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# Construction and Demolition Waste (C&DW) Management

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**Abstract**

*Construction and Demolition Waste (C&DW) constitutes a substantial fraction of the global solid waste stream and presents a critical impediment to sustainable development. This paper critically examines prevailing practices, emerging trends, and pressing concerns in C&DW management worldwide, with particular emphasis on Asia and Nepal. Established practices such as recycling, reuse, material recovery, selective demolition, and the integration of digital technologies including Building Information Modeling (BIM) and artificial intelligence for waste sorting are reviewed in relation to their efficacy and scalability. While developed economies have advanced integrated systems underpinned by stringent regulatory frameworks and market-based instruments, most developing regions remain constrained by fragile policy environments, financial limitations, technical deficits, and a reliance on informal waste economies.*

*The circular economy (CE) paradigm offers a transformative framework to reconceptualize C&DW as a secondary resource, reduce dependence on virgin materials, and diminish the sector's carbon footprint. By reinforcing lifecycle awareness, material efficiency, and innovative business models, CE strategies align directly with broader global sustainability agendas. However, implementation remains highly uneven, largely due to entrenched systemic, economic, and institutional barriers. Overcoming these challenges necessitates targeted investment, adaptive policy reform, inclusive stakeholder engagement, and accelerated technological innovation. Collectively, these measures are essential for advancing C&DW management toward a circular trajectory and unlocking its potential as a catalyst for sustainable growth within the construction sector.*

***Keywords:*** *Construction and Demolition Waste (C&DW), Recycling, Circular Economy, Building Information Modeling (BIM), Sustainable Construction, Waste Management Policy, Material Recovery, Informal Sector*

## 1. Introduction

The rapid rate of urbanization and population growth has therefore greatly increased the demand for housing, urban development, and infrastructure globally (Lee et al., 2024). Building, rebuilding, and reconstruction of bridges, roads, and buildings have therefore become increasingly prevalent, leading to an increase in the generation of construction and demolition waste (C&DW) (Dodampegama et al., 2024). C&DW is a variety of materials that are manufactured in the construction, renovation, or demolition of built structures (Wang et al., 2019), and also results from natural occurrences such as earthquakes, hurricanes, and floods (Radica et al., 2024).

Globally, C&DW constitutes a considerable fraction of municipal solid waste and varies between 20% to 50% of municipal waste in the majority of developed nations (Menegaki & Damigos, 2018). For example, in 2020, construction activities generated approximately 38.4 million tons of waste in the European Union, 600 million tons in the United States, 66.2 million tons in the United Kingdom, and 2,360 million tons in China (Yuan et al., 2023; Gao et al., 2024). Despite this, even large quantities of C&DW are landfilled or even dumped in open piles, causing serious environmental problems such as air and water contamination, noise pollution, and landfill capacity depletion at a very rapid rate (Jahan et al., 2022; Nawaz et al., 2023).

Recycling has emerged as one of the significant solutions for reducing C&DW environmental loads. Recycling decreases landfill demands, conserves natural resources, and enhances sustainability (Patil et al., 2024; Caferra et al., 2023). Recycling supports the principles of the circular economy (CE), which assures waste minimization generation, reuse, and recycling of materials through their lifespan (Maliha et al., 2023; Balletto et al., 2021; Camana et al., 2021). CE principles also emphasize the following actions as Refuse, Rethink, Repair, Refurbish, Remanufacture, Repurpose, and Recover to reduce environmental impacts while increasing resource efficiency (Yang et al., 2022).

These efforts must be grounded in the three pillars of sustainable development-environmental conservation, economic growth, and social justice-to construct more resilient and equitable systems (Yilan et al., 2022). On a policy level, the European Union's Waste Framework Directive (2008/98/EC) has served as the gold standard of advanced waste management. It promotes the waste hierarchy, with the objective of reaching 70% recovery from non-hazardous C&DW and promoting selective demolition and safe handling of materials to facilitate high-quality recycling (European Parliament & Council, 2008).

This review is looking to examine the composition and impact of C&DW, assess the effectiveness of current recycling operations, discuss significant management issues, and provide insight into the way forward, notably within circular economy transformations.

