A Design Approach to Upcycling Waste for Advancing the Circular Economy

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Publication Date: 2026/01/17

Abstract: The linear model of production and consumption – the 'take, make, dispose' economy - is reaching its limits compromising the natural systems from which we extract resources. The creative reuse of no-longer-needed materials, known as 'upcycling', is the new buzzword in design for a circular economy. In this paper, the design strategies, techniques and applications of upcycling waste materials are analysed in relation to enabling a new mode of production that can aid mankind's transition to a more circular economy from its current linearity. Based on the analysis of actual practice across industries, the key design drivers and implementation challenges discussed in this paper show that upcycling is not simply an environmentally-informed imperative but a major economic innovation opportunity for resource conservation and sustainable value creation.

Keywords: *Waste Management, Economy, Resource Efficiency, Upcycling.*

How to Cite: Harshada Samadhan Pawar (2025) A Design Approach to Upcycling Waste for Advancing the Circular Economy. *International Journal of Innovative Science and Research Technology*, 10(11), 3167-3175.
https://doi.org/10.38124/ijisrt/25nov1339

I. INTRODUCTION

At the global level, the production of waste is still increasing at an alarming rate and about 2.12 billion tons per year of municipal solid waste (MSW) are generated worldwide [1]. At the same time, resource extraction and production contribute to nearly 50% of global carbon emissions and a 9 out of 10 frequency of biodiversity losses. The linear economy model, which is defined by rapid extraction of resources, production and disposal of products, has proven to be incommensurate with planetary boundaries and societal wellbeing at large scale [1]. Plastic pollution is a prime example of this crisis, with an estimated 9 billion tonnes being thrown in landfills and our oceans [2]. Standard recycling methods, although useful, typically damage materials. Upcycling, as a concept provides an entirely different focus, than breaking waste into its bare components (down cycling), since it leads to the creative processing of remnants into goods of like or even superior quality. Upcycling is the "process of transforming by-products, waste materials, useless, or unwanted products into new materials or products of better quality or for better environmental value". Unlike recycling as it is traditionally practiced, where equivalent materials are produced with declining quality during multiple processing cycles, upcycling brings waste into higher value applications without loss of quality. This distinction matters: design has been reported to account for as much as 80% of a product's environmental impact, which places designers at the heart of circular economy transitions.

This article contends that upcycling intends to become a systemic approach, allowing us the possibility of change through redesigned principles and procedures for approaching design and market. It considers: (1) theoretical underpinnings relating design thinking and circular economy transitions, (2) practical design methodologies to enable upcycling, (3) sectoral applications and cases studies, (4) economic and environmental implications of adopting upcycling practices, and (5) critical barriers and drivers for scaled take-up.

II. RELATED WORK

- *Circular Economy Principles*

The circular economy is a paradigmatic remodulating of economic organization, substituting the long established linear model with systems that are intended to "close the loop" through reusing, refurbishing and recovering. The Ellen MacArthur Foundation has set out three guiding principles: design out waste and pollution keep products and materials in use regenerate natural systems.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25nov1339

This structure functions through a set of interconnected policies under the banner of the Zero Waste Hierarchy:

- Reduce : Conservation and extraction inputs and outputs in material use.
- Reuse – Keep products in circulation without processing.
- Repair and Reconditioning- prolong product life with maintenance
- Re-man NUF: Products that are taken apart and processed using the re-man NUF method for components reuse.
- Recycle: Convert waste to new use
- Recover: Recycling end of life products

Upcycling clearly takes the higher place where it is concerned with preserving value and emplacing creative transformation before any value loss that downcycling or incineration would induce[3].

➤ *Design Thinking and Upcycling*

Modern design philosophy now more and more accepts sustainability as the methodology than the deferential level. So what are the design thinking perspectives for upcycling?

Systems Thinking Designers consider the full life of a product, looking for points in the system where waste flows can be diverted into richer uses. This systems approach looks beyond the optimization of an individual product to a circular flow at an ecosystem level.

- Creative Problem-Solving: Designing for upcycling requires very clear creative vision regarding what materials most people see as waste and how they can be reinvented into unique designs based on form and function. This is a radical re-conceptualization, taking what we conventionally define as waste and identifying it as a resource of tremendous value.

- Constraints Driven Innovation: Material constraints from working with waste streams' are an effective catalyst to greater creativity. Design constraints often prompt new ideas which then shape further technology development.

