

MARCH 2026

VIEWPOINT

OFFICIAL QUARTERLY MAGAZINE OF CEAI

www.ceai.org.in

Solid Waste Management and the Need for Stricter Waste Management Policies



MASTERS OF INFRASTRUCTURE, ARCHITECTS OF PROGRESS.

Since 1976, Shah Technical Consultants has been shaping essential infrastructure with expertise and dedication. With a strong focus on water and wastewater management, we have established a reputation that spans India and beyond. Decades later, our mission remains the same: delivering solutions that stand the test of time and make a real difference.

OUR SECTORS



Sewerage



Water Supply



Stormwater



Dams and Water Resources



Tourism Infrastructure



Solid Waste



Roads & Bridges



Management Consulting

SHAH TECHNICAL CONSULTANTS PVT. LTD.

No. 407, Raheja Centre, Nariman Point, Mumbai - 400 021.

stc@stc.co.in | www.stc.co.in

INDIA

Assam | Chattisgarh | Gujarat | Haryana | HP | J&K | Jharkhand | Karnataka | Kerala | Ladakh | MP | Manipur
Maharashtra | Meghalaya | Orissa | Punjab | Rajasthan | Tamil Nadu | Telangana | UP | West Bengal

INTERNATIONAL

Angola | Bangladesh | Burundi | Lesotho | Ethiopia | Fiji | Ghana | Maldives | Papua New Guinea | Malawi
Mozambique | Myanmar | Namibia | Rwanda | Tanzania | Uganda

VIEWPOINT

OFFICIAL QUARTERLY MAGAZINE OF CEAI

www.ceai.org.in

CONTENTS

Art#	Article Title & Authors	Page#
	About CEAI, Aims & Objectives, VMV, Code of Ethics	iii
	Greetings from President	viii
	Message from Chief Editor	ix
	Message from Guest Editor	xi
	Articles	
1	Gold from Garbage: Legacy Solid Waste Management as a Policy Imperative for Sustainable Urban Infrastructure - Dr Rajdeep Bhattacharya (hc)	1
2	Taiwan's Solid Waste Management Achievements and Transition to Circular Economy - Justin Wang, Dr Chun-Hsu Lin	5
3	The Recycling Conundrum - Dr Prasad Modak	11
4	The Great Indian Waste Paradox: Bridging the Chasm Between Policy and Reality - Diptarup Kahali	19
5	The 7 Habits of Highly Effective Waste Management: Turning India's Waste Crisis into a Strategic Business Opportunity - Pranav Sinha	26
6	Waste Management Policies in India: Policy Gaps, Implementation Challenges, and Pathways for Effective Governance - Pravinjith K P	32
7	Reforming Solid Waste Management in India: Strategy, Structuring, and Circular Transformation -Era Singla	42
8	Screening Model for Evaluation of MSW Treatment Technologies with Special Context to Indian Conditions - Dr Alok Kumar, Ganesh Kumar Singh	51
9	Economic Analysis of Solid Waste Management and Biogas Plant - A Case Study - Kousik Ahmed, Md. Rucunuzzaman, A K M Shamsuzzoha, Dr S K Bagui, Md. Saidur Rahman	61
10	Extended Producer Responsibility (EPR): A Strategic Instrument For Sustainable Waste Management And Circular Economy - Himanshu Tilwankar	70
11	Garbage by Choice, Not by Chance: India's Solid Waste Management Crisis - Vandana Randhawa	75
12	Solid Waste Management: Producer and Policy Perspective - Dr Vivek S Agrawal	79
13	Circular Recycling of Organic Kitchen Waste in Construction Labour Camps - Kousik Ahmed, Md. Rucunuzzaman, Amit Kumar Chakrabarty, Dr S K Bagui	83
	ETHICS CORNER - Umesh Shrivastava	91
	CEAI News: CEAI Academy ; CEAI Events; Other News; Forthcoming Programmes ViewPoint June 2026	94
	Tech Quiz	102

Editorial Board Members

Ms Sayona Philip
Mr Prashant Kapila
(Ex Officio)

Mr A P Mull
Mr Somenath Ghosh

Mr Sachin Pant
Ms Veera Biradar

Ms Neha Jain
Ms Vandana Radhawa



Join CEAI

the Apex Body of Consulting Engineers

With Over 60 Years of Service to the Profession



CEAI

- ***promotes the interest and works to enhance the status of the Consulting Engineering profession in India***
- ***advocates global networking and co-operation***
- ***helps keep one in touch with the latest professional updates, including technical, regulatory, legal, financial, health & safety, and environmental updates***
- ***provides an excellent opportunity to present papers in seminars and technical lectures organised from time to time***
- ***aids in skill development through regular training programmes including training on FIDIC Conditions of Contract and sharing of legal issues in the Indian context***
- ***takes up various issues confronting the profession with government and other authorities from time to time to make the conditions of engagement on a fair and equitable basis so that Consulting Engineers can function in the best interest of the country***
- ***promotes the cause of Women Engineers with a view to ensuring a rightful place for them in the engineering consultancy arena***
- ***helps to develop Young Engineers to be Future Leaders***

Join Now & Grow

About CEAI

Consulting Engineers Association of India (CEAI) is the apex body of consulting engineers in India having membership of organisations as well as individuals. The membership represents large, medium and small consultancy companies/ organisations both in the private and public sector and eminent individual consultants. EPC organisations are also members of CEAI since they have planning and design engineers, apart from construction management consultants.

CEAI is the Member Association, of the International Federation of Consulting Engineers, commonly known as FIDIC, the acronym for *Fédération Internationale Des Ingénieurs-Conseils*, representing the Consulting Engineering Fraternity in India. FIDIC has membership of more than 100 Member Associations of various countries and is headquartered in Geneva.

CEAI was incorporated in 1996, with the merger of two leading national associations, Association of Consulting Engineers (India) {ACE(I)}, incorporated in 1960 and National Association of Consulting Engineers {NACE}, incorporated in 1976. Thus, CEAI has behind it six decades of accumulated knowledge and experience.

- CEAI promotes the interest and works to enhance the status of the consulting engineering profession in India
- CEAI advocates global networking and co-operation
- CEAI's activities include:
 - Quality development of Consultants.
 - Productivity enhancement.
 - Promotion of ethical practices.
 - Facilitation and interaction with government and other authorities/ bodies to streamline and improve the system of engagement of consultants.
- Regional Centres in Chandigarh, Bengaluru, Kolkata and Mumbai to broad base activities.

Aims & Objectives

- Promote the professional interest and establish the rights and privileges of the status of consulting engineering profession in India
- Represent the consulting engineering profession within India and abroad. Connect the members locally and globally.
- Disseminate among the members information on all matters pertaining to engineering, especially knowledge and information related to consulting engineering profession by way of holding Conferences, Seminars, Courses, Workshops, Field/ Site Visits, etc. and thus assist in Continuing Education for the Professional Development of Members.
- Act as the principal champion for consulting engineering profession through constantly informing and educating the public and lawmakers about key engineering issues and making it possible to have the voice of the profession heard by the policy makers.
- Promote adoption of equitable forms of contracts and other documents used in consulting engineering practice.

Vision

- To represent, promote and enhance the status of consulting engineers in India as an honoured and dignified profession for nation building and propagate Indian engineering consultancy globally.

Mission

- Promote interests of the consulting engineering profession nationally and internationally.
- Promote sustainable, safe and sound engineering practices.
- Upgrade engineering knowledge and skill.
- Propagate code of professional ethics, safety, health and environment.

Values

- Commitment with tenacity to high ethical values, integrity, professionalism and achieving technical excellence and inclusive development.

Code OF Ethics

- CEAI has adopted a Code of Ethics, to which all members must abide. It is not just for the quality of the jobs they work on, but for the safety and well-being of the public at large.
- CEAI is the profession's most respected voice on the practice of ethical engineering.
- The code specifies the responsibilities of Consulting Engineers towards the society as well as the profession, to refrain from performing services unless competent to do so, to act in the legitimate interest of client, to be impartial, and to maintain ethical relations with other consultants.

CODE OF ETHICS

PREAMBLE

Engineering consultancy services make significant contributions to the economic growth and sustainable development of the nation, and in safeguarding health, safety, welfare, and happiness of the society.

For the nation and the society to derive maximum benefits from engineering services, it is essential that, in addition to being of high technical standards, the services provided are of the highest universally accepted moral and ethical standards.

With a view to achieve the stated objective the Consulting Engineers Association of India (CEAI) has framed a “Code of Ethics” which is mandatory for all members of the Association to adopt and abide by.

This Code presupposes that every member of CEAI is a law abiding, truthful, honest, fair and just citizen of the society. In addition, the member must follow the directives of the Code in his/her professional practice.

THE CODE

Each CEAI Member shall:

Responsibility to Society	1	Ensure that he/she shall be ethically and socially responsible, and his/her professional services safeguard and enhance the health, happiness and safety of the society.
	2	Ensure he/she, in his/her profession upholds the principles of environmentally sustainable development and considers climate change in decision-making with appropriate knowledge and training, and also informs clients about the need for its inclusion.
	3	Treat all persons fairly and encourage equitable participation without regard to religion, race, caste, gender, descent, place of birth, or residence, so that everybody works with honesty, integrity, and mutual trust and respect in a transparent manner.
Responsibility to Profession	4	At all times, uphold the dignity, standing and reputation of the profession.
	5	At all times, provide services: (a) in accordance with the principle of ‘Duty of Care’, implying the obligation to take reasonable steps to avoid foreseeable harm to another person, group, or their property and society; (b) to meet and fulfill the requirements as agreed with the client as per the Design Brief of the client, or as required by the employer as per the employment contract, and give feedback for any changed context; and, (c) to ensure that the said services utilise appropriate technology, and be fit for the design life of the product or facility and for its intended purpose and use.
	6	Always be responsible and accountable for all the professional services provided under his/her responsible charge, including using validated and legal algorithms and software.
	7	Refrain from: (a) expressing in public an opinion on a professional topic unless he/she is sufficiently informed on the facts relating to the topic and he/she is competent to comment on it; (b) making public statements which are not in an objective and truthful manner; (c) casting any aspersions of an unjust or malicious nature; and, (d) performing any service beyond his/her competency.
	8	Imbibe, inculcate and emphasise the Code of Ethics periodically and internally within the organisation and also for oneself.

	9	Maintain knowledge and skills at levels consistent with developments in technology, legislation and management, and apply due skill, care and diligence in the services rendered to the client or employer.
	10	Continue professional development and advancement throughout his/her career.
Integrity	11	Act, without prejudice to the rights of other stakeholders, in the legitimate interests of the client or employer, and perform professional services with integrity and faithfulness.
	12	Act with fairness and justice towards his/her client or employer, and towards vendors, contractors, and other professionals in all matters pertaining to contracts relating to his/her professional services.
	13	Refrain from: (a) indulging or being or getting involved in any activity which in any manner seeks to affect or in any way influence the client or employer with regard to the selection of or the compensation for professional services; and/or affect or influence the impartial judgement of the professional himself/herself; and, (b) participating in any shape or form in the process of giving, promising or taking money, gift, or favour which may influence the judgment or conduct of a person in a position of trust or authority.
	14	Inform: (a) the concerned client or employer organisation's management first, of any unethical or unsafe act or situation; known or learnt by him/her in the course of his/her work or in any other work within his/her competency; and (b) the appropriate authorities, if the client or employer organisation's management is unable or unwilling to address the unethical or unsafe act or situation referred to in (a) above
	15	Facilitate in ensuring legal compliance by client or employer, contractors, vendors and others.
	16	(a) Refrain from utilising any data, information, computer hardware or software in his/her work that might infringe upon any Intellectual Property Rights, without obtaining proper legal clearance; and (b) Use all the data, business plans or strategies, and any other sensitive or confidential documents or materials, whether from the client or employer, or internal to the organisation, in a responsible manner, so that their confidentiality and security are not compromised.
	17	Promote an ethical culture in the organisation based on shared values, beliefs and norms such as trust, honesty, integrity, fairness, confidentiality and accountability, and actively adopt them to uphold professional ethics, and make decisions that are above reproach.
Impartiality	18	Be free of prejudice and personal preferences, in his/her professional advice and judgement.
	19	Refrain from accepting an assignment for services which prejudices his/her independent judgement.
	20	Inform the client or employer of any potential conflict of interest that exists or might arise in the performance of an assignment.
	21	Promote the concept of quality based services to encourage fair competition
	22	Cooperate fully with any legitimately constituted investigative body appointed or setup for inquiry into the administration of any contract where the professional is involved.