## 2. Methodology

This review paper adopts a qualitative and narrative method to synthesize and critically examine recent progress, practices, and innovations in the management of construction and demolition waste (C&DW), circular economy principles, and region-specific challenges, including in Nepal. The existing scholarly literature, policy reports, and technical reports between the years 2012 and 2024 were systematically retrieved from databases such as ScienceDirect, ResearchGate, MDPI, SpringerLink, and Google Scholar. A list of keywords was used to attain a broad spectrum of materials, including terms such as "construction and demolition waste," "C&DW recycling," "circular economy in construction," "building information modeling (BIM) and waste," "sustainable construction," and "C&D waste management." The inclusion criteria were peer-reviewed journal papers, case studies, meta-analyses, government reports, and international directives that spoke about some facet of C&DW, such as waste generation, material recovery, reuse strategies, policy implications, and technological interventions. Exclusion criteria removed sources that lacked sufficient relevance, methodological clarity, or peer-review confirmation. A number of sources were selected and reviewed, and information was thematically collated into key topics covering C&DW composition, current management practice, institutional and economic barriers, best practice of developed and developing nations, and emerging innovations such as BIM integration and AI-optimized recycling facilities (Dodampegama et al., 2024; Gao et al., 2024). Specific focus was given to developing country-specific research, particularly Nepal, to strengthen the applicability of global models to local waste problems. This allowed for the identification of evolving trends, important policy and technological gaps, and practical steps for steering towards sustainable and circular construction waste management.

## 3. Composition of Construction and Demolition Waste

Construction and demolition waste (C&DW) typically comprises waste generated during demolition (90 percent of C&DW), and waste from construction (10 percent of C&DW) (Rodriguez-Morales et al., 2024). Demolition and construction waste streams have very different physical and material characteristics where construction waste is generally cleaner and uniform in quality, making it simpler for recycling, whereas demolition waste is often very heterogeneous, especially in post-disaster scenarios like earthquakes (Wang et al., 2024). Traditional C&DW may involve multiple materials including concrete, brick, tile, wood, plastics, ceramics, metals, glass, cardboard, gypsum, bituminous mixtures, and the excavation of soils (Wang et al., 2024).

Demolition waste can be classified into three main categories of material, based on the potential for reuse and risk; (1) reuse value, related to the total percentage of waste that consists of the hard materials potential for reuse. These hard materials generally consist of 40-85% hardened concrete, 10-25% ceramics, and 20-25% bricks and tiles, are frequently reused or recycled into cementitious precursors; (2) recyclable value through easy recycling like glass and metals which represent less than 10% of the waste stream; and (3) hazardous components (i.e., lighting systems, paints and coatings, and materials containing asbestos) (Osmani, 2011; Radica et al., 2024).

The composition of C&DW can differ widely depending on the type of project and location. For example, concrete waste can represent between 40 and 85% of the total waste on site, depending on the construction activities (Yuan et al., 2024). In many EU countries EoL (End-of-Life) concrete is greater than 40% of the total C&DW, and in someareascould be 60 to 70% for the region. This leads to feasible strategies such as urban mining, as recycling this material effectively and efficiently reduces reliance on virgin materials, reduces reliance on landfills, and aims to reduce carbon emissions which acts toward sustainability and resource efficiency goals (Yuan et al., 2024).

Construction material in most Asian regions, including India and Thailand, contains a higher proportion of organic and mixed material such as wood, bamboo, and packaging due to traditional construction and the involvement of the informal sector (Chandrappa & Das, 2012; Luangcharoenrat et al., 2019).

In Nepal's Kathmandu Valley, the dominant compositions of C&DW are mortar waste, concrete, and bricks. Increases in volumes of post-2015 Gorkha earthquake waste indicated the system's vulnerability and the need for better segregation and material recovery policy. Most of the waste is sorted manually by undocumented workers, and recycling quality is thus variable, with inefficient application of the materials (Tuladhar et al., 2016).

C&DW classification practices differ region-wise and influence the companion waste management strategies. Materials are sorted as inert-like earth, soil, rocks, slurry, and crushed concrete-or non-inert-like wood, vegetation, packaging, and other organic wastes-based on their chemical and biological stability (Villoria Sáez & Osmani, 2019). Physical heterogeneity of these materials creates significant recycling challenges, particularly in producing nearly homogeneous mono-material streams with minimal contamination levels. Impurities such as organic matter, imbedded metal, and harmful substances like asbestos can negatively impact the quality of the reclaimed products and limit their application for building construction. Therefore, comprehensive information regarding C&DW composition becomes unavoidable to increase recycling levels, enable more effective sorting measures, and overall quality of reclaimed material.