- User-centred Design: There is a trade-off between environmental credentials and product functional performance, and aesthetic value of successful upcycled products is reached. Design should make people believe that upcycled products perform as well or better than virgin source [4].

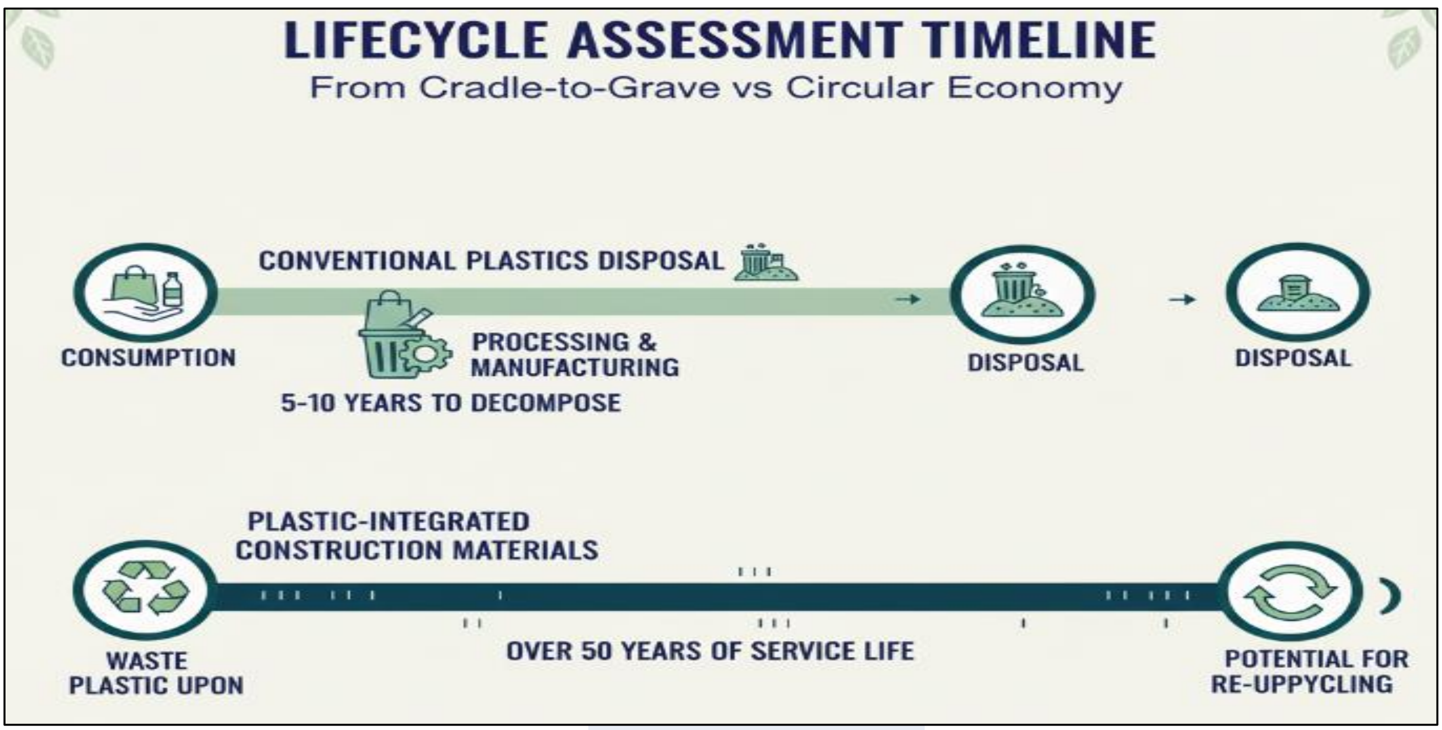

Fig 1: Lifecycle Assessment Timeline

➤ *Design Innovation in Creation of Value*

Upcycling creates value in several ways beyond mere reuse of materials. One, radically reshaping creates value: Discarded things become not trash but carefully considered, expressive design. Second, narratives around sustainability and resourcefulness to an extent seem to shape consumer perception and willingness-to-pay premiums for upcycled items. Third, lower snag extraction and manufacturing energy greatly decrease both production costs and environmental footprints from virgin fabrication. Studies show that around

80% of environmental impacts are fixed at the design stage, which highlights that sustainable upcycling is nothing but an advanced designing innovation. Organizations such as Patagonia (Worn Wear program) and Coach (Re)Loved Exchange have shown that maintaining product shelf-lives through imaginative repairing and reconditioning is not only a commercial proposition but impactful in siphoning waste [5].

