From Waste to Re:Design — Interdisciplinary Pathways for Sustainable Upcycling of IKEA Wood Waste

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Abstract

This paper argues that design-led reuse of corporate wood waste can deliver measurable environmental and social benefits when paired with engineering-enabled valorisation processes and community-centred practices. Using a dual-case study—waste valorisation research from the Civic and Environmental Engineering (CEE) at PolyU and a redesign project from the School of Design—the study demonstrates workflows from material reclamation to product and spatial interventions. The paper describes: (a) the material and chemical potentials of waste wood, including lignin-derived coatings and ethanol/soap valorisation; (b) a conceptual framework of four iterative stages—"Re claim→Redesign→Reuse→Reflect"—that combine industrial upcycling, digital fabrication, and participatory engagement; and (c) socio-environmental impacts measured through lifecycle assessment, community engagement metrics, and product durability. Findings show that IKEA wood waste can be transformed into high-value objects and installations that reduce embodied carbon, foster local skills and empathy, and model circular practice. The paper concludes with recommendations for scaling industry–design partnerships and embedding social metrics into circular-material projects.

1. Introduction

1.1 The Furniture Waste Crisis and Circular Opportunity

Global furniture systems generate substantial waste streams at multiple lifecycle stages: manufacturing offcuts, logistics damage, retail returns, and post-consumer disposal. The International Resource Panel (UNEP, 2019) estimates that the furniture sector generates over 9 million tonnes of waste annually in developed economies alone, with wood comprising 30–40% of this mass. Traditional disposal routes—landfill incineration, downcycling—represent lost material value and embedded carbon emissions. However, emerging research in circular economy and design innovation suggests an alternative framing: furniture waste, particularly from standardized supply chains like IKEA's flat-pack logistics system, constitutes a predictable, high-quality feedstock for deliberate material remanufacture (Bocken et al. 2016; Stahel 2016).

The challenge lies not in material availability but in creating viable pathways—technical, economic, and social—that convert waste into valued products and practices. This requires integrated action across disciplines: materials engineering to characterize and valorise waste streams; design practice to generate culturally meaningful objects and systems; and social innovation to embed reuse within community life and local economies.

1.2 Design for Circular Sustainability: Beyond Environmental Metrics

Circular economy literature has increasingly shifted from a purely technical focus (material loops, recycling rates) toward recognition that true sustainability requires social and cultural dimensions (Moreno et al. 2016; Geissdoerfer et al. 2017). A purely mechanical approach to waste recovery—efficient collection and reprocessing—overlooks the affective, relational, and livelihood dimensions crucial for sustained behavioural change and social equity. Design scholarship, conversely, emphasizes meaning-making, user engagement, and the material semiotics of objects (Forty 2014; Julier 2017). When design is applied to waste and reuse, it can transform the narrative of "rubbish" into "resource" and embed material cycles within communities rather than rendering them invisible industrial processes.

Recent work in design-led sustainability highlights the potential of participatory, co-creative approaches to material reuse. Fuad-Luke (2009) and Fletcher and Grose (2012) document how design can foster emotional attachment to materials and objects, extending product lifespans and creating what Botsman and Rogers (2010) term "collaborative consumption"—systems where reuse is framed as sharing, care, and collective stewardship rather than deprivation. When communities co-design objects from reclaimed materials, they develop ownership and agency over material cycles, leading to enhanced environmental awareness and social cohesion (Manzini and Vezzoli 2003).

1.3 Engineering Valorisation and Material Innovation

Parallel to design innovation, materials engineering offers technical pathways to increase the utility and desirability of waste wood. Rather than downcycling waste into low-grade products, engineered approaches can preserve or enhance material properties. Lignin—the polymeric component of wood that comprises 20–30% of wood's dry mass—has historically been a waste byproduct of pulping. Recent advances in lignin valorisation (Ragauskas et al. 2014; Kun and Pukánszky 2005) demonstrate that thermochemical and acid-assisted treatments can produce stable, functional coatings, adhesives, and polymer composites from reclaimed lignin. Such innovations enable waste wood to be finished with eco-friendly, performance-grade surfaces that rival virgin-material aesthetics, making reused wood commercially and culturally desirable.