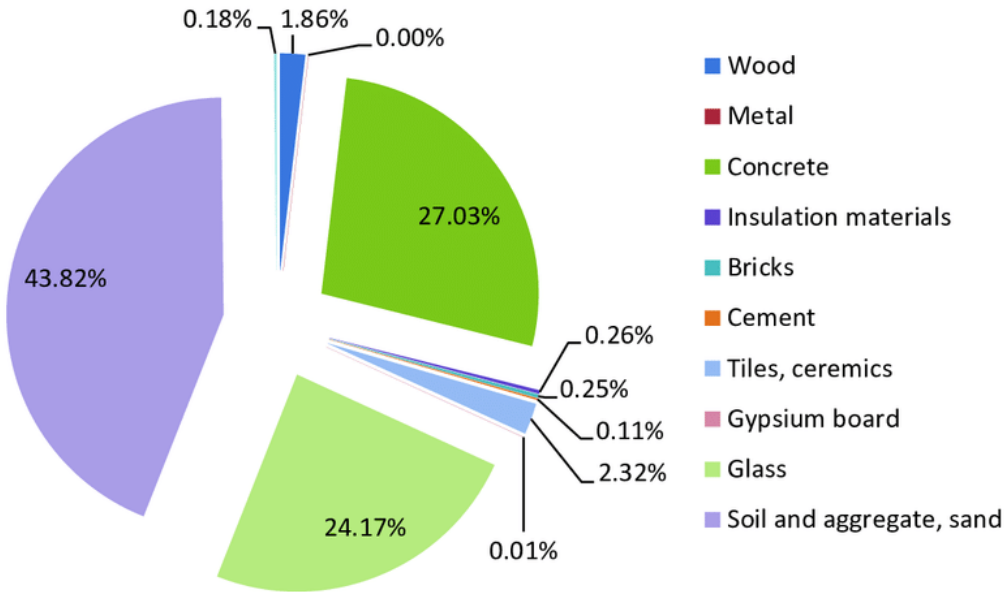


Figure 1: Composition of construction waste materials disposed of at illegal dumpsites (Source: Mahayuddin et al., 2008)

## 4. Sources of Construction and Demolition Waste

Construction and demolition waste (C&DW) originates from a variety of sources across the building lifecycle. The primary sources can be categorized into construction, renovation, and demolition activities, natural disasters with each contributing differently in terms of waste quantity and material type (Osmani, 2011; Yuan et al., 2024).

### 4.1 Construction Activities

Waste generated during the construction phase often results from over-ordering of materials, improper storage, design changes, human errors, and off-cuts from cutting materials like wood, concrete, or tiles (Luangcharoenrat et al., 2019). These wastes are usually cleaner, less contaminated, and easier to recycle compared to demolition waste.

### 4.2 Demolition Activities

Demolition is the largest contributor to total C&DW, accounting for up to 90% of the volume in some contexts (Rodriguez-Morales et al., 2024). The process of dismantling buildings results in mixed materials such as concrete, bricks, metals, wood, and hazardous substances like asbestos-containing materials. In disaster-prone regions, large volumes of heterogeneous waste are generated due to earthquake or flood damage, which complicates recycling efforts (Radica et al., 2024).

### 4.3 Renovation and Remodeling

Renovation and repair work also generate substantial waste, especially from interior refurbishments where tiles, fittings, plaster, and insulation materials are discarded. These works often involve partial demolition, producing both recyclable and non-recyclable fractions (Wang et al., 2024).

### 4.4 Infrastructure Development

Road construction, bridge building, and infrastructure upgrades generate large quantities of asphalt, concrete, and excavation waste (Villoria Sáez & Osmani, 2019). Unlike building C&DW, infrastructure waste is typically more inert and bulkier.

### 4.5 Excavation and Land Clearing

Excavated materials such as soil, rocks, and sand from site preparation are another major source of C&DW. Though inert, they can burden landfills if not reused in landscaping or backfilling (Chandrappa & Das, 2012).