Relations with Other Consultants	23	Refrain from directly or indirectly injuring/damaging or attempting to injure/damage the professional reputation or practice or prospects of another fellow professional, except when the fellow professional is incompetent or has violated ethical norms.
	24	Refrain from associating in work with a professional whose methods of practice do not conform to the ethical practices as laid down in this Code.
	25	Refrain from: (a) trying to supplant another professional in any particular assignment; and (b) intervening in work of any kind which to his/her knowledge has already been entrusted to another professional, except when appointed as a Reviewer by the client or employer.
	26	Refrain from taking over the services being provided by another professional unless the client or employer formally appoints the professional to take over the ongoing assignment, after legally terminating the previous contract, and legally indemnifies the appointed professional against any deficiencies and losses already incurred or liable to be incurred due to the errors of omission and commission by the previous professional.
Relation with Clients	27	(a) Refrain from disclosing confidential information concerning the assignment, any technical process or any related matter, of the client or employer without the client's or employer's consent. (b) making comments in public/ social media regarding the work being done for the client.
	28	Publicity material as well as any paper/ article developed, written and published by the professional regarding the project to be as per the contract and the scope of work therein.
	29	Amicably attempt to resolve any issue with the client.
Relation with Employees	30	Provide opportunities for the professional development and advancement to other professionals in his/her employment or control, aimed to foster a culture where people are motivated, engaged, valued and can learn, develop, and grow.

The undertaking

I, the undersigned, certify that on my behalf and on behalf of the organisation, I have read and understood the Code of Ethics of CEAI and hereby undertake to abide by all its provisions and the Rules of the Association both in letter and in spirit, as may be amended from time-to-time, hereafter.

Member Registration No.:	
Name of Organisation: (for organisational Members only)	
Name of person signing the declaration:	
Designation: (for organisational Members only)	
Signature:	
Place:	
Date:	



Message from President

Solid waste management, the theme for this issue of ViewPoint, stresses on the urgent need for stronger enforcement of policies. As India continues its rapid urbanisation and infrastructure expansion, the challenge of managing waste sustainably has moved from being a municipal concern to a national priority. Poorly managed waste not only degrades the environment but also undermines public health, economic productivity, and the resilience of our cities.

It is evident that incremental improvements will no longer suffice. What is essential is a more robust policy framework, supported by strict enforcement, clear accountability, and integration of technology-driven solutions. As consulting engineers, we have a pivotal role to play - not only in designing efficient waste management systems, but also in advising governments and local bodies on lifecycle approaches, circular economy principles, and climate-resilient infrastructure. From waste segregation at source and recycling systems to waste-to-energy solutions, our profession must lead with innovation, integrity, and sustainability at its core.

At CEAI, we strongly believe that the consulting community must proactively contribute to shaping policies and standards in this domain. Equally important is the need to build capacity - both within consulting organisations and among stakeholders - to adopt global best practices and modern technologies and innovate to tide over waste management issues.

In this context, I am pleased to share that CEAI will be hosting the **FIDIC Global Infrastructure Conference 2026** in New Delhi from 13th to 15th September 2026. This prestigious global event will bring together leaders from across the infrastructure ecosystem - consultants, contractors, policymakers, multilateral agencies, and industry experts - to deliberate on the future of infrastructure, including sustainability and environmental stewardship.

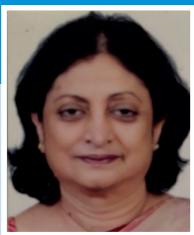
The conference offers unparalleled opportunities for knowledge exchange and networking. As highlighted in the conference materials, participants can expect high-level technical sessions, speaking opportunities, exhibitions, and exclusive networking platforms, including curated social events and access to global participants. Additional engagement opportunities such as welcome receptions, local cultural evenings, and gala events will further enhance the value of participation.

Recognising the importance of strong participation by Indian professionals, CEAI has secured a **50% discounted registration rate for Indian nationals**. I strongly encourage all our members and professionals across the sector to take advantage of this unique opportunity to engage with global peers, showcase India's capabilities, and contribute to shaping the global infrastructure agenda.

As we reflect on the challenges of solid waste management, let us also view them as opportunities - opportunities to innovate, to collaborate, and to lead. I urge all stakeholders to commit to higher standards of practice, to embrace sustainability as a core principle, and to work collectively towards cleaner, more resilient cities.

I look forward to your active participation - both in advancing the discourse on sustainable waste management and in making the **FIDIC GIC 2026** in New Delhi a landmark global event.

Warm Regards
Prashant Kapila
President, CEAI



Message from Chief Editor

A wide range of solid waste streams including plastic, construction and demolition (C&D), electronic waste, industrial and hazardous materials are generated across India and globally. Among these, however, **municipal solid waste (MSW)** occupies the centre of public discourse because of its enormous daily volume and the significant environmental consequences from its improper handling and disposal.

India seems overwhelmed with the mounds of solid waste across its cities and towns reaching gargantuan proportions, with an unrestrained increase in daily waste generation fuelled by a burgeoning population, rapid urbanisation, grossly deficient infrastructure, all coupled with a lack of sensitisation to inculcate habits that keep our surroundings clean.

Apart from the unsightly landfills, unclean roads and overflowing bins, the environmental consequences of poor solid waste management include soil degradation, groundwater contamination, increased greenhouse gas emissions, particularly methane from decomposing organic waste, and the loss of land occupied by the dump area.

Linearity, the traditional "take-make-dispose" model, is inimical to India's waste management story because it perpetuates its severe environmental, health, and infrastructural crises, making handling of the country's rapidly rising volume of waste, an uphill task.

A more sustainable pathway lies in transitioning towards a **circular waste management framework**. Central to this transition is the segregation of waste at source into organic (wet) and inorganic (dry) fractions. When combined with the effective integration of the informal sector - particularly waste pickers - such segregation can significantly strengthen the implementation of the **3Rs principle: Reduce, Reuse, and Recycle**. This hierarchy prioritises reducing waste generation at its origin, promoting innovative reuse of materials, and recycling residual waste into new products. Together, these practices help conserve resources, minimise landfill dependency, and support a regenerative approach to urban waste management.

India has already taken important policy steps in this direction. Comprehensive Solid Waste Management Rules were first introduced in 2000 and subsequently strengthened through the revised Solid Waste Management Rules, 2016, alongside the nationwide momentum created by the Swachh Bharat Mission. The most recent revision is Solid Waste Management (SWM) Rules, 2026, to be implemented soon, which mandates a four-stream source segregation to promote a circular economy. Several judicial interventions, including landmark decisions by the Supreme Court and directives from the National Green Tribunal have further strengthened the regulatory architecture. But implementation gaps persist, as the challenge is the difficulty of translating policy intent into effective action, and involving public participation.

Municipal governance capacity is often inadequate, monitoring systems are weak, and performance evaluation of urban local bodies and contractors remains inconsistent. These institutional shortcomings are compounded by behavioural factors, including limited civic participation and weak public compliance with waste segregation norms.

In the mid 1990s the **pneumonic plague outbreak in Surat** turned into a pivotal moment that forced the Surat Municipal Corporation (SMC) to transform the city. Under determined municipal leadership, the Surat Municipal Corporation implemented sweeping reforms, including improved waste collection systems, and over the years, GPS-enabled garbage trucks, centralised monitoring mechanisms, and an effective grievance redressal framework. **Citizens were actively mobilised to support the city's transformation, and cleanliness gradually became embedded in the civic culture.** Today, Surat consistently ranks among India's cleanest cities - illustrating the power of strong municipal governance, community engagement, all integrated through the adoption of technology.

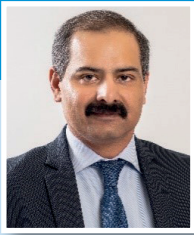
India possesses a robust civil services framework and a vast workforce across multiple tiers of governance. What is required is a motivated and sustained leadership, institutional accountability, and a clear prioritisation of sanitation and environmental management. The continued implementation of the Swachh Bharat Mission must therefore proceed with renewed commitment, urgency and vigour.

Public sensitisation is equally essential. Environmental responsibility and civic cleanliness must be instilled early in the education system so that future generations internalise the value of maintaining clean surroundings and protecting natural resources.

As engineering consultants, the responsibility to advance Solid Waste Management (SWM) lies in integrating digital innovation with operational expertise to enforce regulations and improve sustainability. The fraternity has a responsibility to build capacity and technical expertise, and use emerging tools such as artificial intelligence and data analytics to predict waste generation patterns, optimise collection routes, improve sorting efficiency, and enable automated processing systems. Thus, consulting engineers can and must play a major role in partnering with local bodies to enforce and implement SWM Rules in letter and spirit.

***Let Us All Pledge
to Keep Our Environment Clean & Green
And Leave a Better Planet
For Future Generations***

With warm regards
Sayona Philip



Message from Guest Editor

India's Waste Crisis is Really a Resource Crisis

Why Stricter Waste Management Policies Are Central to India's Economic Security, Climate Goals, and Industrial Future

Consider a paradox at the heart of India's development story. A nation that imports nearly 89% of its crude oil - spending upwards of USD 137 billion annually - simultaneously buries recoverable polymers, metals, and organic carbon in its landfills every day. India generates over 200,000 tonnes of municipal solid waste daily, amounting to more than 73 million tonnes annually, yet a massive portion goes unprocessed. The rest joins a growing archipelago of toxic dump-mountains that, by one estimate, will require 1,450 square kilometres of land by 2051 if current practices persist - an area almost as large as Delhi. This is not merely a sanitation problem. It is a failure of lifecycle engineering and a resource haemorrhage with profound implications for economic sovereignty, industrial competitiveness, and climate commitments.

The Scale of What We Bury - and What It Costs Us

Of the 73 million tonnes of waste produced annually, only a fraction is scientifically treated. Tens of millions of tonnes are dumped in landfills, and a significant portion never enters the collection stream at all. By 2030, waste generation is expected to surge to 165 million tonnes as consumption patterns shift with rapid economic growth.

Here is the genuinely shocking dimension: embedded in that discarded waste are billions of dollars' worth of recoverable materials. This includes plastics derived from imported petroleum, alongside copper, aluminium, ferrous metals, and rare earth elements locked in the 2.2 million metric tonnes of e-waste generated in 2025 alone (making India the world's third-largest e-waste producer). Every tonne consigned to a landfill represents not just an environmental burden, but a strategic resource permanently lost due to linear design thinking.

The Strategic Resource Imperative

India's import dependency extends far beyond crude oil. The country is 100% import-dependent for lithium, cobalt, manganese and nickel - minerals essential for batteries, EVs, and renewable energy. It relies on imports for 80% of its rare earth needs, at a time when some exporters have weaponised their dominance through export restrictions. Oil import dependence has climbed to 88.6% in the current fiscal year, projected to reach 92% by 2035. Collectively, the crude import bill, scramble for critical minerals, and polymer feedstock dependence represent perhaps independent India's single largest economic vulnerability.

