi.org/10.21203/rs.3.rs-4345687/v1

[73] HALFAR, Jan; ČABANOVÁ, Kristína; VÁVRA, Karel ***et al.*** 2023. Microplastics and additives in patients with preterm birth: The first evidence of their presence in both human amniotic fluid and placenta. *Chemospehere*. 343, 140301. https://doi.org/https://doi.org/10.1016/j.chemosphere.2023.140301

[74] FOUR ELEMENTS CONSULTING & OMNI TECH INTERNATIONAL. 2022. *Life Cycle Assessment of HempWood® Natural Flooring*: *Third-Party Verified Report in Preparation for an Environmental Product Declaration*. [Accessed: 2024-11-04] https://5po4a0.p3cdn1.secureserver.net/wp-content/uploads/2023/02/HempWood%C2%AE-Organic-Flooring-LCA.pdf

[75] INEKE HANS. 2021. *REX the first Dutch deposit chair2021, with circuform (not Ahrend)*. [Accessed: 2024-11-04] https://www.inekehans.com/studio/work/rex

[76] VIANELLO, Alvise; JENSEN, Rasmus Lund; LIU, Li; VOLLERTSEN, Jes. 2019. Simulating human exposure to indoor airborne microplastics using a Breathing Thermal Manikin. *Sci Rep.* 9, 8670. https://doi.org/10.1038/s41598-019-45054-w

[77] BEY, Niki. 2000. *The Oil Point Method: A tool for indicative environmental evaluation in material and process selection.* Disertation Thesis. DK - 2800 Lyngby, Denmark: Department of Manufacturing Engineering, IPT Technical University of Denmark. ISBN 87-90855-09-4. [Accessed: 2024-11-04] https://polynet.dk/lenau/niki_bey_phd_thesis.pdf

[78] MINISTRY OG HOUSING, SPATIAL PLANNING AND ENVIRONMENT NETHERLANDS. 2000. *Eco-indicator 99 Manual for Designers: A damage oriented method for Life Cycle Impact Assessment*. [Accessed: 2024-11-04] https://pre-sustainability.com/files/2013/10/EI99_Manual.pdf

[79] PUETTMANN, Maureen; KAESTNER, Dominik; TAYLOR, Adam. 2016. *CORRIM REPORT – Module D2 Life Cycle Assessment of Softwood Plywood Production in the US Southeast*. [Accessed: 2024-11-04] https://corrim.org/wp-content/uploads/Module-D2-SE-Plywood.pdf

[80] KILIÇ, E.; MCLAREN, S. J.; HOLMES, G. *et al* 2023. Product environmental footprint of New Zealand leather production. Online. *The International Journal of Life Cycle Assessment*. 28, 349–366. https://doi.org/10.1007/s11367-023-02143-3

[81] GANDHI, Neeti; FARFARAS, Nicholas; LINDA WANG, Nien-Hwa and CHEN, Wan-Ting. 2021. Life Cycle Assessment of Recycling High-Density Polyethylene Plastic Waste. Online. *Journal of Renewable Materials.* 9(8), 1463–1483. ISSN 2164-6341. https://doi.org/10.32604/jrm.2021.015529

[82] LIPTOW, Christin; TILLMAN, Anne-Marie. 2009. *Comparative life cycle assessment of polyethylene based on sugarcane and crude oil*. Chalmers University Of Technology Report No. 2009:14, ISSN 404-8167. [Accessed: 2024-11-04] https://research.chalmers.se/publication/107576/file/107576_Fulltext.pdf

[83] PUETTMANN, Maureen E.; WILSON, James B. 2005. Lifecycle Analysis of Wood Products: Cradle-To-Gate Lci of Residential Wood Building Materials. Online. *Wood and Fiber Science.* 37 Corrim Special Issue, 18–29.

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