### 4.6 Natural Disasters

Earthquakes, floods, hurricanes, and tsunamis generate massive quantities of debris, often in an unplanned and urgent context. These materials can include collapsed concrete, timber, roof tiles, furnishings, and hazardous materials such as oil containers and asbestos (Radica et al., 2024). Post-disaster C&DW is usually highly mixed, contaminated, and logistically difficult to manage due to the urgency of relief efforts and the absence of formal segregation processes.

## 5. Current Practices in C&DW Management

### 5.1 Recycling, Reuse & Recovery

C&DW management typically includes the collection, sorting, transport, reuse, recycling, landfilling, and resource recovery of materials-supported by comprehensive planning and monitoring frameworks (Yuan et al., 2024). Recycling broken concrete into recycled aggregates (RA) conserves natural resources and reduces $CO_2$ emissions (Yuan et al., 2024). In the European Union, recovery rates vary between 10% and 95%, averaging 89% in the EU-28, thanks to established waste separation systems and life-cycle thinking (Villoria Sáez & Osmani, 2019; Banias et al., 2022). Recycling methods typically involve two-stage crushing, washing, and contaminant screening. Advanced techniques such as vertical shaft impactors and autogenous cleaning improves aggregate quality by removing adhered mortar (Sivamani et al., 2021; Trivedi et al., 2023). Nonetheless, ensuring material purity remains critical, as contamination (e.g., fine particles, organics, heavy metals) can limit market acceptance and usability (Serranti & Bonifazi, 2020).

### 5.2 Selective Demolition

Selective demolition sorting valuable materials on-site before full demolition boosts recovery rates and reduces contamination. Although often more labour-intensive and costly, the approach is recommended through EU circular economy policies and shows increasing uptake in some pilot projects (Villoria Sáez & Osmani, 2019; Al-Raqeb et al., 2023).

### 5.3 Informal vs. Formal Sector Roles

In developing nations, informal workers frequently perform manual sorting of C&DW under precarious and unsafe conditions; while this supports livelihoods, it results in inconsistent recovery quality (Tuladhar et al., 2016). In contrast, formal collection and processing systems,common in Europe-offer better-standardized outputs but require higher investment and regulatory oversight (Villoria Sáez & Osmani, 2019).

### 5.4 Digital Tools: BIM, AI & Automated Sorting

Digital tools are emerging as game-changers in C&DW. Building Information Modeling (BIM) supports material quantification, design-for-deconstruction, and waste reduction during planning (Chandrappa & Das, 2012). Artificial Intelligence (AI) and machine vision are being piloted for automated sorting such as the CODD image dataset that demonstrates improved object recognition for recycling (Demetriou et al., 2024). Despite this, adoption in regions like Hong Kong is slow due to cost and technical training barriers (Bao et al., 2020). Stakeholder engagement and capacity-building are essential to integrate these systems more widely.

## 6. Challenges in Construction and Demolition (C&D) Waste Management

An effective C&D waste management (C&DWM) approach must strike a balance between economic feasibility, policy and regulatory consistency, market readiness, sustainability, and appropriate business models (van den Berg et al., 2023). Each of these dimensions presents distinct challenges that hinder the successful implementation of circular economy (CE) principles in the construction sector.

### 6.1. Economic Feasibility

In many cases, the cost of recycling C&D waste (including transportation, labor, and sorting) exceeds the cost of landfilling, especially in developing countries with resource constraints (van den Berg et al., 2023). Although reuse-oriented demolition can yield environmental benefits and long-term savings, it typically involves higher initial labor costs (Roussat et al., 2009; Bentaha et al., 2020).

In Asia, particularly in Nepal, the lack of large-scale recycling infrastructure and investment further inflates recycling costs, making informal dumping more common. Construction waste is often mixed with municipal waste due to poor segregation practices and limited financial incentives for recycling (ADB, 2020; Sapkota, 2023).

### 6.2. Policy and Regulatory Inconsistencies

Despite the EU's push for CE integration, a lack of harmonized definitions and procedures among member states has led to fragmented waste management systems (Colmenero Fonseca et al., 2023; D'Adamo et al., 2024). Ghisellini et al. (2018) emphasize that such gaps reduce recycling incentives and perpetuate backfilling as a disposal method. The regulatory variance creates barriers to cross-border knowledge sharing and standardization (Ghaffar et al., 2020; Alhawamdeh et al., 2024).