III. DESIGN METHODOLOGY FOR UPCYCLING

➢ *Phase 1: Inventory and mapping of resources*

Efficient upcycling stem from the proper analysis of available waste material for value added processing. This step requires an inventory of waste streams according to the characteristics of material, quantity, physical form, and variation. Study of the material properties, in terms of strength, flexibility, durability and toxicity is very important for selection of a material that can be used for commercial purpose. Furthermore, geographic presence and access to supply chains are evaluated for continued supply. Seasonal or cyclic differences in production of waste also need to be addressed as it affects long term sustainability and planning for production.

➢ *Phase 2: Conceptual Ideation*

After the properties of materials are defined, generation of new concepts and technologies to use natural resources This relationship is known as structure through which all other relevant factors will be analyzed. Design thinking processes such as brainstorming, morphological analysis, and the SCAMPER technique are used to help identify many different product ideas. At this point, design can be reviewed in light of actual needs and possibilities and commercial opportunities. The first preliminary sustainability analysis is performed comparing environmental impacts for upcycling products to that of virgin materials, which confirm the concepts applied on contracts and goals towards circular economy.

➢ *Phase 3: Prototype Development*

The design will then advance to prototyping, where concepts are realized in the form of working models. This phase is about testing how the material will perform under normal use conditions and verifying performance benchmarks, including safety and strength. Prototypes are crucial feedback which enable you to improve your design, based on shortcomings or material specific constraints that have been encountered. For larger production, durability evaluations are performed based on the simulation of in-use condition so to guarantee that upcycled product is both quality and safety compliant.

➢ *Phase 4: Supply Chain Integration*

For moving from the prototypes to a large scale production, developing an optimised supply chain for waste material is key. There is a high focus in this phase on developing system for the regular collection, sorting and pre-process- ing so that material inputs are uniform. QC specifications are established to accommodate waste material variance and ensure consistent product quality between production cycles. Waste generators, collection centers and recycling networks are partners to ensure consistent material streams. Traceability mechanisms are analogously employed to record the origin, processing of materials and transparency enhancement as well as circular economy principles support.

➢ *Phase 5: Scaling and Production*

Once you are confident in your supply chain the design process moves on to scale and production. That stage means taking polished prototypes into manufacturing processes that can scale to commercial volumes. Modular, flexible production systems are developed to accommodate internal waste materials variations. Rigorous quality assurance is implemented to ensure the effectiveness, safety, and excellence of each product. Furthermore, employee training programmes and workplace safety instructions are implemented as well to promote compliance with industrial standards and environmental protection targets.

➢ *Phase 6: End-of-Life Planning*

The last step of the upcycling design framework revolves around establishing long-term circularity through end-of-life planning. Designers favour disassembly into products with separation of components and materials for ease in recovering value or re-use. Careful selection of the materials' combinations enables future recycling or upcycling. In addition to setting up recycling facilities, take-back programs have been implemented to encourage users to bring back their end-of-life products, completing the resource cycle. Wherever feasible, closed loop series is sought where materials are presented back into the chain of production rather than the waste line [6].

IV. MATERIAL SELECTION CRITERIA

Designing the material accordingly is thus an important determinant for the environmental benefit as well as manufacturability and performance of products in upcycling. First, they need to perform an environmental impact assessment to consider the upstream ecological costs of finding and processing materi- als, acknowledging that even within waste streams some materials also cause more or less environ- mental harm (e.g. chemically treated textiles) and hence require closer consideration. Equally important are the functional qualities of the material; attributes such as strength, loadbearing ability, chemical resistances and finishing possibilities must adequately match that of application in order to prevent mismatched material versus function pairings presenting early-life failure rates which negate any environmental benefit. Processing needs also influence feasibility, since materials requiring significant processing (such as toxic chemical treatments, or unique equipment) present barriers in terms of scale ability, compared to simpler process flows that improve the viability and economy of production8. Stability of the supply chain also impacts successful upcycling because a regular and reliable access to characterized waste material is required in order to enable efficient production, while splitstroms or unpredictable sources

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25nov1339

of supplies may limit scalability. Ultimately, as a clear strategy for both disassembly and separation are required in multi-material product designs where it is critical to address materials compatibility due to incompatible material combinations preventing future recycling routes, potentially re-enforcing linear waste pathways rather than achieving circularity [9].