The circular economy offers a powerful counterweight. Government estimates project India's circular economy could exceed USD 2 trillion in market value by 2050, creating 10 million jobs. NITI Aayog has estimated circular

interventions could unlock USD 45 billion in annual economic value while cutting emissions by up to 44%. The National Critical Mineral Mission (INR 34,300 crore over seven years) explicitly recognises urban mining and recycling as pillars of mineral security. The waste we discard is increasingly the resource we desperately need.

The Forgotten Half: Decarbonising Materials, Not Just Energy

India's climate discourse rightly emphasises decarbonising energy - solar, wind, etc. But this addresses only part of the equation. Globally, producing steel, cement, aluminium, and plastics accounts for roughly a quarter of all CO₂ emissions. Cement alone contributes about 8% steel another 7%. In India, where 70% of urban infrastructure needed by 2047 is yet to be built, the embodied carbon in buildings will increasingly overshadow operational emissions.

One study estimates the current embodied-to-operational emissions split at 40:60 - a ratio that will tilt further as buildings become more energy-efficient. This is where engineering, waste management, and climate strategy intersect. Every tonne of recycled steel processed through Electric Arc Furnaces (EAF) avoids roughly 1.5 tonnes of CO₂ versus virgin production. Recycled aluminium uses 95% less energy than primary smelting. Specifying low-carbon blended cements (like LC3) and recycled construction aggregates fundamentally slashes the carbon footprint of concrete. India cannot meet its net-zero-by-2070 target without simultaneously decarbonising its material flows. [Circularity is not a parallel track; it is an essential one.](#)

The Case for Stricter, Smarter Policies

India's policy framework has been evolving meaningfully, with the SWM Rules 2016 mandating source segregation, EPR frameworks for plastics and e-waste; over 51,000 producers registered under EPR, and more than 15.7 million tonnes of plastic packaging waste recycled since 2022. Yet the gap between intent and execution remains wide. Over 70% of waste at disposal points is still unsegregated. About 10% of recyclables are actually scientifically recycled. The informal sector - millions of waste-pickers recovering an estimated 60% of recyclables - remains largely outside the formal system.

What is needed: market-based instruments to make recycling attractive; mandatory recycled-content standards across industries; digital traceability for material flows; and a National Circularity Mission with recycling hubs in the top 20 cities, which contribute 35% of India's municipal waste. Integration of the informal workforce into formal value chains is not just socially imperative - it is economically essential.

A Positive Inflection

We are currently at a critical regulatory inflection point. As of April 1, 2026, the new Solid Waste Management (SWM) Rules, 2026 supersede the decade-old 2016 framework. This is not a mere incremental update; it is a structural shift toward a digital-first, circular economy model that engineers and facility managers must immediately internalise.

Key upcoming changes include:

- **Mandatory Four-Stream Segregation:** Moving beyond the loosely enforced wet/dry split, all generators must now segregate waste into Wet, Dry, Sanitary, and Special Care (hazardous items like batteries and paints) streams.

- Extended Bulk Waste Generator Responsibility (EBWGR): Entities with a floor area > 20,000 m², or waste generation > 100 kg/day are now legally accountable for the complete lifecycle of their waste. They must process wet waste on-site or procure EBWGR certificates.
- Digital Traceability & Centralised Portal: A new CPCB-led online portal will track waste from generation to final disposal, replacing physical reporting with mandatory digital audits and geo-tagged verification.
- Refuse Derived Fuel (RDF) Mandate: Industrial units, specifically cement and waste-to-energy plants, are now mandated to progressively increase their fuel substitution with RDF from 5% to 15% over the next six years.

The encouraging truth is that India is better positioned for this transition than many assume. A new generation of AI-powered sorting facilities, chemical recycling ventures utilising pyrolysis to convert mixed plastics into virgin-quality feedstock, and digital waste-commerce platforms are attracting serious investment. The plastic circularity market alone is forecast to grow at 24% annually, exceeding USD 10 billion by 2030.

For the consulting engineering community, the implications are direct: every infrastructure project must now account for lifecycle material flows, every facility must integrate waste-material recovery, and every urban master plan must embed material recovery as core civic infrastructure.

India's waste crisis is, at its core, a resource crisis masquerading as a sanitation problem.

*In a nation spending USD137 billion on crude oil imports, 100% dependent on imports for lithium and cobalt, and needing to build 70% of its 2047 infrastructure from scratch – **the Argument for Stricter Waste Management is Not Merely Environmental. It Is Economic, Strategic, and Existential.***

The question is no longer whether India can afford to invest in a circular economy. The question is whether it can afford not to.

With regards,
Masood Mallick
MD & Group CEO
Re Sustainability Limited
Chairman, CII National Committee on Waste to Worth



FIDIC GLOBAL INFRASTRUCTURE CONFERENCE 2026

**Engineering a Bright Future, Together:
Quality Infrastructure for People and Prosperity**

New Delhi | 13–15 September 2026

JOIN THE WORLD'S LEADING INFRASTRUCTURE EVENT

The **FIDIC Global Infrastructure Conference (GIC) 2026** brings the global infrastructure community to India for an unparalleled exchange of ideas, innovation, and collaboration.

Organised by FIDIC and supported by CEAI, this flagship event gathers:

- ✓ Industry Leaders
- ✓ Policymakers & Government Representatives
- ✓ Engineers & Consultants
- ✓ Financiers & Contractors
- ✓ Legal & Infrastructure Experts

 **100+ Countries | One Global Platform**

WHY ATTEND?

- High-level global dialogue on infrastructure challenges
- Insights into future-ready, sustainable infrastructure
- Networking with international leaders & decision-makers
- Exposure to global best practices and innovations

SPECIAL BENEFIT FOR INDIAN PARTICIPANTS

CEAI has facilitated a **special 50% registration discount** for **Indian participants**
(Automatically applied during registration with Indian address)

 **Register Now: <https://events.fidic.org/gic26/10478293>**

Be part of this global gathering—right here in New Delhi

Gold from Garbage: Legacy Solid Waste Management as a Policy Imperative for Sustainable Urban Infrastructure



Dr. Rajdeep Bhattacharya (hc)
Chief Project Officer
LEAP INDIA

Abstract

Solid Waste Management (SWM) has become one of the most pressing urban challenges in India, driven by rapid urbanisation, rising consumption patterns, legacy dumping practices, and uneven enforcement of regulatory frameworks. Although the Solid Waste Management Rules, 2016 provide a comprehensive policy foundation, the management of legacy waste continues to remain fragmented, reactive, and largely project-driven rather than institutionalised.

This article presents a real-life Indian case study from Pune, where an abandoned municipal dumping ground was scientifically remediated and transformed into the Vanaz Metro Depot - now a fully functional and critical asset of the city's metro rail system. The project demonstrates how scientific segregation, material recovery, reuse, and environmentally responsible engineering can convert legacy waste from an environmental liability into a valuable urban resource.

Beyond project execution, the article critically examines policy gaps, regulatory lessons, and the urgent need for stricter and enforceable waste management policies. It argues that legacy waste remediation must be mandated as an integral component of urban infrastructure

planning and approvals, enabling Indian cities to progress toward sustainable, resilient, and resource-efficient development.

Introduction

Indian cities today generate vast quantities of solid waste, much of which continues to be managed through inadequate and unscientific disposal practices. Decades of uncontrolled dumping have resulted in thousands of legacy waste sites across the country, occupying valuable urban land while posing serious environmental and public health risks. These sites contribute to groundwater contamination, air pollution, vector-borne diseases, and degradation of surrounding neighbourhoods.

The principles of Reduce, Reuse, and Recycle (3Rs) form the cornerstone of sustainable waste management. Among these, reduction at source and reuse of materials deliver the highest environmental benefits. However, in practice, waste management systems in India have focused predominantly on collection and disposal, with limited emphasis on material recovery and reuse. Legacy waste management, in particular, has remained an under-prioritised area despite its scale and long-term consequences.

At the same time, Indian cities are witnessing rapid growth in urban infrastructure—metro rail systems, highways, depots, utilities, and transit-oriented developments. These projects increasingly face land constraints, especially in dense urban cores. Integrating scientific waste remediation into infrastructure planning offers a unique opportunity to address environmental liabilities while unlocking land and materials for productive use. The Vanaz Metro Depot project in Pune illustrates the effectiveness of this integrated approach.

Background of the Vanaz Legacy Waste Site

The Vanaz site had functioned as a municipal solid waste dumping ground since the early 1990s. Over nearly three decades, approximately 460,000 cubic metres of mixed municipal waste accumulated at the site, forming waste mounds reaching heights of up to 12 metres. The site was located within a densely populated urban area and was surrounded by residential neighbourhoods.



Figure 1: View of the Consolidated Waste



Figure 2: View of the Consolidated Waste

The prolonged presence of the dump created severe environmental and social challenges, including leachate generation, odour nuisance, air pollution, infestation by stray animals, and heightened public health risks. The land remained unusable for any meaningful urban purpose, effectively becoming a brownfield site within the city.

With the rapid expansion of the Pune Metro network, the requirement for a modern maintenance, stabling, and operations depot became critical. Given the acute shortage of available land in the city, the Vanaz site was identified as the only feasible location. This decision necessitated the complete and scientific remediation of the legacy waste before any civil construction activities could commence.

Scope of Work and Project Complexity

The scope of work extended significantly beyond conventional depot construction and encompassed:

- Scientific processing and clearance of approximately 460,000 cubic metres of legacy municipal solid waste
- Detailed physical and chemical characterisation of waste to identify appropriate segregation and reuse pathways
- Design and deployment of site-specific screening and material recovery systems
- Implementation of comprehensive environmental mitigation measures
- Ensuring occupational health and safety for workers and protection of nearby communities

The project was executed in a constrained urban environment, requiring coordination among multiple stakeholders, compliance with environmental regulations, and continuous monitoring to mitigate risks associated with legacy waste handling.

Scientific Processing and Material Recovery

Conventional approaches involving excavation and transportation of waste to distant landfills were assessed as environmentally unsustainable and logistically impractical. Accordingly, an on-site scientific processing strategy was adopted.

GARBAGE SCREENING MACHINE



Figure 3: Garbage Screening Machine

Legacy waste was subjected to systematic analysis to determine its physical composition and chemical characteristics. Based on these findings, a multi-stage segregation process was designed using vibratory screening followed by conveyor-based mechanical segregation systems. This enabled separation of biodegradable fractions, recyclable materials, and inert components.



Figure 4: Primary Manual Segregation of Non-Degradable Waste



Figure 5: On Site Mass Screening Plant

Approximately 57 percent of the processed waste - equivalent to about 160,000 cubic metres - was recovered and reused internally as backfill material for depot development and metro pier foundations. Inert residues were utilised in road works after appropriate processing and blending, while only the residual unusable fraction was transported to authorised disposal facilities.

This approach significantly reduced dependence on virgin construction materials, avoided additional landfill burden, and demonstrated the feasibility of applying circular economy principles within large-scale urban infrastructure projects.

Environmental, Social, and Safety Considerations

Environmental protection and public safety were treated as critical priorities throughout project execution. Dust suppression systems, controlled excavation and handling methods, real-time monitoring, and physical barricading were implemented to minimise impacts on surrounding residential areas.

Strict occupational health and safety protocols were enforced to safeguard workers from exposure to hazardous materials associated with legacy waste. Regular health monitoring, use of personal protective equipment, and controlled site access formed integral components of the safety framework.

The project also addressed social considerations by engaging informal waste workers within a regulated and dignified framework, enabling value recovery while ensuring safety and compliance. By reclaiming more

than 12 hectares of degraded land, the project eliminated a longstanding environmental hazard and improved the overall quality of the urban environment.