In Nepal and other South Asian nations, national-level regulations on C&D waste are either weak or nonexistent. Most municipal plans do not distinguish between household and construction waste, resulting in regulatory blind spots and enforcement challenges (UN-Habitat, 2018; Sapkota, 2023).

### 6.3. Market Readiness and Acceptance

Recycled materials often suffer from lower quality (downcycling), leading to skepticism among construction professionals and clients (Allwood et al., 2011; Otasowie et al., 2024). Resistance is compounded by restrictive standards such as those limiting recycled aggregates in structural concrete (de Andrade Salgado & de Andrade Silva, 2022; Plaza et al., 2021) and the limited availability of commercial-grade recycled products (Papamichael et al., 2023).

In many Asian contexts, including Nepal, there is minimal awareness or confidence in recycled materials due to the absence of product standards and labeling systems, further deterring their adoption in mainstream construction projects (ADB, 2020; Victar & Waidyasekara, 2024).

### 6.4. Sustainability Assessment Limitations

While Life Cycle Assessment (LCA) is increasingly employed, its application remains inconsistent across project phases (Stylianou et al., 2023; H & S, 2022). Studies recommend shifting focus toward early-stage interventions during design to fully realize CE benefits (Islam et al., 2024; Li et al., 2023). Integrating sustainability into early planning is also essential to support SDG 12 (responsible consumption and production) (D'Adamo et al., 2025).

### 6.5. Inadequate Circular Business Models

Circular business models are key to CE success but are underdeveloped globally (Ingrao et al., 2025). Many demolition contractors lack decision-support tools for planning sustainable waste strategies (van den Berg et al., 2023; Bentaha et al., 2020). Moreover, certifications such as environmental labels and consumer-driven recognition (Colasante et al., 2024) are not widely adopted, despite their ability to enhance market trust and transparency (Chioatto et al., 2024).

Across Asia, including Nepal, business models for CE are rarely implemented due to low private sector participation, weak incentives, and a lack of scalable partnerships between public institutions and private waste processors (Sapkota, 2023; ADB, 2020).

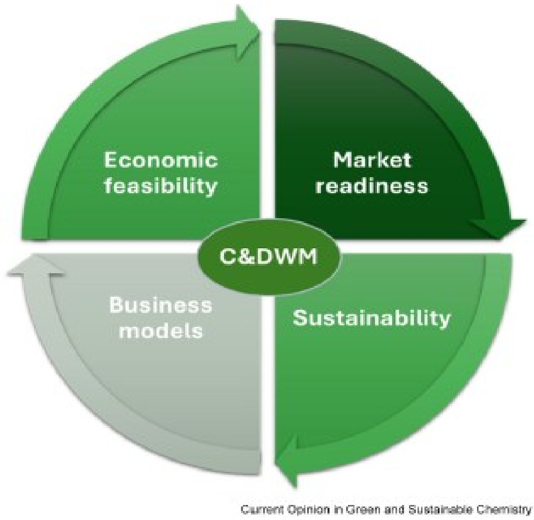


Figure 2: Elements of an Effective Construction and Demolition Waste Management (C&DWM) Approach (Source: Papamichael et al. (2024))

## 7. Future Directions

### 7.1 Merging Circularity in Policy & Design

Circular design techniques-such as design-for-deconstruction, modularity in construction, and material passports-must be incorporated into initial building cycles and supported by policy. The European Environment Agency (2020) explains that the incorporation of proper regulatory systems and clearly established recycling criteria would facilitate a shift from low-grade backfilling to high-grade reuse of C&D waste.

### 7.2 Upscaling Digital and Smart Technologies

Interoperability of Building Information Modeling (BIM) and Geographic Information Systems (GIS) improves precision in waste forecasting, resource planning, and overall project management (Oti et al., 2020). IoT-based sensors and AI-based sorting systems also further enhance real-time waste monitoring and sorting, as pioneered by Zolfagharian et al. (2018), but large-scale deployment waits on cost reduction and providing technical training.

### 7.3 Emerging Circular Business Models

To recycle economically, new business models such as materials leasing, reverse logistics, and product-as-a-service need to emerge. These, along with monetary incentives such as green bonds or purchasing requirements, can significantly drive investment in recycling plants and service-based construction activities.