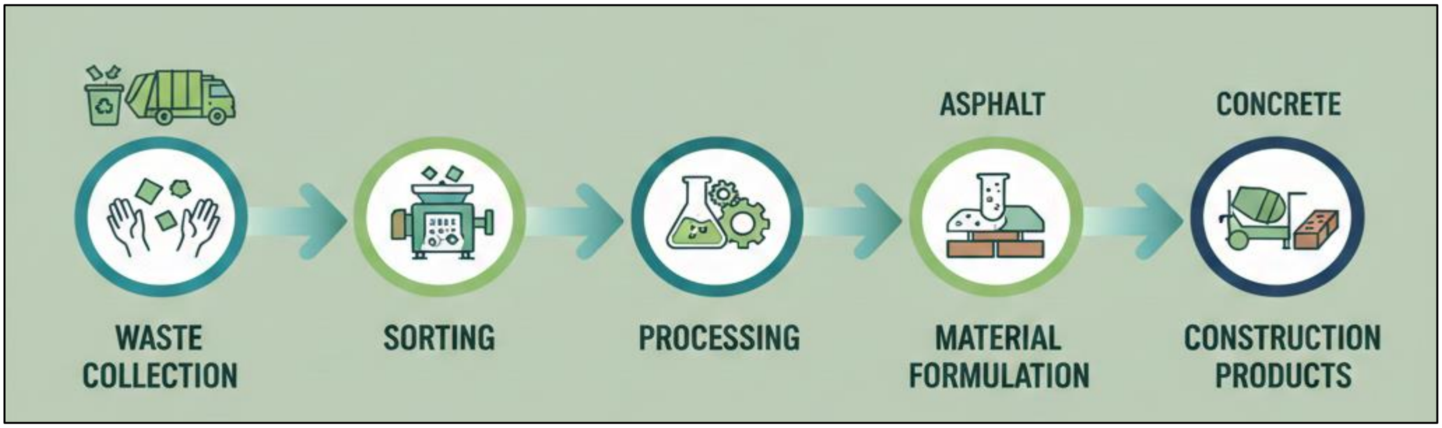

Fig 2: Plastic Waste Upcycling Flow Diagram

V. SECTORIAL APPLICATIONS AND CASE STUDIES

➢ *Construction and Building Materials*

One such application for upcycling is the building construction industry, which has resulted in various attempts to incorporate plastic waste in construction materials providing environmental and financial benefits. Around 9% of global plastic waste is utilised in construction, with significant advances made on the development of recycled composite materials for both structural and non-structural application to maximise added value whilst reducing environmental impacts . Turning plastic into asphalt, bricks, and concrete does double duty: tackling the problem of waste while lessening their use of natural aggregates. One notable approach is to add waste plastic fragments to concrete, which has been found to enhance flexibility and impact resistance with a reduction in the overall environmental footprint of the material. Recent advances in design allow concrete compositions that contain 5–20% recycled plastic not only to maintain structural performance but also to save millions of tonnes of waste from landfill and reduce dependence on virgin materials. What's more, using plastic in long-lived applications keeps materials in circulation far longer than conventional disposal times of 5–10 years, making per-use environmental efficiency significantly greater and aligning reuse with the principles that circular economy. Economic advantages also support its adoption, since plastic-modified construction materials have lower production costs compared to virgin alternatives and are competitively priced, in particular in developing areas where waste collection and processing forces a drop in material prices. Furthermore, increased investment along the waste collection, sorting and treatment chain additionally creates jobs and increases income in newly developing branches of waste management, thereby increasing economic development and reducing poverty [7].

➢ *Upcycling in the Furniture Industry*

The furniture industry is an excellent example of how to successfully integrate upcycling, as a source material for turning recyclable waste wood, textiles and metals into quality design products. The variety of materials is a key advantage in this industry structural supply comes from reclaimed wood, abandoned doors, unused textile fragments and diluted metal: creating one-of-a-kind looks with distinctive features. With design imagination, these constraints on material are turned into unique design features which add both value and character to the product in-spite of the traditional view that they should be limitations. The great thing about upcycled furniture is that there is always an unparalleled value proposition, as each piece is already original. This distinctiveness allows upcycled products to stand apart from their mass-produced counterparts, appealing to consumers interested in uniqueness and providing room for higher than average prices which play a role in the economic sustainability of small-scale craftspeople and local producers . A myriad of design ideas illustrate this passion including re-purposing old doors into practical tables, reclaiming industrial pallet wood to use as a base for chairs and remnant textiles into upholstery. These inventive uses not only prolong the useful life of waste materials, but can also inform (mainstream) design aesthetics, taking what was once a niche upcycled genre and transitioning it into accepted styles. From environmental point of view, the use of such reclaimed materials directly diminishes virgin forest demands thereby controls the loss in biodiversity and destruction of ecosystems. So even if small cutbacks at the level of raw material consumption are not large in relation to the industry as a whole, such measures carry substantial cumulation effects for environmental improvement [8].