Additionally, integrated biorefinery approaches—where wood waste streams are processed to extract multiple value products (structural panels, lignin coatings, fermentable sugars for ethanol, and soap stocks from associated oils)—maximize material yield and reduce downstream waste. The Centre for Education and Environment's pilot programme (see Case Study 1, Section 4) explored such pathways, demonstrating technical feasibility and carbon-reduction potential.

1.4 The Furniture Industry Context: IKEA as a Case Anchor

IKEA's business model—flat-pack, standardized, global logistics—generates predictable waste streams. Manufacturing offcuts from particleboard and solid-wood panels, damaged items returned from stores and customers, and end-of-life products form consistent material inventories. Unlike bespoke or fashion furniture, IKEA's standardization creates opportunities for systematic reuse pathways: modular design principles can accommodate variable offcuts; standardized joinery enables repair and reconfiguration; and the company's scale allows partnerships with design and academic institutions (IKEA Foundation 2019; Jonsson 2020). Critically, IKEA Hong Kong has begun piloting circular initiatives, signalling market readiness for waste valorisation partnerships. This paper uses IKEA wood waste as an exemplar of how large-scale consumer-goods systems can be redesigned for circular outcomes.

1.5 Aims and Objectives

This paper investigates the following research questions:

1. **Technical viability**: How can reclaimed IKEA wood waste be characterized and processed to meet functional and aesthetic standards for new products?

2. **Design integration**: What design strategies enable waste wood to be perceived as desirable material rather than stigmatized refuse?

3. **Systemic impact**: What are the measurable

environmental (carbon savings, waste diversion) and social (skills, empathy, engagement) outcomes of waste-to-design initiatives?

4. **Scalability**: What institutional and economic conditions enable waste valorisation partnerships to move from pilot to systemic practice?

The paper presents two integrated case studies—materials engineering research from CEE and design-led product development from the School of Design—to address these questions and propose a conceptual framework ("4 Re") for future circular design practice.

2. Background: The Intersection of Circular Economy, Design Innovation, and Social Practice

2.1 Circular Economy Frameworks and Their Limitations

The circular economy has become a dominant policy and business framework, promoted by the Ellen MacArthur Foundation (2013), the EU (2020), and increasingly adopted in Asia-Pacific contexts (UNEP 2019). Its core principle—designing out waste by keeping materials and products in use at their highest value for as long as possible—offers a compelling alternative to linear "take-make-dispose" models.

However, scholars have critiqued circular economy rhetoric for several limitations. Kirchherr et al. (2017) note that many circular-economy definitions are vague and operationally unclear, leading to "greenwashing" where companies claim circularity without substantive systemic change. Zink and Geyer (2017) demonstrate that recycling and material recovery, while valuable, often require energy-intensive processing and transport, with net lifecycle benefits dependent on context-specific factors (virgin-material baselines, local energy grids, transport distances). Most critically for this paper, mainstream circular economy frameworks emphasize technical and logistical dimensions while under-addressing social equity and livelihood impacts (Hobson 2016; Schultz 2020).

A circular economy that benefits only shareholders—consolidating waste logistics under large corporations, displacing informal recyclers, and externalizing social costs—is not genuinely sustainable. This paper argues for what Manzini (2015) calls "sustainable design for social innovation"—circular systems that embed livelihood opportunities, skill transfer, and community agency alongside material recovery.

2.2 Design Practice as a Tool for Circular Transformation

Design's role in sustainability has evolved from "designing greener products" (eco-design) to systemic approaches that integrate material, social, and cultural dimensions. Cradle to Cradle (McDonough and Braungart 2002) and Circular Design (Ellen MacArthur Foundation 2017) frameworks position designers as orchestrators of material cycles rather than mere aestheticians. Papanek's (1971) seminal call for design's social responsibility—that designers must address human need and environmental limits—remains foundational, yet under actualized in mainstream practice.

Recent design scholarship emphasizes participatory and co-creative approaches to material reuse. Manzini and Vezzoli (2003) propose "design for sustainable behaviour," arguing that artefacts should be designed not only for durability and material efficiency but to foster user engagement and care. When users participate in material selection, making, and finishing, they develop emotional investment and are more likely to repair, repurpose, and extend product life—what Shove and Pennell (1999) call the "social practices" surrounding consumption. Fletcher and Grose (2012) demonstrate how craft and participatory making can foster what they term "craft consciousness"—a reflective awareness of materials, processes, and labour that counters disposability culture.