Sustainability and Economic Benefits

The reuse of recovered waste delivered substantial sustainability benefits. The project avoided the mining of approximately 160,000 cubic metres of natural soil and aggregates, thereby conserving natural landscapes and reducing energy consumption and greenhouse gas emissions associated with material transport.

From an economic perspective, internal reuse of processed waste resulted in significant cost savings by reducing reliance on externally sourced construction materials. The project demonstrated that environmentally responsible waste management practices can simultaneously deliver economic efficiency, reinforcing the concept that waste can be transformed into a valuable resource.

Policy and Regulatory Lessons

While the success of the Vanaz project can be attributed to proactive leadership and technical innovation, it also revealed systemic gaps in the existing policy framework. Although the Solid Waste Management Rules, 2016 encourage scientific processing of waste, enforcement related to legacy waste remediation remains inconsistent across urban local bodies.

In many cities, remediation of old dumpsites is delayed or partially implemented due to financial constraints, technical capacity gaps, or lack of clear accountability. Infrastructure projects often treat waste clearance as a preliminary or isolated activity rather than integrating it into core project planning.

The Vanaz experience underscores the need for stricter regulatory mandates that require scientific remediation of legacy waste as a prerequisite for urban redevelopment. Clear timelines, enforceable compliance mechanisms, and incentives for material recovery are essential to mainstream such practices. Infrastructure agencies, municipal bodies, and regulatory authorities must share accountability to ensure consistent implementation.

Replicability and Emerging Opportunities

The methodologies adopted at Vanaz are scalable and replicable across Indian cities facing similar challenges. Integrating waste remediation with infrastructure development can unlock new opportunities for specialised waste processing technologies, sustainable construction practices, and public–private partnerships.

Multilateral development banks and funding agencies can accelerate adoption by linking financial assistance to compliance with scientific waste management standards. Such conditionalities would encourage institutionalisation of best practices and ensure that sustainability considerations are embedded within urban infrastructure financing.

Conclusions

The Vanaz Metro Depot project demonstrates that legacy solid waste, when managed scientifically, can be transformed from an environmental liability into a strategic asset for urban infrastructure development. However, isolated project-level successes are insufficient to address the magnitude of India's waste challenge.

There is an urgent need for stricter waste management policies, stronger enforcement mechanisms, and institutional frameworks that mandate scientific remediation of legacy waste. By aligning policy intent with execution and integrating waste management into infrastructure planning, Indian cities can move decisively toward sustainable, resilient, and resource-efficient urban development.

References

1. Solid Waste Management Rules, 2016, Ministry of Environment, Forest and Climate Change, Government of India
2. Central Pollution Control Board Guidelines on Legacy Waste Management
3. Project documentation and environmental compliance records

Taiwan's Solid Waste Management Achievements and Transition to Circular Economy



Justin Wang
Associate Researcher



Dr. Chun-Hsu Lin
Director/Research Fellow

Center for Green Economy Chung-Hua Institution for Economic Research, Taiwan

Abstract

This article examines Taiwan's transformation from a waste-burdened industrial state into a global leader in the circular economy. Following the "Garbage Wars" of the 1990s, Taiwan implemented the pioneering 4-in-1 Recycling Program, which synergises residents, local governments, private recyclers, and a government-managed fund under an Extended Producer Responsibility (EPR) framework. This system successfully decoupled economic growth from waste generation through unique practices like the "Waste Not on the Ground" protocol and musical collection trucks.

Current successes include high-tech "urban mining" for precious metals, PET-to-fibre textiles, and world-first liquid crystal recovery. Looking forward, the proposed Resource Circulation Promotion Act and the "8+N" Circular Alliance shift the focus from waste management to resource management. By integrating Digital Product Passports and "Product-as-a-Service" models, Taiwan is establishing a resilient, zero-waste blueprint that serves as a vital national security strategy for resource-constrained island nations.

Background

Between the 1960s and 1990s, Taiwan was recognised as one of the "Four Asian Dragons" for its rapid industrialisation and extraordinary economic development¹. Alongside South Korea, Hong Kong, and Singapore, Taiwan maintained near double-digit average growth rates for decades². However, this "economic miracle" came at a severe environmental cost; prior to the 1980s, environmental protection was secondary to industrial output, and formal waste management policies were virtually non-existent. Without structured collection or treatment processes, waste was frequently subject to open dumping and unregulated incineration, precipitating a dire pollution crisis across Taiwan's air, water, and soil. The first legislative turning point occurred in 1974 with the enactment of the Waste Disposal Act, which established a legal framework for landfilling³. Yet, this "end-of-pipe" solution soon faced a spatial reality: as a small, densely populated island, Taiwan was running out of land. By 1992, daily waste generation had tripled from 1974 levels - rising from 8,800 to 21,900 metric tonnes - while nearly 90% of this volume was diverted to rapidly disappearing landfill space. With recycling efforts still in their infancy, the mounting "Garbage

Wars” of the early 1990s signalled that the landfill-centric model was no longer sustainable⁴.

The Four-in-One Recycling Program

Since its enactment, the Waste Disposal Act has gone through numerous revisions and amendments, adjusting to the shifting socio-economic status of Taiwan, and institutional overhaul culminated in 1997 with the implementation of the 4-in-1 Recycling Program, a pioneering framework designed to reduce waste generation at the source. The program is called 4-in-1 Recycling Program because it synergises the efforts of residents, local government, the private sector, and a government-operated Recycling Fund⁵. In addition to the recycling program, a national Extended Producer Responsibility (EPR) scheme was developed to further ensure proper recycling and treatment of products/goods in fourteen categories.

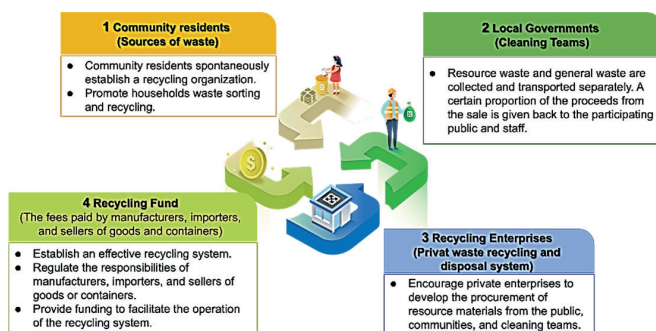


Figure 1: Taiwan 4-in-1 Recycling Program

Source: Resource Circulation Administration, Ministry of Environment

The four pillars of the programme are elaborated hereinafter.

1. Residents

The fundamental pillar of the program is the active participation of the local residents and communities. The residents are mandated by law to categorise waste into three primary streams: general waste, recyclables, and food waste. In a significant departure from many Western models where refuse is placed in kerbside bins, Taiwan utilises the “Waste Not on the Ground” practice, requiring citizens to personally deliver their sorted

materials directly to collection trucks at designated times. Non-compliant waste is subject to denied collection on the first offense, with repeated violations resulting in administrative fines. Furthermore, any disposal of waste outside of the official collection process is legally classified as littering and carries financial penalties. To further incentivise reduction at the source, the local governments in the Greater Taipei Area (Taipei and New Taipei cities) have implemented a “pay-per-bag” system. Under this scheme, general waste must be discarded in pre-paid, government-certified bags, while recyclables are collected free of charge. These certified bags range in capacity from 3 litres to 120 litres, with prices scaling accordingly from approximately USD 0.03 to USD 1.39 per bag⁶. By internalising the cost of disposal, this system provides a direct economic incentive for citizens to maximise their recycling efforts and minimise total waste generation.

2. Local Government

Local governments serve as the logistical backbone of the recycling program, managing a specialised fleet of collection vehicles widely recognised as the “musical garbage trucks”⁷. This distinctive system utilises classical compositions, such as Beethoven’s “Für Elise,” to provide audible notification to residents of the trucks’ arrival along designated routes. The standard collection unit comprises a yellow vehicle dedicated to general and organic waste and a white vehicle⁸ for the consolidated collection of all recyclables. Depending on the specific demographic density and route requirements, municipal governments provide collection services two to three times daily, five days per week. Beyond their primary transport functions, local authorities act as critical enforcement units; staff members are responsible for inspecting waste streams to ensure that materials are accurately sorted and discarded according to national environmental standards. This frontline auditing is essential for maintaining the purity of the recycling stream and ensuring the overall integrity of the 4-in-1 framework.

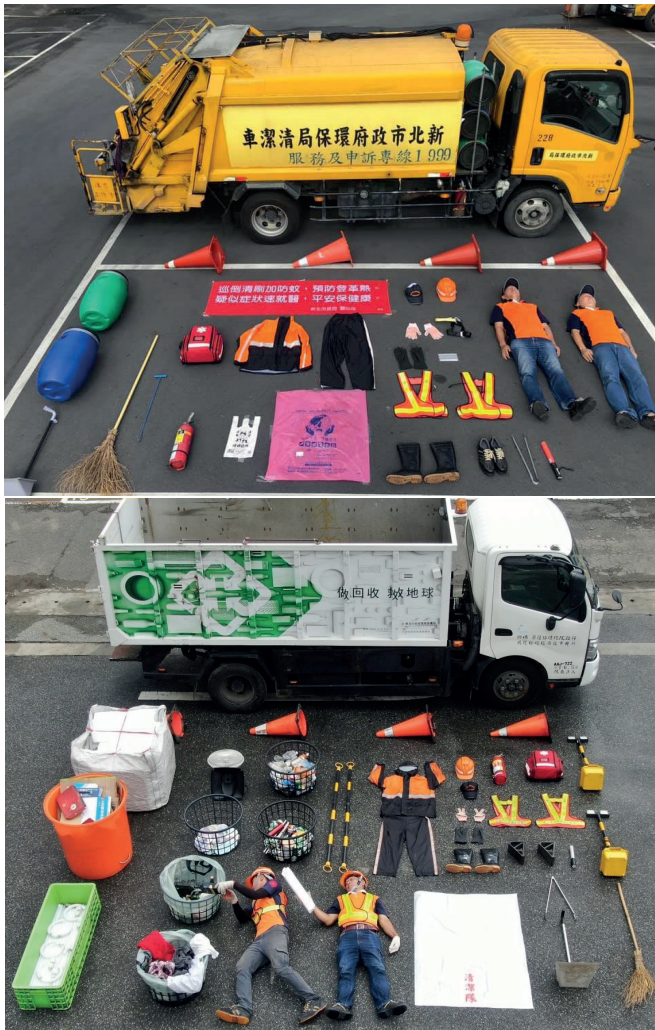


Figure 2: New Taipei City Collection Trucks
Source: New Taipei City Government Environmental Protection Department Facebook page

3. Recycling Industry

Taiwan's structured regulatory framework has facilitated the development of a robust private recycling sector, effectively transforming waste into high-value secondary resources. To qualify for government subsidies, recycling enterprises are mandated to register with the Fund Management Board (FMB), maintain strict adherence to national environmental standards, and undergo rigorous periodic audits. As of 2025, approximately 300 registered recycling^{9,10} facilities actively participate in the program, managing a diverse portfolio of materials that includes tires, motor vehicles, PET

bottles, and complex electronic waste. By integrating these private entities into the national waste management strategy, Taiwan leverages market competition and industrial expertise to ensure that recovered materials are efficiently reprocessed and reintegrated into the global supply chain.

4. Fund Management Board

The FMB, situated in the Resource Circulation Administration of the Ministry of Environment, operates under the principle of the extended producer's responsibility (EPR) scheme by collecting recycling fees from manufacturers and importers of regulated products. Manufacturers and importers of regulated products are required to pay recycling fees into the National Recycling Fund. These funds are redistributed as subsidies to registered recyclers, financial support to local governments, and operational expenses for oversight and auditing.