➢ *Textile and Fashion Industry*

The textile and fashion sector is considered one of the most immediate and impactful areas for upcycling

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25nov1339

interventions, as an annual estimated 92 million tonnes of waste are produced. Fast fashion's quick production and consumption cycles result in large pre-consumer and post-consumer textile waste, with a significant amount disposed of into landfills. Upcycling approaches aim to tackle this problem by turning discarded clothes and textile cuts into new garments and accessories, thus prolonging the life of materials and minimizing environmental repercussions related to virgin textile production. New business models have also risen to meet the tide. Companies like Patagonia (Worn Wear) and Coach (Re)Loved have created these programs where customers to send the items back for various forms of repair, refurbishment and resale. Not only do these models extend the usability period of garments, but also generate consumers' revenues and brand bonding by way of sustainability-focused consumer engagement. In terms of product redesign, the creative use of textile upcycling is evident as designers produce patchwork garments of fabric leftovers,- accessories made from garment scraps and upholstery made out of old textiles. This innovation shows that, in a field like fashion design, upcycling limitations can serve not to restrict but to foster aesthetic/functional creativity [9].

➢ *Plastic and Polymer Waste*

Plastic and polymer waste are currently one of the major problematic challenges for upcycling due to their environmental burden, landfill build-up, and marine pollution. Chemical upcycling provides a promising route to recycle post-use-waste polymers (for example, PET) into recycled monomers and valuable chemicals which paves the way for a true circular and sustainable value chain. This technique is expected to lower reliance on fossil fuels, reduce CO_2 emission and promote the complete carbon utilization under circular economy concepts. The range of upcycling applications for plastics extends beyond the construction industry. This ranges from Pilot pen made out of post consumer plastic bottles to athletic wear made out the salvaged polymer fibers, to novel packaging solutions derived from recovered plastic waste streams thereby emphasizing the widespread potential of polymer upcycling. At a global scale, upcycling programmes are currently processing around 157 lakh tons of recycled plastic packaging waste every year and the Indian commitment highlights an opportunity for large-scale polymer upcycling in developing economy contexts[10].