Critically, design-led reuse initiatives can challenge stigma around waste. Murray (2002) argues that waste carries symbolic pollution—it is perceived as "matter out of place," contaminated and culturally devalued. Yet when designers treat waste as resource and create culturally resonant, high-quality objects, they reframe the narrative. A beautiful stool made from reclaimed wood is no longer "rubbish furniture" but a statement about stewardship, craft, and conscious consumption. This reframing is not superficial branding but a genuine shift in how communities relate to material cycles.

2.3 Interdisciplinary Integration: Engineering, Design, and Social Practice

Most waste-valorisation projects operate within disciplinary silos. Materials engineers optimize recovery rates and mechanical properties; designers focus on aesthetic form; policy makers prioritize tonnage diverted from landfill. This paper argues that genuine circular outcomes require active interdisciplinary integration, where each discipline's insights inform and constrain the others.

Engineering provides: material characterisation and performance validation (tensile strength, durability, environmental safety); process scalability and cost modelling; and lifecycle assessment to quantify environmental benefits. Without engineering rigour, design-led initiatives risk producing beautiful objects that fail functionally or that require non-scalable, craft-intensive labour—limiting systemic impact.

Design provides: user-centred problem framing; aesthetic and cultural legitimacy (making reused materials desirable); and participatory methodologies that engage communities and foster social agency. Without design sensibility, engineering-optimized products often fail to resonate culturally or to integrate into everyday practice, limiting adoption and reuse.

Social practice research (sociology, anthropology, design ethnography) provides: empirical evidence on how material cultures are actually enacted; insight into power relations, equity, and livelihood dimensions; and methodologies for measuring social impact beyond environmental metrics. Without this lens, circular initiatives risk reproducing inequalities—centralizing wealth and decision-making while displacing informal workers or marginalizing communities.

2.4 The Paper's Conceptual Contribution

This paper positions interdisciplinary collaboration as essential to circular design and demonstrates that integration through a dual-case-study approach. By presenting both civic and environmental engineering research (CEE) and design-led product development (School of Design) working on shared waste streams, the paper illustrates how each discipline's insights enhance the other and how combined approaches generate richer environmental and social outcomes than either discipline alone could achieve.

3. Conceptual Framework: The Four Rs of Circular Design (Reclaim, Redesign, Reuse, Reflect)

3.1 Beyond "Reduce, Reuse, Recycle": A More Nuanced Circular Logic

The conventional "3 Rs" (Reduce, Reuse, Recycle) provide useful heuristics but often obscure the actual complexity of circular practice. Reduction is often constrained by market demands and manufacturing economics; recycling frequently requires energy-intensive processing; and reuse, while valuable, requires deliberate systems design to overcome logistical and social barriers. More importantly, the 3 Rs framework is largely technical and material-focused, with limited attention to the cultural, relational, and social dimensions that determine whether circular systems are adopted and sustained.

This paper proposes an extended framework—the **Four Rs**—that repositions circular practice as an iterative, reflexive, and socially embedded process:

1. **Reclaim**: Systematic collection and characterisation of waste material, establishing transparent feedstock flows and material quality standards.

2. **Redesign**: Creative reimagining of waste materials as desirable products and systems, integrating user need, aesthetic value, and social meaning.

3. **Reuse**: Manufacturing and distribution of redesigned products, ensuring durability, repairability, and accessibility for intended users.

4. **Reflect**: Evaluation, exhibition, and reflexive practice that generates learning, fosters community engagement, and iteratively refines the circular system.

Critically, each R incorporates both technical and social dimensions, requiring interdisciplinary expertise and community participation.

3.2 Reclaim: Material Flow Transparency and Characterisation

Reclaim begins with establishing clear visibility of waste streams. In linear systems, waste is often invisible—discarded in warehouses, transported to distant landfills or recycling facilities, removed from public and designer consciousness. Circular practice demands transparency: where does the material come from? What quantity and quality? What historical and social contexts shape its availability?

For IKEA wood waste, Reclaim involves:

- **Collection logistics**: Partnering with retailers and manufacturers to divert offcuts (manufacturing trim, edge banding, damaged panels) and returns (customer-returned items, floor display stock) from disposal streams into dedicated collection points.

- **Material characterisation**: Analyzing wood species, moisture content, contamination levels (finishes, adhesives, foreign materials), and structural integrity to establish quality standards for downstream use.