Currently, fourteen product categories fall under the EPR framework, including containers, packaging materials, motor vehicles, tyres, batteries, information technology equipment, appliances, and lighting products. Recycling fees and subsidies are predetermined and periodically reviewed. Annual fund revenues have averaged approximately USD 250 million in recent years, exceeding USD 350 million in 2024. The major part of the funds is allocated to recycling subsidies and local government support, while the remainder covers administrative and logistical costs.

Taiwan's Circular Economy in Action

Taiwan's transition toward a circular economy has evolved from a matter of waste management into a core national security strategy for resource resilience. As an island that imports over 90% of its energy and a significant portion of its raw materials, Taiwan has aggressively pivoted toward a "resource circulation" model that aims to decouple economic growth from material consumption. Taiwan's most recognisable circular economy success is its highly optimised PET-to-Fiber pipeline, which has transformed the island

into a global supplier of recycled functional textiles. In advanced facilities like those operated by Far Eastern New Century, rPET flakes are melted and extruded into fine filaments. Unlike standard polyester, these recycled fibres are often engineered with specific cross-sections to provide moisture-wicking, thermal regulation, and UV protection. This mastery of “green” textiles was famously showcased during several FIFA World Cups, where a significant portion of the players’ jerseys were manufactured from Taiwanese recycled plastic¹¹.

Parallel to this textile innovation is the high-stakes world of Electronics-to-Gold (Urban Mining). Companies like Solar Applied Materials have moved beyond traditional smelting - which is energy-intensive and often toxic - to utilise advanced hydrometallurgical processes. By using proprietary, cyanide-free stripping solutions, these firms can dissolve and recover 99.99% pure gold and other precious metals like silver, palladium, and copper from discarded circuit boards¹². This “urban mine” is significantly more concentrated than any natural ore; while a ton of gold ore might yield only 5 grams of gold, a ton of discarded smartphones can yield up to 400 grams. This recovered gold is then refined back into targets for the semiconductor industry, ensuring that the same gold used in yesterday’s phone becomes a component in tomorrow’s high-performance chip.

Similarly, Taiwan has pioneered a global first with LCD Panel-to-Liquid Crystal Recovery¹³, a process developed to handle the massive volume of discarded television and monitor screens. Historically, LCDs were difficult to recycle because the liquid crystals and heavy metals were sandwiched between glass sheets. However, through a collaboration between industry and the Industrial Technology Research Institute (ITRI), Taiwan now uses an automated, closed-loop system that “un-zips” the glass panels. The liquid crystals are extracted, filtered, and purified through a sequence of chemical processes to remove impurities. This recovered material is of such high quality that it can be reintroduced directly into the production of new displays, preventing the hazardous leakage of liquid crystals while recovering a material that is incredibly expensive and complex to synthesise from scratch.

Finally, the remnants of these LCD panels and other waste glass are diverted into Glass-to-Green Building Materials, led by innovators like Spring Pool Glass¹⁴. Rather than downcycling glass into low-value sand or road base, Taiwan transforms it into specialised foaming glass and fireproof bricks. By crushing the glass into a fine powder and mixing it with a foaming agent before kiln-firing, the industry creates a material that is 70% lighter than traditional concrete yet structurally resilient. These “green bricks” offer superior thermal insulation and soundproofing, making them ideal for Taiwan’s dense urban environments where energy efficiency is a priority. By turning brittle waste into a resilient construction resource, Taiwan has effectively decoupled the demand for new building materials from the extraction of natural sand and gravel.

Moving Forward

To further address the challenges of limited resources while advancing towards a sustainable development and 2050 net-zero emission and zero waste, the Ministry of Environment has proposed a drafted amendment to the existing Waste Disposal Act and Resource Recycling Act. The proposed Resource Circulation Promotion Act, the legislative cornerstone of Taiwan’s environmental policy, represents a fundamental shift from “waste management” to “resource management.” By consolidating the existing Waste Disposal Act and the Resource Recycling Act, this new legal framework treats all discarded matter as potential feedstock for the economy. A primary feature of the Act is the institutionalisation of Digital Product Passports (DPP), which require manufacturers to provide transparent data on material composition and disassembly instructions. To operationalise this vision, the government has fostered the “8+N” Circular Alliance, a strategic network consisting of eight major industrial sectors - including electronics, textiles, plastics, and construction - plus “N” innovative startups and research institutions. This alliance acts as a collaborative platform where cross-industry waste is matched with secondary material needs. For example, the alliance facilitates “industrial symbiosis,” where calcium fluoride sludge from a semiconductor fab is

repurposed by the steel industry, or waste heat from a power plant is piped into a neighbouring chemical facility.

Complementing this legislation is Taiwan's 2050 Circular Economy Roadmap, which outlines a multi-decadal strategy to achieve a "Zero Waste" society. The roadmap focuses on four key transitions: process innovation, material substitution, business model transformation, and cross-industry symbiosis. In the immediate term leading up to 2030, the roadmap prioritises the creation of Circular Industrial Parks where the 8+N Alliance members can pilot integrated resource loops. This is a critical concern for Taiwan's national resource security, as the island imports the vast majority of its energy and raw materials. By shifting the focus from individual recycling to a networked alliance, the government aims to double resource productivity and increase the national circularity rate significantly.

Looking toward the future, the roadmap emphasises the shift toward Product-as-a-Service (PaaS) models, encouraged by the 8+N Alliance to minimise total material throughput. Rather than owning goods, consumers and businesses are encouraged to lease "utility," such as lighting-as-a-service or furniture-as-a-service. This keeps the ownership of the physical materials with the manufacturer, who then has a direct financial incentive to ensure the product lasts as long as possible and is easily recyclable at the end of its life. By 2026, these efforts are being integrated with Taiwan's Net-Zero goals, recognising that approximately 45% of global carbon emissions come from the way that products are made and used. By closing the loop through the 8+N framework, Taiwan is not just cleaning up its environment - it is building a resilient, high-tech economy that thrives within the ecological limits of an island nation.

Conclusion

Taiwan's journey from the "Garbage Wars" of the 1990s to its current status as a global leader in resource recovery is a testament to the power of integrated policy and civic engagement. By synergising the

responsibilities of producers, citizens, and the state through the 4-in-1 program and the EPR scheme, Taiwan has successfully transformed an environmental liability into a sophisticated industrial asset. As the nation moves toward its 2050 net-zero goals via the Resource Circulation Promotion Act and the 8+N Circular Alliance, it continues to provide a scalable, high-tech blueprint for other resource-constrained regions. Ultimately, Taiwan's model proves that environmental sustainability and economic resilience are not competing interests, but two sides of the same coin.

About CIER

The Chung-Hua Institution for Economic Research (CIER) is a highly esteemed think tank in Taiwan which holds distinguished international recognition. Since its establishment in 1981, CIER has provided economic and industry-related research and recommendations to the Taiwan government. As an independent organisation, it represents Taiwan while actively engaging with international institutions to improve global and local economic affairs. In 2018, CIER was ranked 140th out of 6,000 global think tanks in the TTCSP Global Go to Think Tank Index Reports. This places CIER as the sole Taiwan-based think tank amongst the top 2%.

Reference

1. Gulati, U. C. (1992). The Foundations of Rapid Economic Growth: The Case of the Four Tigers. *American Journal of Economics & Sociology*, 51(2), 161–172.
2. Day, D.-C. (2021). Four Asian Tigers' Political and Economic Development Revisited 1998-2017: From the Perspective of National Identity. *Asian Journal of Interdisciplinary Research*, 4(4), 54–61.
3. Waste Disposal Act. 1974. Ministry of Environment, Taiwan. <https://oaout.moeenv.gov.tw/law/EngLawContent.aspx?lan=E&id=186>
4. Garbage Wars. 1993. Taiwan Today. <https://taiwanreview.nat.gov.tw/AMP/Environment/Taiwan-Review/23865/%7B%7Burl%7D%7D>
5. The 4-in-1 Recycling Program. Resource Circulation Administration, Ministry of Environment. https://recycle2.moeenv.gov.tw/EN/recycling_knowledge_01.html

6. Sizes and Prices of Designated Garbage Bags in Taipei City. Department of Environmental Protections, Taipei City Government. https://english.dep.gov.taipei/News_Content.aspx?n=E56771B61602F277&sms=DFFA119D1FD5602C&s=A84013B75DC58F3C
7. Kaza, Silpa; Yao, Lisa C.; Bhada-Tata, Perinaz; Van Woerden, Frank. 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050, 173.
8. New Taipei City Government Environmental Protection Department. (2019, Sept. 18). Garbage and recyclable trucks. <https://www.facebook.com/share/p/14SNCYTU1Q/>
9. Ministry of Environment. (2025). Subsidized Organizations Handling Regulated Recyclable Waste (Recyclers). Ministry of Environment Environmental Information Open Platform. https://data.moe.gov.tw/en/dataset/detail/WR_P_16
10. Ministry of Environment. (2025). Subsidized Organizations Handling Regulated Recyclable Waste (Collectors). Ministry of Environment Environmental Information Open Platform. https://data.moe.gov.tw/en/dataset/detail/WR_P_15
11. Taiwan Textile Industry Eco Innotech Assisted FIFA World Cup Qatar 2022. (2022, November 17). Business Wire. <https://www.businesswire.com/news/home/20221115006595/en/Taiwan-Textile-Industry-Eco-Innotech-Assisted-FIFA-World-Cup-Qatar-2022>
12. Solar Applied Materials Technology Corp Becomes First in Precious Metal Refining to Achieve UL 2809 Recycled Content Val. (2021, March 11). UL Solutions. <https://www.ul.com/news/solar-applied-materials-technology-corp-becomes-first-precious-metal-refining-achieve-ul-2809>
13. Crook, S. (2023). Environmental Impact Assessment: A circular-economy solution to the problem of waste LCD panels. Taipei Times. <https://www.taipeitimes.com/News/feat/archives/2023/07/26/2003803747>
14. Hsieh, Y.-C., Lin, K.-Y., Lu, C., & Rong, K. (2017). Governing a Sustainable Business Ecosystem in Taiwan's Circular Economy: The Story of Spring Pool Glass. Sustainability, 9(6), 1068. <https://doi.org/10.3390/su9061068>

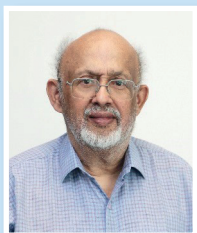
How Bengaluru aims to reorganise its waste transfer system

The Bengaluru Solid Waste Management Ltd (BSWML) plans to establish 30 large garbage transfer stations across the city to replace the long-standing practice of loading waste on roadsides, a system that has often drawn complaints over hygiene and traffic disruption. But the move to build high-capacity stations, instead of smaller decentralised facilities, is raising concerns among waste management experts who say the model could increase travel distances for auto tippers and affect door-to-door waste collection in some parts of the city.

So far, the waste management agency has operationalised three transfer stations in Koramangala, Chamarajpet and Sarvagna Nagar, while work is underway in constituencies such as Vijayanagar and Shivajinagar. These are meant to handle 150 tonnes of waste.

Now, the BSWML has proposed to set up 23 more and much larger stations in areas such as CV Raman Nagar, Hebbal, Yelahanka, Mahadevapura, RR Nagar and Jayanagar, among others, at a total cost of Rs 316.52 crore. The Government of India will provide Rs 68.42 crore under the Swachh Bharat Mission 2.0, while the state government will bear Rs 43.79 crore. The remaining Rs 204.31 crore will be funded by the five city corporations. Under the new system, garbage-laden auto tippers unload waste into static containers at the facility. A hook loader then lifts the container and pushes the waste into a 15-tonne capsule mounted on a 10-wheeler truck. Once full, the truck transports the waste to processing facilities, waste-to-energy plants or landfill sites located 20 to 30 km away from the city. Within a year, all of Bengaluru's Assembly constituencies — whose geography and population size vary widely — are expected to have a waste transfer station.