VI. ECONOMIC AND ENVIRONMENTAL BENEFITS

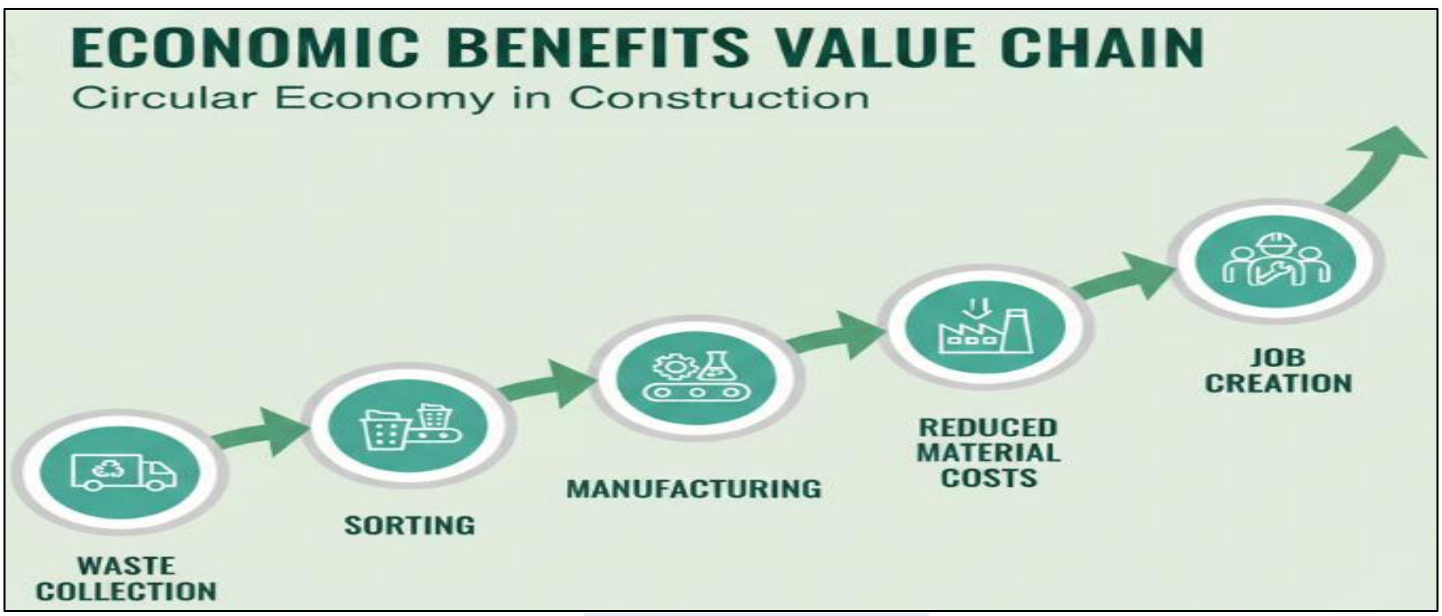

Fig 3: Economic Benefits Value Chain

A. *Environmental Advantages*

Upcycling is a win-win even though it may not end up as glamorous looking final product, primarily because we're taking resources out of the waste stream and preventing them from filling up landfills (where they create methane emissions and leachate). In areas where landfill capacity is restricted, waste diversion also reduces the burden of transportation and demands on current waste facilities. Second, resource conservation is a major advantage because upcycling closes the loop by maintaining materials in the economy while lowering virgin extraction of resources/conserving natural habitats/preventing biodiversity loss and ecological degradations stemming from extraction. For each ton of waste that is upcycled as oppose to dissipated, there will be a certain amount of primary raw material extraction weaved. Upcycling also has a much lower energy requirement than processing virgin materials, because making something from waste usually requires only a fraction of the energy involved in their extraction, cleaning and conversion to an end product through conventional production processes. These cumulative energy

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25nov1339

savings are directly transferred into carbon savings, with studies showing 30–50% less CO2 emission by the upcycled product compared to virgin material depending on the material and its processing. In addition to which, the longer lives made possible through durable upcycled product design expands resource flow from several years to decades, spreading environmental impact over a longer period of use and increasing sustainability benefits even when processes have an initial higher input requirement [11].

B. Economic Benefits

Economic benefits as well, also are derived through the practice of upcycling where a low cost is invested in materials that would otherwise be disposed for landfill. These economical and technical benefits are particularly important for small-hold farmers and companies located in developing countries, they generate reduced input costs allowing companies to be more competitive on the market and better earning margins. Another important upcycling benefit is job creation as these systems create employment in a jobs value chain full (collection, sorting, processing and manufacturing). Formalizing waste management and upcycling companies may create as many as 300,000 production jobs, offering new sources of income and contributing to poverty reduction especially in the least developed areas. Also, circular business models such as product-as-a-service, lease and refurbishment provide long-term income streams compared to traditional single sales. Return into material value at EoL, converting disposal costs into economic benefits by creating take-back schemes and through extended product responsibility. Increasing consumer appetite for environmentally friendly products has widened market possibilities and they allow brands to enjoy up to 15 - 40% higher price premiums from upcyled goods, like manufcatuturers of other products do, simply by being unique and sustainable [11]. Enterprises implementing circular business models consistently achieve cost savings 20–30% on average by saving materials and energy, and prolonging product lifetimes thus strengthening the case for large-scale adoption of circular model principles even further.

C. Social and Institutional Benefits

From a sociological point of view, upcycling increases consumer fidelity by addressing trending sensitivity toward environmental issues, especially within the younger consumers whose purchase is more frequently linked to environment awareness. Transparent material sourcing and processing add to the bonding because it reinforces brand loyalty, trust creation, and connection between consumer and producer [12]. Upcycling systems also contribute to livelihoods, particularly in low-income regions where local waste collection, processing and reuse initiatives can create locally distributed economies and make communities more resilient. Waste management co-operative structures are social capital enhancing and support institution capacity to manage assets more sustainably. Institutionally, the switch towards circular economy models triggers policy innovation. Emerging policy constructs e.g., right-to-repair legislation, extended producer responsibility relations, circular procurement policies bake sustainability into PRG structure and drive businesses towards valuing the long-term stewardship of materials.