### 7.4 Formalising the Informal Sector

In most developing nations, informal operators perform the majority of material recovery in C&D activities. Dias et al. (2018) present compelling evidence of formal integration of informal laborers-through training, certification, and protection-to improve recovery performance along with ensuring social inclusion.

### 7.5 Data Transparency, Education & Research

Openness to construction material flow data and circular performance indicators facilitates enhanced policy planning and innovation. Training higher education curricula on circular design principles will shape future experts. Xue et al. (2021) promote expanded academic and industrial R&D in synergies of BIM-LCA recommend upscaled research on waste tracking to piloted and large-scale application.

Table 1: Summary Table of C&D Waste Types and Management Techniques

| C&DW Type | Management Technique |
|---|---|
| Concrete and Masonry (Bricks, Tiles) | Crushed to recycled aggregates; used in road sub-base, pavement, or as cement replacement. (Yuan et al., 2024; Rodriguez-Morales et al., 2024) |
| Wood and Timber | Recycled in construction or furniture; bioenergy generation from waste wood. (Chandrappa & Das, 2012; Villoria Sáez & Osmani, 2019) |
| Metals (Steel, Iron, Aluminum) | Sorted and sent for melting and reuse in metal industries. (Osmani, 2011; Patil et al., 2024) |
| Glass and Ceramics | Crushed for aggregate or insulating material; used in tile and asphalt. (Gao et al., 2024; Serranti & Bonifazi, 2020) |
| Plastics and Packaging Waste | Recycled into plastic pellets, reused, or used in energy recovery. (Camana et al., 2021; Jahan et al., 2022) |
| Gypsum and Drywall | Processed to be recycled into new plasterboards or soil conditioners. (Ghisellini et al., 2018) |

| | |
|---|---|
| Soil and Excavation Waste | Reused in land reclamation, backfilling, or landscaping. (Luangcharoenrat et al., 2019; Papamichael et al., 2023) |
| Hazardous Waste (Asbestos, Paints) | Requires special treatment and disposal in controlled facilities. (Serranti & Bonifazi, 2020; Radica et al., 2024) |

## 8. Implications for Nepal

Referring to the table and global best practices, Nepal can significantly increase C&DW management through initiating segregation at the source, especially in cities like Kathmandu where most of the waste is mixed and sorted manually (Tuladhar et al., 2016). Promoting crushing plants for bricks and concrete, establishing metal and wood collection centers, and coordinating with industries for timber reuse and plastic recycling would all improve circular flows. Further, formalizing the informal sector's contribution, backed by training and protection, can upgrade recycling quality and livelihood. For dealing with hazardous waste like asbestos, Nepal must strengthen regulations and adopt specialized disposal facilities. Municipalities must also adopt digital tools like BIM for better planning, promote selective demolition, and invest in pilot-scale recycling plants that can later be scaled up. These actions, as tailored to the Nepalese socio-economic context, will convert C&DW from an environmental hazard to a sustainable development resource.

## 9. Conclusion

Rapid urbanization has sharply increased construction and demolition waste (C&DW) worldwide. Although circular economy (CE) principles offer sustainable solutions, adoption remains constrained by economic, technical, and regulatory barriers. Landfilling dominates due to its lower short-term costs, despite resource depletion and environmental harm. Advances in recycling technologies, market incentives, and EU policy reforms show potential, yet global progress requires stronger policy alignment and industry collaboration. Emerging tools such as AI-driven sorting, hyperspectral imaging, BIM, and LCA-based decision systems—enhance recovery efficiency, reuse design, and material traceability. However, operationalizing CE demands institutional frameworks, robust data systems, and incentives that offset the cost disadvantage of recycling. Improving sorting precision and material quality is crucial to build market confidence in secondary construction materials.

In Asia, particularly Nepal, C&DW management remains nascent. Kathmandu illustrates common issues: weak regulation, poor segregation, and insufficient infrastructure. Recycling initiatives are limited, highlighting the need for locally adaptive approaches such as integrating informal operators, piloting recycling plants, and incentivizing source segregation. Partnerships among municipalities, contractors, NGOs, and academia could scale context-specific models. Achieving a circular C&DW system requires blending technological innovation with inclusive governance and sustainable business models. For South Asia, balancing global CE frameworks with grassroots engagement is essential. With targeted investments, policy reform, and community participation, C&DW can evolve from a burden into a catalyst for sustainable development and green employment.

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