Source: Excerpts from Deccan Herald



Dr Prasad Modak

Managing Director
Environmental Management Centre Pvt Ltd, India

Abstract

Recycling is widely assumed to be environmentally and economically beneficial, yet its true value depends on how it is designed, measured, and governed. This article discusses the distinctions between upcycling and downcycling, limitations of single-stream collection, chemical risks in plastic recycling, and hidden social costs of informal labour. It highlights the need to optimise rather than maximise recycling, through policy frameworks that reward material quality over tonnage and integrate informal recovery systems.

Recycling is today assumed to be environmentally responsible, economically sensible, and socially virtuous. It conserves natural resources by reducing extraction of virgin materials and diverts waste from incinerators and landfills. Landfills consume valuable space and emit methane, a potent greenhouse gas. While incinerators are less polluting than before, they still produce noxious emissions. Effective recycling is only possible with segregation of waste at source. The two must always go hand in hand.

In the western world, recycling was introduced through the kerbside programmes that asked people to separate paper, glass and cans into distinct bins. In India, the three-bin approach at the household level is followed, as per the Municipal Waste (Management & Handling) Rules, 2000. Yet, the ground reality tells a different

story. It is frustrating to see waste-pickers mix carefully segregated bins into one big bin, dumping the mixed waste into the collection vehicle every day. Japan, on the other hand, follows a seven-bin segregation system.

Single Stream Collection Systems: Pros and Cons

Single-stream collection is a waste collection system where all designated recyclables, paper, cardboard, plastics, metals, and often glass, are co-mingled in one bin by the generator, with sorting occurring later at a centralized Material Recovery Facility (MRF). It relies on mechanical and automated separation technologies such as screens, magnets, eddy currents, optical sorters, and AI vision systems, and is typically paired with a separate bin for organic waste. Its defining feature is post-collection sorting.

Pure single-stream collection, however, collects all municipal solid waste, recyclable and non-recyclable, in one undifferentiated stream, with no mandatory segregation at source. Recovery depends entirely on downstream sorting, carrying high contamination risk from organics and sanitary waste. Material recovery rates depend heavily on technology and labour intensity, often leading to lower-quality outputs and higher reject rates. The two systems are frequently conflated, but are fundamentally different.

Most Western “single-stream” systems are not truly pure single-stream as they still separate recyclables from organic waste. India is habituated to pure single-stream. In high-moisture waste environments such as Indian cities, this approach almost certainly destroys material value (e.g. paper) and degrades plastics through wet contamination.

The recent trend in many countries has shifted back to co-mingled or single-stream collection, where recyclables are placed in one bin and later sorted at centralised mechanised or automated MRF facilities. It has been reported that San Francisco’s Recology system, operating a single-stream model, achieves diversion rates approaching 80% in recent years, among the highest in the United States¹. Technologies commercialised by companies such as TOMRA have been claimed to identify different polymers and paper grades with high accuracy under controlled conditions². Many modern MRFs integrate these systems to process mixed recyclables at scale³.

Single-stream or co-mingled recycling offers convenience but comes with real drawbacks. Mixed materials containing non-recyclables, food residue, or glass shards degrade the quality of recovered paper and plastics, forcing entire batches into landfill or downcycling while reducing commodity prices. Sorting facilities (MRFs) require more complex equipment and labour, often costing more per ton than dual-stream systems. Glass breakage spreads contamination into fibres and plastics, making downstream sorting and recycling harder and increasing the risk of downcycling into lower-value products.

See Table-1 for a comparison.

Will this Trend Continue with Better Technology?

In a single-stream system, three things can happen simultaneously. First, the measured recycling rate rises at the collection stage as higher participation increases the *tonnage entering the system*, improving the apparent recycling rate, particularly when the metric is based on material collected for recycling. Secondly, outbound material quality falls. Co-mingled collection increases contamination through food residue, glass shards in paper, mixed polymers, and multilayer packaging. Even with optical sorting and AI, some degradation is irreversible, especially for paper fibres resulting in higher reject rates, lower bale purity and downcycling instead of closed-loop recycling. Third, market price per tonne drops. Recyclables are commodities and price is highly sensitive to purity. High-quality old corrugated containers or PET flakes fetch premium prices while contaminated or mixed grades fetch discounted prices or may be unsellable. It may therefore be observed that a higher recycling rate can coexist with lower unit revenue per tonne.

The trend toward automated single-stream sorting is likely to continue internationally, especially where labour costs are higher and investment capital is available. However, where informal sector sorting is strong and labour costs are low, as in many parts of India, mixed models integrating segregation at source with technology at MRFs may be more practical. Technology can mitigate but not eliminate the contamination penalty inherent in co-mingled systems.

In the Indian context, the economics differ significantly. Labour costs are relatively low and a substantial share

Table 1: Comparison between Single-Stream and Pure Single-Stream Systems

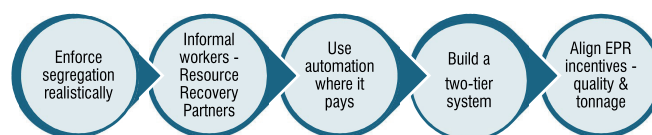
Feature	Single-Stream	Pure Single-Stream
Source segregation	Yes (recyclables separated from wet waste)	No
Recycling bin	One co-mingled bin	No separate recycling bin
Contamination risk	Moderate	High
Material value preservation	Possible	Structurally difficult

of recycling is performed by the informal sector prior to formal MRF processing. A full single-stream high-tech model assumes that higher contamination can be tolerated and value recovered later through expensive sorting. The reality in India is different. Wet contamination quickly destroys paper value and complicates plastics recovery. The informal sector already delivers high recovery at low cost for high-value fractions such as PET, HDPE, OCC and metals. Automation is capex-heavy, demanding reliable uptime, trained technicians, spare parts, and stable feedstock, conditions often missing outside the top-tier metros.

What “Hybrid” Should Mean in Practice

- Enforce segregation realistically. At a minimum, a two-stream system separating wet from dry recyclables is essential, moving to three streams in high-performing wards by adding domestic hazardous and sanitary waste, protecting material value and lowering reject rates.
- Integrate informal workers as formal resource recovery partners, not as charity but because it is operationally smart. They reduce costs, improve capture of high-value fractions, and provide local intelligence on waste generation and leakage. Formalisation through self-help groups, cooperatives, contracts, identity cards, safety gear, buy-back centres, and performance-linked payments makes this possible.
- Use automation where it pays. Conveyors, screening, magnets, and eddy currents are low-regret investments. Optical sorters and AI vision systems are justified only where throughput is large and end-markets demand purity, while robotics make sense only at metro-scale hubs.
- Build a two-tier system combining ward-level dry waste sorting and buy-back centres with regional high-capacity MRF hubs that polish outputs to market specifications.
- Finally, align Extended Producer Responsibility (EPR) incentives with quality, not just tonnage.

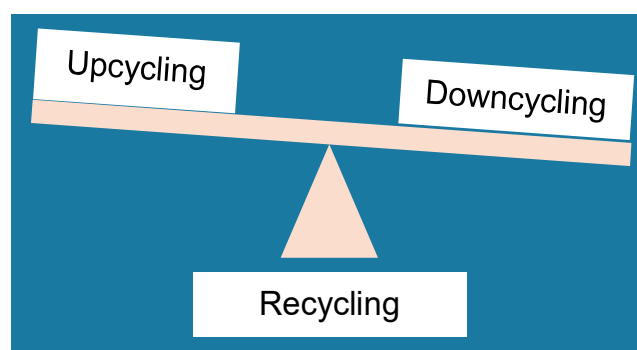
Rewarding verifiable recycling and quality drives investment in better segregation and outputs. Rewarding only tonnage delivers more material but worse quality.



Recycling, Upcycling, and Downcycling: Economic Realities

The term “recycling” conceals critical distinctions. Upcycling processes waste into a product of equal or higher quality than the original. Aluminium scrap melted into equivalent purity and steel scrap reintegrated into electric arc furnace production are close examples. Downcycling, by contrast, processes waste into lower-quality applications. A PET bottle becomes fibre filling; a multilayer packaging film becomes low-grade board. Material properties degrade, additives accumulate and the product eventually reaches disposal after fewer cycles. The economic implications are profound. Upcycling preserves embodied energy and material value competing directly with virgin production. Downcycling degrades value, often delaying disposal rather than preventing it, and may require blending with virgin material to maintain performance.

When policymakers celebrate “recycling rates,” they rarely differentiate between upcycling and downcycling. A recycling rate of 70% tells us little about whether value is preserved or degraded. Recycling rates vary widely across countries. The United Kingdom, records recycling rate around 44-45% from household waste in



recent years⁴, while the United States reported a 32.1% municipal solid waste recycling and composting rate for 2018⁵. Japan stands at around 19–20% in recent fiscal years⁶, while Australia reports over 60% “resource recovery,” though this includes broader recovery streams beyond strict municipal recycling⁷.

Japan’s apparently lower recycling rate needs to be understood in its correct context. It relies heavily on high-efficiency waste-to-energy (WtE) incineration counted as thermal recovery rather than recycling, lowering its reported percentage. Limited landfill space and strict sanitary controls have historically driven investment in incineration over material reprocessing. Its waste accounting is conservative, measuring recycling after processing losses rather than at collection. Finally, Japan’s producer responsibility systems separate “material recycling” from other recovery categories, making international comparisons sensitive to classification choices rather than purely to performance.

India does not have a single, economy-wide statutory definition of “recycling rate” comparable to the EU’s harmonized municipal recycling metric. Definitions are embedded in sector-specific rules under the Environment (Protection) Act, and the meaning of “recycling” therefore varies by waste stream. For municipal solid waste, the Central Pollution Control Board (CPCB) data for 2020-21 has been reported to show that around 50% of the total waste generated is treated through composting, recycling, and other recovery, while 18% is landfilled. Roughly 31-32% of waste remains unaccounted for in formal treatment, implying significant informal recovery activity⁸. For plastics, the Ministry of Environment figures and multiple industry assessments have historically been cited to suggest around 60% of plastic waste is recycled, though this varies widely depending on whether informal recycling by ragpickers and scrap markets is included. Some recent analyses have suggested effective recycling may be as low as 15-20% when only formal streams are considered⁹. For other waste fractions independent summaries and market reports indicate paper recycling rates at around 25-

30% and metal recycling in the 20-25% range, though these are broad estimates rather than consolidated government figures. Precise official recycling figures in India are challenging to pin down as national statistics are fragmented across waste categories (e.g., plastic, paper, metals, e-waste) and depend heavily on how recycling is defined, and whether informal recovery, composting or energy recovery is counted alongside material reprocessing.

When Recycling Recirculates Risk: Case of Plastic Waste Recycling

Plastic waste recycling introduces a deeper complication chemistry. Plastics are not pure polymers. They contain plasticizers, stabilizers, flame retardants, pigments, and other additives with significant regulatory histories. Mechanical recycling does not remove these additives, it redistributes them. A plastic product manufactured decades ago may contain brominated flame retardants now subject to restriction, which when shredded and reprocessed can reappear in new consumer goods. The European Chemicals Agency’s REACH regulation has been noted to restrict several such substances¹⁰. The European Environment Agency has highlighted concerns regarding hazardous substances in recycled plastics, particularly in sensitive applications¹¹. The Basel Convention has also addressed the growing complexity of transboundary plastic waste, acknowledging contamination and hazardous components as significant challenges¹². This leads to an uncomfortable but necessary truth. Indiscriminate plastic recycling may perpetuate chemical risk rather than eliminate it. If contaminants re-enter circulation, risk is displaced not reduced. For engineers and policymakers, higher recovery automatically translates to environmental improvement.