D. Design System Integration

Effective CE transitions are dependent on the embedding upcycling principles into the whole of product lifecycle comprehensive design systems. One of the paradigm shifts in materials design is design for disassembly where product is purposely designed to be able to separate easily at its end-of-life for material recycling. E.g., it can involve the choice of materials that are compatible, locating material types unambiguously or construction in modules designed for easy disassembly and hence being able to [14recycle/downcycle individual parts. Designing for longevity is equally important, since prolonged product lifetimes mitigate material throughputs and decrease the environmental burden per unit of delivered service. The disposability factor will be alleviated when modules and components can be replaced or upgraded without needing to dispose the entire product, extending the lifetime of materials in the economy. The development of a materials palette also reinforces the incorporation of design and results in shared use of materials—where appropriate—and standardization, particularly when it comes to use materials derived from waste streams, across product lines. "Evaluations by companies like Toyota illustrate the benefits of keeping material specifications consistent, thus simplifying manufacturing processes and combatting complexity while also enabling efficient end-of-life recovery". Finally, the proliferation of take-back programs more formalizes ItC, and thus bring into focus firm responsibility for post-use product management. Such a funding proposal allows the balance of economic incentives for circular recovery with product designs that make explicit reference to remanufacturing feasibility and material recapture.

E. Organizational Capability Development

Successful circular economy transitions require organizational capabilities extending beyond conventional linear manufacturing expertise:

- Cross-Functional Collaboration: Effective upcycling integration requires collaboration across design, engineering, operations, supply chain, and marketing functions. Siloed decision-making impedes systemic circular integration.

- External Partnership Development: Organizations must develop partnerships with waste generators, collection infrastructure, processing facilities, and component suppliers. Ecosystem development enables access to material flows and specialized capabilities unavailable internally.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25nov1339

F. *Ecosystem-Level Coordination*

Ultimately, circular economy transitions require ecosystem-level coordination involving multiple stakeholders across value chains:

- Industry Association Engagement: Collaborative standard-setting, knowledge sharing, and collective infrastructure development accelerates circular adoption across competitive firms. Industry associations enable horizontal coordination without antitrust concerns.

- Regional Hub Development: Establishing geographic clustering of waste processors, manufacturers, and designers creates economies of agglomeration, reduces transportation impacts, and enables knowledge transfer. Regional circular economy hubs facilitate symbiotic industrial relationships.

- Supply Chain Transparency: Blockchain and digital tracking technologies enable material provenance documentation and circular flow monitoring. Supply chain transparency builds consumer confidence while enabling operational optimization.

VII. GLOBAL IMPLEMENTATION PERSPECTIVES

A. *Developed Economy Models*

Developed economies benefit from established infrastructure, consumer purchasing power, and regulatory capacity enabling sophisticated upcycling implementation. Germany's Extended Producer Responsibility frameworks, for instance, established legal responsibility for product end-of-life management, driving innovation in circular product design across consumer electronics and packaging.

Corporate leadership through voluntary commitments—Patagonia's commitment to material circularity, Unilever's waste elimination targets, and Nike's manufacturing process redesign—demonstrates that sustainability commitments drive innovation and competitive advantage in mature markets

Consumer willingness to pay premiums for sustainable products in developed markets enables business model profitability despite higher processing costs. European and North American consumers increasingly prioritize sustainability, creating market demand supporting premium pricing.

B. *Emerging Economy Applications*

Developing economies demonstrate distinct circular economy characteristics reflecting different constraints and opportunities. India's transformation of 157 lakh tonnes of plastic packaging waste represents the world's most ambitious circular implementation, driven by waste management necessity and emerging entrepreneurship. Informal waste management sectors in developing economies, while unregulated and sometimes hazardous, have historically operated circular principles through necessity. Formalizing and professionalizing informal waste management creates employment while improving working conditions and environmental standards. Community-based upcycling enterprises in emerging economies generate livelihoods through creative material transformation. Women-led cooperatives in Sub-Saharan Africa and South Asia demonstrate that upcycling creates dignified employment alternatives to extractive industries.

➢ *Technological Innovation*

Material innovations are transforming the quality and performance of upcycled materials in a meaningful way. Recent studies have aimed to maximize material performance, processing productivity and performance durability and hence matched or even over performed their virgin counterparts? . Nanomaterials, additive manufacturing and other technologies have helped to drive the trend towards more tailored solutions for upcycled products; it is now possible for designers to specify properties such as a material’s structure, thermal or tensile capabilities when designing an end-upcycling product.