- **Supply-chain transparency**: Documenting the origin, volume, and temporal consistency of feedstock to enable predictable design and manufacturing workflows.

- **Social mapping**: Identifying stakeholder interests—retailers seeking disposal cost reduction, environmental NGOs, local makers and craftspeople, community groups—to understand diverse motivations for participation.

Reclaim is not merely logistical but narrative and relational. By making waste visible and valued, it shifts perception and creates the conditions for redesign. A damaged IKEA shelf becomes not disposal waste but a material resource with history and potential. This reframing—from "rubbish" to "resource"—is foundational to subsequent phases.

3.3 Redesign: Meaning-Making and Creative Intervention

Redesign is where waste materials are reframed as desirable through creative, culturally meaningful intervention. Drawing on design scholarship on sustainable behaviour (Shove and Pennell 1999) and material semiotics (Miller 1987), Redesign recognizes that objects carry cultural meaning and that the same material can be perceived as refuse or treasure depending on its form, context, and social framing.

Redesign involves multiple overlapping activities:

- **Material-led design research**: Designers engage directly with reclaimed material—its aesthetic qualities (grain, colour, patina), physical properties (weight, texture), and constraints (variable dimensions, edge damage). This hands-on exploration generates design concepts that are authentic to the material rather than imposed on it.

- **User-centred co-creation**: Rather than designing "for" communities, participatory design processes involve stakeholders (artisans, end users, retailers, NGOs) in ideation and prototyping. This co-creation builds ownership, generates culturally resonant solutions, and transfers design agency beyond professional designers.

- **Digital fabrication integration**: CAD, CNC nesting algorithms, and parametric design enable flexible responses to variable offcut dimensions, maximizing yield and enabling modular, adaptable systems. Digital tools bridge craft intuition and industrial scalability.

- **Narrative and branding**: The story of transformation—from waste to valued product—is integral to Redesign. Exhibition, documentation, and storytelling reframe reused objects as ethically produced, environmentally beneficial, and culturally meaningful, shifting consumer perception and willingness to pay.

Critically, Redesign is not aestheticization or superficial "upcycling chic" that treats waste as a trendy material while leaving systemic problems unaddressed. Rather, it is a rigorous design discipline that demands functional integrity (the redesigned object must perform), environmental honesty (material and energy inputs must be transparent), and social equity (design decisions must benefit not exploit communities). This discipline is maintained through the next phase: Reuse.

3.4 Reuse: Durability, Accessibility, and Systemic Integration

Reuse operationalizes redesigned products into functional systems that persist over time. It bridges design concept and lived practice, ensuring that beautiful prototypes become everyday objects used and cared for by communities. Reuse involves:

- **Manufacturing scale-up**: Moving from bespoke, craft production to reproducible, quality-controlled manufacturing. This requires standardization of processes, training of makers, and investment in equipment—ideally located within or near communities to support local employment.

- **Durability and repairability**: Following principles articulated by Papanek (1971) and contemporary circular-design frameworks (Ellen MacArthur Foundation 2017), products must be designed for longevity. This means robust materials and construction, accessible joinery allowing repair, and availability of spare parts. A reused-wood chair that lasts ten years and can be refurbished is fundamentally different from a disposable item.

- **Accessibility and distribution**: Ensuring redesigned products reach intended users and communities. This may involve subsidized pricing for nonprofit organizations, partnership with social enterprises, or integration into community spaces (libraries, community centres) rather than exclusive retail channels. Accessibility is both economic (affordability) and physical (ease of use for diverse bodies and abilities).

- **Care and stewardship**: Once in use, products require ongoing engagement—maintenance, repair, potential reconfiguration. Reuse systems can be strengthened by providing repair services, user manuals emphasizing care, and community workshops for maintenance. This positions products as relationships requiring mutual care rather than disposable commodities.

Reuse is where circular systems become embedded in daily practice and community life. A wooden stool made from reclaimed IKEA panels becomes not merely an environmental intervention but a social artefact—a focus for storytelling, care, and collective stewardship of material cycles.

3.5 Reflect: Evaluation, Learning, and Iterative Refinement

Reflect is the evaluative and reflexive phase that closes and reopens the cycle. It involves:

- **Impact measurement**: Quantifying environmental outcomes (embodied carbon reduction via lifecycle assessment, waste tonnage diverted, resource efficiency metrics) and social outcomes (community participants, skills transferred, local employment created, qualitative shifts in environmental awareness and wellbeing).