The Standards Dilemma: Safe Upcycling can be Expensive

Once chemical risks are acknowledged, the next logical question becomes how recycling safety can be ensured. True upcycling requires chemical transparency, additive disclosure, hazardous component removal,

testing protocols, traceability, and strict contamination thresholds. Advanced chemical recycling technologies that break polymers down to monomers promise higher purity outputs, but the International Energy Agency has noted their high energy requirements and significant economic challenges¹³. Stricter safety standards reduce risk but inevitably increase cost.

Virgin polymer production benefits from standardised inputs, controlled processes, and economies of scale. Recycled polymers, by contrast, face heterogeneous waste streams, additive variability, and testing requirements making each layer of quality assurance more expensive. It may be argued that more the safe upcycling standards are enforced, more the recycled materials risk becoming economically uncompetitive relative to virgin production unless policy instruments internalise externalities. The OECD has repeatedly noted that such market failures justify policy intervention in waste management systems¹⁴. Without carbon pricing, minimum recycled content mandates, or extended producer responsibility frameworks, markets alone may not support high-standard recycling. Thus, safety and competitiveness can pull in opposite directions and a chemically responsible recycling system may require economic support to survive.

Informal Recycling and Hidden Social Costs

In many developing economies, recycling systems rely on informal workers who perform critical recovery functions but often under unsafe conditions. Exposure to fumes during melting, open burning of residual plastics, and inadequate ventilation create occupational health risks. The World Bank's "What a Waste 2.0," report has been noted to document the scale of informal waste management and associated vulnerabilities¹⁵. If recycling systems depend on labour operating without adequate safety controls, then marginal social cost is underestimated. Recycling may reduce landfill mass while increasing worker exposure. These externalities must be included in any serious evaluation of recycling's worth.

Socially Optimal Recycling: Maximisation is not Optimisation

Public discourse treats higher recycling rates as unqualified progress. Welfare economics suggests a more disciplined benchmark: a recycling system is socially optimal when marginal social benefit equals marginal social cost. Benefits include avoided landfill externalities, reduced extraction impacts, energy savings, and lower geopolitical resource dependency. Costs include collection, transport emissions, processing energy, contamination losses, occupational health risks, and compliance costs. Beyond the point where marginal cost exceeds marginal benefit, additional recycling reduces net welfare. Three implications follow. Maximum recycling is rarely efficient as aluminium may justify near-total capture given substantial energy savings, but mixed low-grade plastics may not, making uniform targets across all materials thermodynamically and economically unsound. Recycling rates are also sensitive to system design as measuring at collection inflates performance relative to measuring after contamination losses. What matters is not tonnage entering the system but usable secondary material exiting it. Finally, volatility matters - falling oil prices make virgin polymers cheaper than recycled resins thus destabilising recycling budgets. However, rising oil prices would result in just the opposite. A socially optimal system must remain viable under realistic market cycles, not only ideal price assumptions. Recycling should be optimised, not maximised, through material-specific targets, region-specific system design, dynamic adjustment to market signals, and explicit accounting of informal labour and health costs.

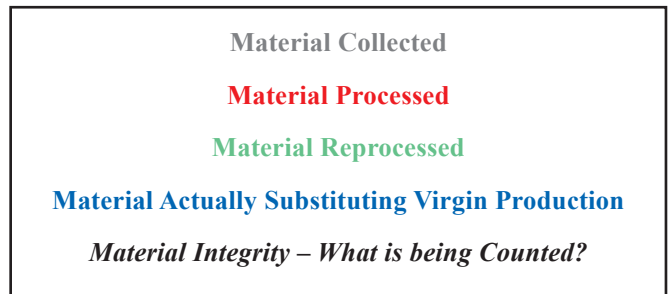
Overall Recycling Economics: Policy, Regulation, and System Design

Markets alone do not deliver optimal recycling outcomes, a poorly designed regulation produces inefficiency too. The central economic challenge is that recycling competes against virgin production that rarely internalise environmental externalities. Virgin material prices typically exclude carbon emissions,

ecological degradation, water stress, and biodiversity loss, while recycled materials carry contamination risk, sorting and testing costs, and market uncertainty. Without policy correction, recycled material can remain structurally disadvantaged even when environmentally preferable. Policy interventions must therefore be carefully calibrated. EPR frameworks shift end-of-life costs to producers. Designed around verifiable material recovery and quality, they improve segregation, support high-purity recycling, and encourage design for recyclability. Designed around tonnage alone, they inflate collection figures, encourage downcycling, and reward volume over value. The difference lies entirely in performance metrics. Minimum recycled content mandates can stabilise demand for secondary materials but work best when accompanied by traceability and quality certification. Weak standards reduce quality; overly strict standards without supply readiness surge prices; and weak enforcement makes compliance nominal. Carbon pricing and resource taxes that reflect true extraction impacts make recycled materials structurally competitive. Without them, recycling relies on subsidy rather than genuine market competitiveness. In countries like India, informal recovery already performs economically efficient pre-sorting of high-value materials. Replacing this with capital-intensive automation without evaluating comparative advantage would be a policy error. The rational pathway is integration through formalisation with safety standards, performance-linked payments, decentralised aggregation, and selective mechanisation where scale justifies it.

Measurement Integrity: What Exactly Are We Counting?

Recycling economics are not determined only by engineering performance or market prices. They are fundamentally shaped by how recycling is measured. The term “recycling rate” appears straightforward, but conceals critical methodological differences. The same system can appear highly successful or structurally inefficient depending on what stage of material flow is counted. Four measurement points matter. Material collected for recycling captures



participation and diversion effort but says nothing about contamination losses or final usability, often overstating system performance. Material processed at MRFs may still include contaminated fractions later rejected. Processing does not equal recovery. Material reprocessed into usable secondary feedstock is a more accurate indicator but still does not reveal whether it substitutes virgin material. Material actually substituting virgin production is the most economically meaningful metric, as real environmental benefit occurs only when secondary material displaces primary extraction and production. Each step narrows the flow. Losses occur at every stage through contamination, moisture damage, sorting inefficiencies, market rejection, and quality downgrading. If policy measures performance at the point of collection, incentives favour volume. If measured at the point of substitution, incentives favour purity and system efficiency. These distinctions are not academic. They determine whether municipalities invest in participatory campaigns or contamination reduction, whether EPR systems reward tonnage or material quality, whether recycling targets promote upcycling or tolerate downcycling, and whether public funds are directed toward infrastructure that actually reduces virgin material demand.

Without harmonised definitions, international comparisons become misleading. A city reporting a 70% recycling rate based on collection may perform worse in material substitution terms than one reporting 45% based on post-processing metrics. Transparent and standardised measurement frameworks are therefore not bureaucratic formalities but preconditions for rational regulation. If volume is measured, systems tend to optimise for volume. If material substitution and quality are measured, systems tend to optimise

for value. Recycling economics must begin with clear definitions.

The Strategic Question

The conundrum remains since recycling is not an isolated environmental intervention. It sits within a larger material economy.

When products are not designed for disassembly, additives remain undisclosed, multilayer composites proliferate and virgin extraction remains artificially cheap, recycling becomes structurally disadvantaged.

Policy must therefore address upstream design, not merely downstream recovery.

A system that prioritises design for recyclability, chemical transparency, material simplification, and economic internalization of environmental costs reduces the burden on end-of-life systems.

Conclusion

The debate is not “recycling versus no recycling.” It is whether material systems are being designed to allow recycling to function as a high-value recovery mechanism rather than a symbolic diversion activity. Recycling becomes socially justified when it preserves material value, controls chemical risk, protects worker health, internalises environmental externalities, and operates within economically rational thresholds. Otherwise, increasing recycling rates may improve optics while diminishing welfare. The engineering challenge is technical. The economic challenge is structural. The policy challenge is institutional. The real task is not to defend recycling. It is to design it so that it deserves defence.

Acknowledgement

The author acknowledges that this article draws upon professional experience in environmental management, waste systems planning, and circular economy policy, along with insights from publicly available reports and institutional publications cited under References. The perspectives presented are informed by long-standing

engagement with regulatory frameworks, industry practices, and sustainability strategy discussions. Any interpretations, opinions, or errors remain solely the responsibility of the author. The author would like to thank Ms Kalpana Saini for assisting in formatting and in citing the references.

References

1. Webmaster. San Francisco reports record 80% diversion rate. Energy Justice Network, 26 August 2025. Available at: <https://energyjustice.net/san-francisco-reports-record-80-diversion-rate/>
2. TOMRA. Sensor-based sorting solutions for maximum recovery. Available at: <https://www.tomra.com/waste-metal-recycling/products/machines>
3. US EPA. Recycling Infrastructure and Market Opportunities Map, 6 August 2025. Available at: <https://www.epa.gov/circulareconomy/recycling-infrastructure-and-market-opportunities-map>
4. GOV.UK. UK statistics on waste, 23 July 2025. Available at: <https://www.gov.uk/government/statistics/uk-waste-data/uk-statistics-on-waste>
5. US EPA. National Overview: Facts and figures on materials, wastes and recycling, 19 December 2025. Available at: <https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials>
6. Ministry of the Environment, Government of Japan. Sound Material-Cycle Society. Available at: <https://www.env.go.jp/en/recycle/smcs/>
7. Department of Climate Change, Energy, the Environment and Water. Resource recovery from waste: Material analysis 2024, 2024. Available at: <https://www.dceew.gov.au/environment/protection/waste/publications/national-waste-resource-recovery-reporting/resource-recovery-waste-material-analysis-2024>
8. Central Pollution Control Board. Annual report on solid waste management 2020–21, 2021. Available at: https://cpcb.nic.in/uploads/MSW/MSW_AnnualReport_2020-21.pdf
9. CEEW. Plastic waste recycling, 12 May 2025. Available at: <https://www.ceew.in/plastic-waste-recycling>
10. European Chemicals Agency (ECHA). Understanding

REACH. Available at: <https://echa.europa.eu/regulations/reach/understanding-reach>

11. European Environment Agency. Hazardous flame retardants in recycled plastic consumer goods, 2024. Available at: <https://www.eea.europa.eu/en/european-zero-pollution-dashboards/indicators/hazardous-flame-retardants-in-recycled-plastic-consumer-goods>
12. Basel Convention. Overview. Available at: <http://www.basel.int/Implementation/Plasticwaste/Overview/tabid/6068/Default.aspx>
13. International Energy Agency. The future of petrochemicals: Analysis and outlook until 2050, 2018. Available at: <https://www.iea.org/reports/the-future-of-petrochemicals>
14. Organisation for Economic Co-operation and Development (OECD). Waste. Available at: <https://www.oecd.org/environment/waste/>
15. Kaza, S., Yao, L., Bhada-Tata, P., and Van Woerden, F. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050, World Bank Group, 2018. Available at: <https://openknowledge.worldbank.org/entities/publication/d3f9d45e-115f-559b-b14f-28552410e90a>

About EMC

Environmental Management Centre Pvt. Ltd. (EMC) is a Mumbai-based strategic sustainability consulting firm with 30 years of experience, more than 20 technical professionals, and over 1000 global assignments across governments, UN agencies, corporates, and financing institutions. Focused on ESG, Circular Economy, and Climate Change, EMC's ESG services cover over six billion dollars in assets, targeting ten billion dollars in the next three years. Selected for the Stanford Seed Transformation Program in 2025. EMC serves financial institutions and corporates through ESG due diligence, decarbonisation strategies, GHG inventorisation, sustainable finance advisory, and circularity metrics. Combining global expertise with local insights, EMC delivers future-ready solutions balancing economic growth, environmental responsibility, and social impact.