➢ *Artificial Intelligence and Automation:*

Sorting of waste with the use of "AI" technology Sorting technologies based on "AIs" are changing the approaches to waste management by making them faster through advanced material recognition. Computer vision systems can recognize colors, shapes and polymer types in real time to significantly enhance the sorting effectiveness and minimize contamination in recycle streams. It's also minimizing labor and increasing consistency, which will make large-scale upcycling more viable from a cost perspective.

- Biotechnology: Recent biotechnological advancements are paving the way for chemical upcycling through enzymatic and microbial processes. Customized enzymes that degrade materials like PET or composite polymers, traditionally resistant to recycling, help recover material with less heating and energy. This biological path provides an eco-friendly alternative to the traditional high-heat or chemical-intensive recycling processes.

- Digital Tracking: Distributed trust and transparency in supply chains using blochcain and IoT-based systems are giving complete visibility to product histories. By tracking each transaction or transformation that a material goes through, digital platforms enable companies to certify recycled content, stop waste leakage and optimize circular supply chains. Furthermore, the trust and responsible purchase of products are encouraged by making sustainability information verifiable to consumers using these technologies.

C. Business Model Evolution

- Circular Service Models: Companies transform from selling into service-based organisations in circular business models to they can offer leasing, rental or product-as-a-service solutions. By keeping product ownership, manufacturers are motivated to create products that can last, be repaired, or recoup value. It is a way to give very long lifetimes and effective material recovery when things reach end-use[13].

- Cradle-to-Cradle Design: Cradle-to-cradle (c2c) design favors either safe biological decomposition or full technical recovery into new materials. "The goal is to make waste disappear by making everything cyclical, where nothing goes to waste." This mindset is one of profound circularity: companies that adopt it are looking past mere recycling and toward entire closings of the loop regarding product creation and waste [14].

- Shared Economy Platforms: Sharing models — facilitated by digital businesses — drive efficient use of resources as the same good or service is shared among several users. Models like sharing of equipment, second-hand clothes or mobility services diminish the demand for ownership and with it material requirement and ecological impact. These bridges allow devices to be as efficient as possible, and waste not.

D. Policy and Governance Evolution

- Circular Economy Legislation: Around the world, governments are implementing legislation and policies that seek to require circular practices through waste reduction goals, product design mandates and extended producer responsibility. Regulations like the Action Plan for a Circular Economy in the EU, and China's circular economy law offer national roadmaps that tilt industries toward sustainability, and go great lengths to provide firm legal incentives for upcycling.

- Carbon Pricing: Carbon pricing be it carbon taxes or cap-and-trade programs holds industries responsible for greenhouse gas emissions. By attaching an economic value to carbon-intensive production, such policies increase the price of extracting virgin material and sweeten the financial proposition of upcycled substitutes. This transition is driving companies to implement low-carbon, circular material strategies.

- Right to Repair Legislation: The right-to-repair legislation would force companies to sell repair tools, spare parts and offer the official technical documentation. These laws extend the life of products, minimize waste and encourage maintenance rather than disposal. Such policies are directly in support of the principles of durability and circular product design by facilitating repair.

- Circular Procurement: Government-initiated circular procurement policies aim to purchase products that are recyclable, reparable or made of upcycled materials. Public demand (at large scale) in the public sector is a powerful pull factor in the market, inducing sectors to invest in circular products and infrastructure. This incentive drives faster adoption and creates stable markets for upcycled materials.

VIII. CONCLUSION

When integrated within innovative design strategies, upcycling waste, constitutes the means that shapes the increasing inroad of the society towards a circular economy. Design plays the dominant role in determining product lifecycles and environmental impacts, placing designers at the heart of any move to sustainability. There is evidence that upcycling provides environmental, economic and social value at the same time, which is appealing to industries, policymakers, and communities. But for significant large-scale deployment, systemic integration is necessary – connecting product design with supply chain infrastructure, regulation support, tech innovation and consumer involvement. Supply chain fragmentation, competition with virgin materials and low public awareness can be addressed through harmonised policy instruments like Extended Producer Responsibility, carbon pricing and right-to-repair laws combined with infrastructure investments in collection and sorting. Global examples, such as large-scale recycling programs in India, right down to corporate- and community-led upcycling programs, indicate that circularity is already possible and effective. At the end of the day up cycling is not a stand-alone solution but a facilitator within larger circular systems, which allow for resource management and environmental responsibility in societies that are reaching crucial environmental tipping points.

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