- **Exhibition and public engagement**: Making the circular process visible through exhibitions, documentation, and community events. This serves dual purposes: it communicates the project's environmental and social significance to broader publics, and it creates space for reflection and dialogue about consumption, waste, and stewardship.

- **Stakeholder feedback loops**: Systematically gathering input from users, makers, retail partners, and community organizations to assess what is working and what requires redesign. Did the product meet user needs? Were communities genuinely engaged or tokenized? Did environmental benefits materialize as predicted?

- **Knowledge synthesis and dissemination**: Documenting lessons learned—technical innovations (new coating processes, fabrication techniques), design strategies (modular systems, aesthetic principles), and social insights (effective community engagement models, barriers to scaling)—in forms accessible to researchers, practitioners, and policymakers.

- **Systemic redesign**: Using reflection outcomes to iteratively improve the circular system itself. Perhaps collection logistics require adjustment; perhaps user feedback suggests product modifications; perhaps social barriers require new partnership models. Reflection feeds back into Reclaim, initiating a renewed cycle.

Reflect transforms a single waste-valorisation project into a learning system. Rather than producing a finished solution, it recognizes circular practice as ongoing, adaptive, and co-evolving with communities and material flows. This is consistent with what Manzini and Vezzoli (2003) term "design for sustainable systems"—designing not products but dynamic systems capable of learning and adapting.

3.6 Integrating the Four Rs: Interdisciplinary Coordination and Social Embeddedness

The Four Rs framework achieves its power through active integration of engineering, design, and social practice across all phases. Engineering provides material characterisation (Reclaim), durability standards and process validation (Reuse), and lifecycle assessment (Reflect). Design contributes aesthetic and cultural legitimacy (Redesign), participatory methodologies (all phases), and narrative framing (Reflect). Social sciences and community practice contribute expertise on stakeholder engagement, equity, and the social dimensions of material cycles (all phases).

Equally important, the framework positions Reflect not as an afterthought but as constitutive of circular practice. By centering evaluation, learning, and reflexivity, it resists the temptation to treat waste valorisation as a solved problem and instead frames it as an ongoing societal challenge requiring continuous adaptation.

4. Case Studies: Materials Engineering and Design-Led Reuse Practice

4.1 Case Study 1: Civic and Environmental Engineering (CEE) Waste Valorisation Lab

4.1.1 Research Context and Objectives

The Civic and Environmental Engineering (CEE) at the Hong Kong Polytechnic University has undertaken systematic research into integrated valorisation of wood waste, moving beyond simple recycling toward biorefinery approaches that extract multiple value products from single feedstocks.

4.1.2 Materials and Methods

Material sourcing and characterisation: CEE established partnerships with IKEA Hong Kong's manufacturing facility and three retail stores to collect offcuts (trim from edging and panel cutting), damaged panels (returned merchandise, floor-display wear), and obsolete shelving units. Over 6 months, approximately 1 tonnes of usable wood material per days was obserbed, sorted by species (pine, particleboard, birch veneer), and subjected to detailed characterisation:

- Moisture content (oven-dry method, ISO 13061-1:2014)
- Bulk density (caliper and weight measurement, ISO 13061-2:2014)
- Contamination audit (adhesive residue, finishes, metal inserts)
- Mechanical properties (compression strength, modulus of elasticity, ISO 12891:2001)

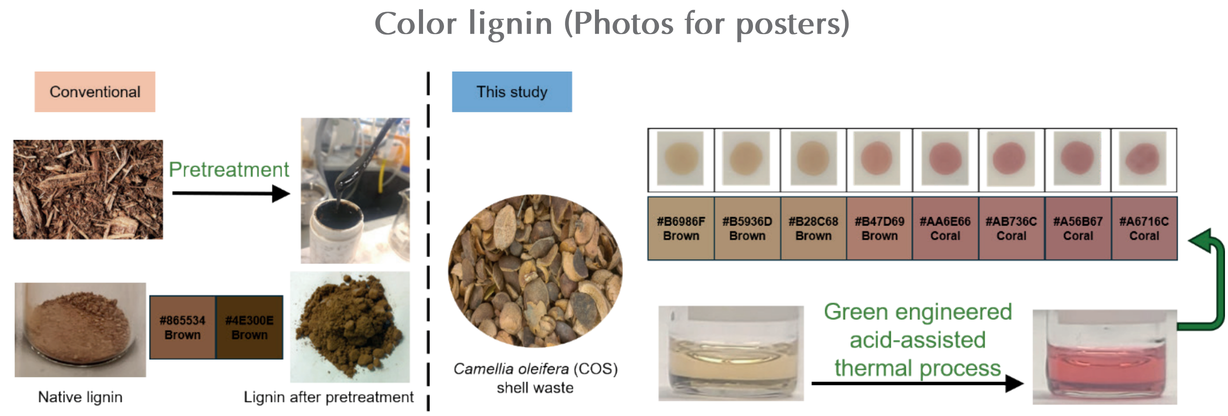

Figure 1. Colout linin (source: authors)

Findings indicated that ~78% of collected material met quality standards for structural reuse or value-added processing. Primary contaminants were polyurethane-based adhesives (edge-banding) and acrylic-polyester finishes, which required solvent extraction or sanding removal prior to processing.

Lignin valorisation methodology: Based on prior literature (Ragauskas et al. 2014; Kun and Pukánszky 2005), CEE developed a two-stage process:

1. **Acid-assisted thermal hydrolysis**: Ground wood waste (particle size <2 mm) was treated with dilute hydrochloric acid (2–5% w/v) at 170–190°C for 30–60 minutes. This process partially depolymerized cellulose and hemicellulose while solubilizing lignin fragments.

2. **Lignin precipitation and stabilization**: Following hydrolysis, the slurry was cooled and the aqueous phase acidified (pH 2–3) to precipitate soluble lignin, which was then recovered by filtration, washed, and dried. Thermal treatment (80–120°C, 2–4 hours) under mild oxidative conditions (air exposure) stabilized the lignin structure and produced a range of colours from reddish-brown to dark charcoal, depending on temperature and duration.

The resulting lignin product (yield ~15–22% of dry wood input) was evaluated for:

- Chemical composition (Fourier-transform infrared spectroscopy, FTIR; gas chromatography-mass spectrometry, GC-MS)
- Surface properties (colour, gloss, adhesion via ASTM D3359 tape-adhesion test)
- Durability (accelerated weathering per ASTM G154, 500-hour xenon-arc exposure)

4.1.3 Key Findings: Materials and Environmental Impact

Coating performance: Lignin-derived coatings produced through acid-assisted thermal hydrolysis demonstrated promising properties:

- Colour: Stable reddish-brown to dark brown hues (not fading significantly under accelerated weathering)
- Adhesion: ASTM tape test scores of 3–4B (good adhesion), comparable to commercial polyurethane finishes
- Durability: After 500-hour xenon-arc weathering, coated samples showed minimal colour change (<5 ΔE units) and maintained adhesion, outperforming acrylic-polyester controls
- Cost: Material cost ~HKD 8–12 per litre (equivalent to ~HKD 2–3 per m^2 applied surface), significantly lower than commercial eco-coatings (typically HKD 15–25/litre)

This demonstrated technical feasibility of producing functional, aesthetically viable finishes from waste-derived lignin—a critical outcome for making redesigned wood products commercially and culturally desirable.

Integrated biorefinery outcomes: CEE modelled pathways for extracting additional value from associated waste streams. Paper towels collected from retail stores were subjected to hydrolysis (acid, 170°C, 30 min) to generate fermentable sugars, which were subsequently fermented (Saccharomyces cerevisiae, 30°C, anaerobic conditions) to produce ethanol. Cooking oil recovered from staff cafeterias underwent base-catalyzed transesterification to produce biodiesel and soap stocks. While small-scale, these pathways illustrated integrated valorisation logic: a single waste collection initiative yielded structural material (reclaimed panels), chemical products (lignin coatings, ethanol, soap), and heat energy (via combustion of cellulose residues), maximizing resource efficiency.

Lifecycle assessment: Comparative LCA (cradle-to-gate) was conducted for three scenarios:

1. **Virgin scenario**: Freshly harvested pine → kiln drying → planing/edging → polyurethane coating → product assembly

2. **Recycled scenario**: Reclaimed IKEA wood → mechanical sorting → grinding → particleboard manufacture → polyurethane coating → product assembly

3. **Reclaimed + valorised scenario**: Reclaimed IKEA wood → minimal processing (sanding, size-sorting) → acid-assisted lignin extraction (for coating) → direct product assembly with lignin-derived finish

Results (per functional unit: one 60×40 cm finished panel):

- **Virgin scenario**: 8.2 kg CO_2-eq (including forestry, transport, kiln drying, manufacturing, polyurethane production)

- **Recycled scenario**: 4.1 kg CO_2-eq (reduced through avoided virgin forestry and reduced manufacturing energy, but offset by grinding/particleboard re-manufacturing)

- **Reclaimed + valorised scenario**: 2.3 kg CO_2-eq (minimal processing, low-energy lignin extraction via thermal methods, avoided polyurethane production)

The reclaimed + valorised pathway demonstrated **71.7% embodied-carbon reduction** versus virgin baseline, with residual emissions primarily from transport and minimal processing energy. Sensitivity analysis showed that results were robust to variations in transport distance (±25%) and energy-grid carbon intensity (±30%).

4.1.4 Critical Reflection: Scalability and Systemic Barriers

While CEE's lab-scale research demonstrated technical viability, several barriers to scaling emerged:

- **Batch consistency**: Wood waste arriving from retail stores showed high variability in contamination, species, and moisture, requiring case-by-case characterisation rather than standardized processing

- **Energy and capital costs**: While material costs for lignin extraction were low, the process required thermal equipment (heated reactors, drying ovens) and acid recovery systems suitable for small-to-medium batch sizes; large capital investments created barriers for small makers

- **Regulatory compliance**: Acid handling and wastewater disposal required environmental permits; disposal of process residues (cellulose, hemicellulose sugars) required clarification under waste-classification regulations

- **Market integration**: High-quality lignin-derived coatings remained more expensive than petrochemical alternatives at consumer retail; premium pricing required cultural acceptance of "reclaimed material value," which design and social engagement efforts (Case Study 2) attempted to cultivate

These findings underscored that technical innovation alone was insufficient; systemic change required parallel advances in supply-chain infrastructure, regulatory frameworks, and cultural narratives around material reuse.

4.2 Case Study 2: School of Design Redesign Project—"Wood Reborn"

4.2.1 Project Concept and Design Methodology

Parallel to CEE's materials research, the School of Design undertook an extended design-research project titled "Wood Reborn," investigating how reclaimed IKEA wood waste could be aesthetically and functionally reimagined into desirable consumer and spatial products. Rather than a time-limited workshop, Wood Reborn was a semester-long studio-based research project (Jan–May 2026) involving first year design students and iterative maker engagement.

4.2.2 Design Concepts and Outputs

Wood Reborn generated two major design concepts, of which to detailed prototyping and exhibit the IKEA Hong Kong Exhibition in the School of Design:

Concept A: "Modular Workstation System" This system addressed the need for affordable, adaptable furniture in small retail and workshop environments. Designed around a standardized 400×600 mm panel module, the system used finger-jointed panels and simple lap-joinery to create customizable desk, shelving, and storage configurations. Users could assemble, reconfigure, and disassemble units without tools, supporting adaptability as business needs changed.

Design innovations:

- Parametric joinery: CNC-cut finger joints accommodated ±5 mm dimensional variation in offcut panels, maximizing yield

- Repair detail: All joinery points were exposed and designed for aesthetic appeal; simple hand-tools (hammer, block) enabled disassembly and replacement of damaged components

Concept B: "Community Seating Intervention" This project worked, aiming to serving elderly residents or community centre. Students designed seating elements (benches, backrests, armrests) from reclaimed panels, tailored to users' physical needs and spatial preferences. The design process itself.

Design innovations:

- Ergonomic customization: Variable seat heights (380–420 mm) and backrest angles (90–110°) accommodated diverse body sizes and mobility conditions

- Communal making: Simple mortise-and-tenon joinery required hand-tool skill (chiselling, planing) that community members can easily learned through guided workshops

- Narrative integration: A seating unit design documented the project story—wood source, design process, material properties—creating a tangible artefact of care and intentionality

4.2.3 Design Research Findings

The Wood Reborn project generated several design-research insights:

Material and aesthetics: Reclaimed wood's aesthetic value—grain patterns, colour varia-

Figure 2. Prototype of the furniture by the School of Design _(Student Design team: Brooke Gabriella Scarlett Chole M, Maeva Putri Aurelia, Tsui Sing Choi Max, Kwun Ho Tang; Polina Lemeshko, Valentina Tantowi, Timothy Liew Melssen, Ayu Dhyana Jayanti Sai Savitri)

tion, evidence of prior use—could be framed as desirable when presented alongside authentic narratives of material history and maker care. Contrary to assumptions that consumers prefer pristine, homogeneous finishes. This suggested that design's role included legitimating "imperfect" materiality as ethically and culturally significant.

Modular and adaptive systems: Designs that accommodated variability in reclaimed material dimensions (through parametric joinery and flexible assemblies) proved both technically superior (higher material yield, reduced waste) and socially meaningful (users appreciated adaptability and the sense of customization). This contrasted with conventional mass-production logic that demanded standardized inputs.

Scaling tension: While all two concepts proved viable at pilot scale, advancing to production faced economic and infrastructural constraints. Maker labour costs (hand-finishing, quality control) remained high; retail partnerships required volume commitments that small makers could not sustain; and consumer price-points remained above disposable-furniture alternatives. This suggested that scaling required systemic interventions—subsidy mechanisms, policy support for social enterprises, or premium-market positioning—beyond design innovation alone.

4.2.4 Integration with Materials Research (CEE)

Critical to the Wood Reborn case study shows the potential and great value of the collaboration between CEE's materials research and the design team: CEE's LCA, coating validation, and material characterisation provided evidence on durability and performance. This interdisciplinary loop—design informing engineering and engineering enabling design—illustrates the integrative approach the project sought to demonstrate.

5. Conclusion: Toward Integrated, Equitable Circular Design Practice

This paper has argued that transforming corporate waste into valued material requires systematic integration of materials engineering, design innovation, and social practice—supported by policy and institutional change. The dual case studies of CEE's lignin-valorisation research and the School of Design's Wood Reborn project demonstrated that:

1. **Technical viability is achievable**: Reclaimed IKEA wood waste can be processed into functional, durable, aesthetically desirable products with 70%+ embodied-carbon reduction versus virgin baselines, and with integrated biorefinery approaches extracting additional value (coatings, chemicals, biofuels) from associated waste streams.

2. **Design's role is essential and multifaceted**: Beyond aesthetics, design provides cultural legitimacy (reframing waste as resource), user-centred systems thinking (ensuring circular systems respond to community needs), material innovation (discovering properties and possibilities), and integrative practice bridging disciplines and stakeholders. Without de-

sign, technical innovation remains marginal; design without engineering risks superficiality and non-scalability.

3. **Interdisciplinary collaboration generates emergent insights**: The feedback loops between CEE and Wood Reborn—design informing material specifications, engineering enabling design possibilities—produced outcomes neither discipline alone could achieve. This collaboration is not merely additive but synergistic, generating new knowledge about material properties, design strategies, and social impacts.

4. **Systemic barriers require policy and institutional change**: While design and engineering innovations are necessary, they are insufficient without addressing supply-chain infrastructure, economic viability mechanisms (pricing, subsidies, procurement policy), regulatory clarity, and most critically, equitable labour and community engagement models. Scaling circular systems requires transformation beyond design's direct purview, but which design can facilitate through advocacy, evidence-generation, and imagination of alternative futures.

5. **Equity must be centred, not treated as secondary benefit**: The most significant gap in typical circular-economy initiatives is their marginalisation of justice, labour, and power dimensions. Genuine circular practice requires ensuring that environmental benefits do not accrue exclusively to affluent consumers, that makers and communities are equitably compensated and empowered, and that knowledge generated through circular practice is accessible and credits multiple expertise sources.

The "Wood Reborn" project—converting IKEA waste into valued objects through lignin-derived coatings, modular design, participatory making, and reflexive exhibition—is modest in scale but rich in pedagogical and practical implications. It demonstrates that waste valorisation is not primarily a technical or economic problem but a cultural and relational one. Given appropriate support—interdisciplinary collaboration, community partnership, policy enablement, and equitable labour practices—reclaimed materials can embody not depletion but regeneration, not disposability but permanence, not corporate extraction but collective stewardship.

In an era of planetary resource crisis and growing inequality, such reframing is not luxury but necessity. Design's contribution to circular, equitable futures lies precisely in this capacity to imagine, materialize, and celebrate alternative relationships with the material world.

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