Cancellation of Highest Bid in Public Auction Impermissible Without Valid Grounds

The Hon'ble Supreme Court in *Golden Food Products India v. State of Uttar Pradesh* (decided on January 6, 2026) held that a public authority cannot cancel the highest bid in a validly conducted auction merely on the expectation of securing a higher price in a future auction. The Court observed that where the highest bid exceeds the reserve price and there is no fraud, collusion, or illegality in the process, cancellation on speculative grounds would be arbitrary and violative of Article 14 of the Constitution. The decision reinforces the importance of certainty and credibility in public auction processes, particularly in government land and infrastructure asset allocations.

Source: https://api.sci.gov.in/supremecourt/2024/33449/33449_2024_4_1502_67224_Judgement_06-Jan-2026.pdf

The Great Indian Waste Paradox: Bridging the Chasm Between Policy and Reality



Diptarup Kahali

Freelance Consultant - Water & Waste Management

Abstract

As India's cities expand, municipal solid waste management has shifted from a peripheral civic concern to a defining test of urban governance and environmental resilience. Although the Solid Waste Management Rules, 2016 (SWM Rules)¹ articulate an ambitious transition toward circularity - mandating segregation, processing, financial reform, and informal-sector inclusion - the gap between promulgating a regulation and its implementation remains substantial. This paper examines the behavioural, technical, financial, and institutional frictions that undermine compliance, and puts forth the view that regulatory sophistication alone cannot deliver outcomes. Drawing on Indian city-level experience, the paper advances the case for combining administrative enforcement with social realism, particularly in relation to citizens' behaviour and the informal recycling economy.

Keywords: Municipal Solid Waste, Circular Economy, Source Segregation, Urban Governance, Informal Sector, India.

The Urban Metabolism and the Regulatory Shift

The metabolism of Indian cities is undergoing a fundamental transformation. Rapid economic growth and shifting consumption patterns have led to a waste stream that is not only increasing in volume but also

in complexity. India currently generates roughly 62 million tonnes of waste annually, with a projected increase to 165 million tonnes by 2030 (SWM, 2016, p. 14)¹. Historically, the management of this waste was rudimentary, focused on the evacuation of refuse from residential areas to distant, invisible peripheries. The dump areas have now transformed into gargantuan legacy dumpsites, such as the Ghazipur mound in Delhi, which has frequently reached heights exceeding 65 metres, comparable to the Qutub Minar. Earlier empirical studies on Indian cities had already warned that rapid urbanisation, changing consumption patterns, and weak institutional capacity would overwhelm conventional waste management systems if disposal-oriented approaches persisted (Sharholly et al., 2008).²

The SWM Rules of 2016 represented a structural inflection point in India's waste governance framework in Indian environmental law. They reoriented regulatory intent from disposal-centric compliance toward material recovery and valorisation from simple 'disposal' to 'resource recovery'. The rules are comprehensive, covering everything from the duty of the generator to the remediation of old dumpsites. Yet, the implementation of these rules is stymied by a series of 'existing situations' that are deeply rooted in the urban fabric. To understand why progress is slow, it is necessary to deconstruct the waste value chain and identify where the gap and friction occur between policy and practice.

The Psychology and Logistics of Source Segregation

The most critical bottleneck in the entire waste management cycle is the failure to segregate at source. While the 2016 Rules mandate a three-way split - wet (biodegradable), dry (recyclable), and domestic hazardous waste - the national reality is far from this ideal. The logic of the rules is simple: if waste is mixed at the point of generation, its value as a resource is immediately compromised. Organic waste contaminated with plastic and glass is notoriously difficult to compost, and recyclables soiled by food waste lose their market value.

The bottleneck here is twofold: behavioural and infrastructural. From a behavioural perspective, many households still perceive waste management as a 'service' they pay for through taxes, which they feel absolves them of any personal responsibility. There is a profound lack of awareness regarding the 'why' of segregation. Furthermore, a 'trust deficit' plays a major role. The persistence of mixed waste collection is not merely a function of citizen apathy but reflects a breakdown in institutional credibility. When municipal systems fail to preserve segregation downstream, behavioural compliance upstream becomes irrational rather than negligent.

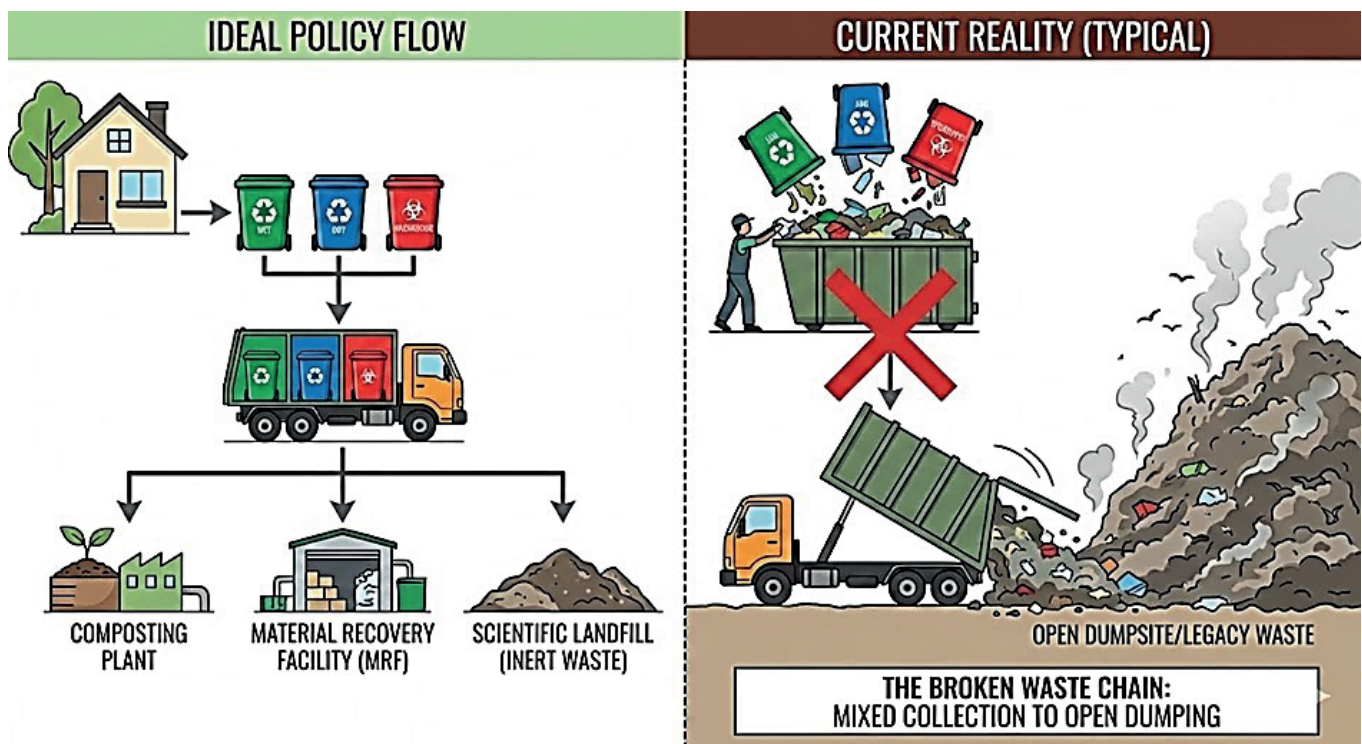


Figure 1: Ideal Policy Flow versus the Broken Municipal Solid Waste Chain in Indian Cities

Infrastructurally, many Urban Local Bodies (ULBs) lack the specialised fleet required for segregated collection. A 'stricter' policy suggests clear penalties for non-compliance, yet municipal authorities are often hesitant to enforce fines due to political pressure. To resolve this, some cities have experimented with 'Differential User Charges'. In this model, households that segregate pay a lower monthly fee than those that do not. However, implementing this requires a

robust digital tracking system - often using Radio Frequency Identification (RFID) - that many smaller municipalities simply cannot afford or manage (NITI Aayog, 2021, p. 42)³. National policy guidance has increasingly emphasised that behavioural change must be reinforced through economic signals and service differentiation, rather than relying solely on awareness campaigns (MoHUA, 2021).⁴

The Technical Crisis: Processing vs. Landfilling

The policy goal is a progressive reduction in the amount of untreated waste reaching landfills. In an ideal scenario, only ‘non-recyclable and non-combustible’ inert waste should be landfilled. However, most Indian cities still dump over 70% of their collected waste in non-engineered sites.

This continued reliance on non-engineered dumping is corroborated by national compliance assessments, which indicate that a majority of urban local bodies remain non-compliant with scientific landfill and processing requirements under the SWM Rules (CPCB, 2022).⁵

The primary technical bottleneck is the mismatch between waste composition and processing technology. Many Indian cities invested heavily in ‘Waste-to-Energy’ (WtE) plants, modelled on European designs. However, Indian waste typically has high moisture content (40-60%) and low calorific value (800-1100 kcal/kg). Consequently, these plants often struggle to maintain combustion without expensive auxiliary fuels, leading to financial failure and environmental hazards (Planning Commission, 2014, p. 28)⁶. In the Indian context, the persistence of WtE investment despite known feedstock incompatibility reflects not technical ignorance but contractual inertia and sunk-

cost bias within urban infrastructure decision-making.

Conversely, wet waste processing through composting or biomethanation is often hampered by poor input quality. If the incoming organic waste contains even 5% plastic or glass, the resulting compost is unmarketable. This creates a feedback loop of failure: poor segregation leads to poor processing, which leads back to the convenience of the dumpsite.

The technological impasse in Indian cities is not the absence of processing options but the misalignment between waste characteristics, chosen technologies, and governance capacity. As summarised in Table-1, each major processing pathway - composting, biomethanation, waste-to-energy, and biomining - faces context-specific constraints that are particularly pronounced in Indian urban local bodies (ULBs). Composting and biomethanation remain highly sensitive to upstream segregation quality, while waste-to-energy plants struggle with the low calorific value and high moisture content of mixed municipal solid waste. Importantly, Table-1 demonstrates that technology viability in India is less a technical question than a governance one, with scale, contractual structure, and state-level support emerging as decisive factors. This emphasises the need to move away from uniform technology prescriptions toward city-specific processing strategies anchored in institutional capacity and waste composition.

Table 1: Comparative Assessment of Waste Processing Technologies and Governance Implications for Indian ULBs

Technology	Ideal Feedstock	Key Bottleneck in Indian Cities	Market Viability	Governance Implication for Indian ULBs
Composting	Source-segregated biodegradable (wet) waste	Contamination by plastics and inert material due to weak household segregation	Low to Moderate; constrained by subsidised chemical fertilisers and variable compost quality	Best suited for small to medium ULBs ; requires strict ward-level segregation enforcement and assured compost offtake through state agriculture departments

Technology	Ideal Feedstock	Key Bottleneck in Indian Cities	Market Viability	Governance Implication for Indian ULBs
Biomethanation	High-moisture, high-organic food waste (markets, hotels, bulk generators)	High capital cost; operational sensitivity to feedstock variability	High, where bio-CNG or power offtake is contractually secured	Appropriate for ULBs with dense commercial zones ; needs state-backed power purchase or bio-CNG procurement guarantees
Waste-to-Energy (WtE)	High-calorific, low-moisture dry waste	Low calorific value and high moisture content of mixed Indian MSW	Low without tipping fees or viability gap funding	Feasible only for large metropolitan ULBs with assured tipping fees and pre-segregated RDF supply; unsuitable as a default national solution
Biomining (Legacy Waste)	Old, mixed, dumped waste from legacy dumpsites	Disposal and market linkage for RDF and fine inert fractions	Medium; dependent on cement and road-sector uptake	Primarily a state-level remediation intervention ; requires inter-departmental coordination beyond municipal capacity

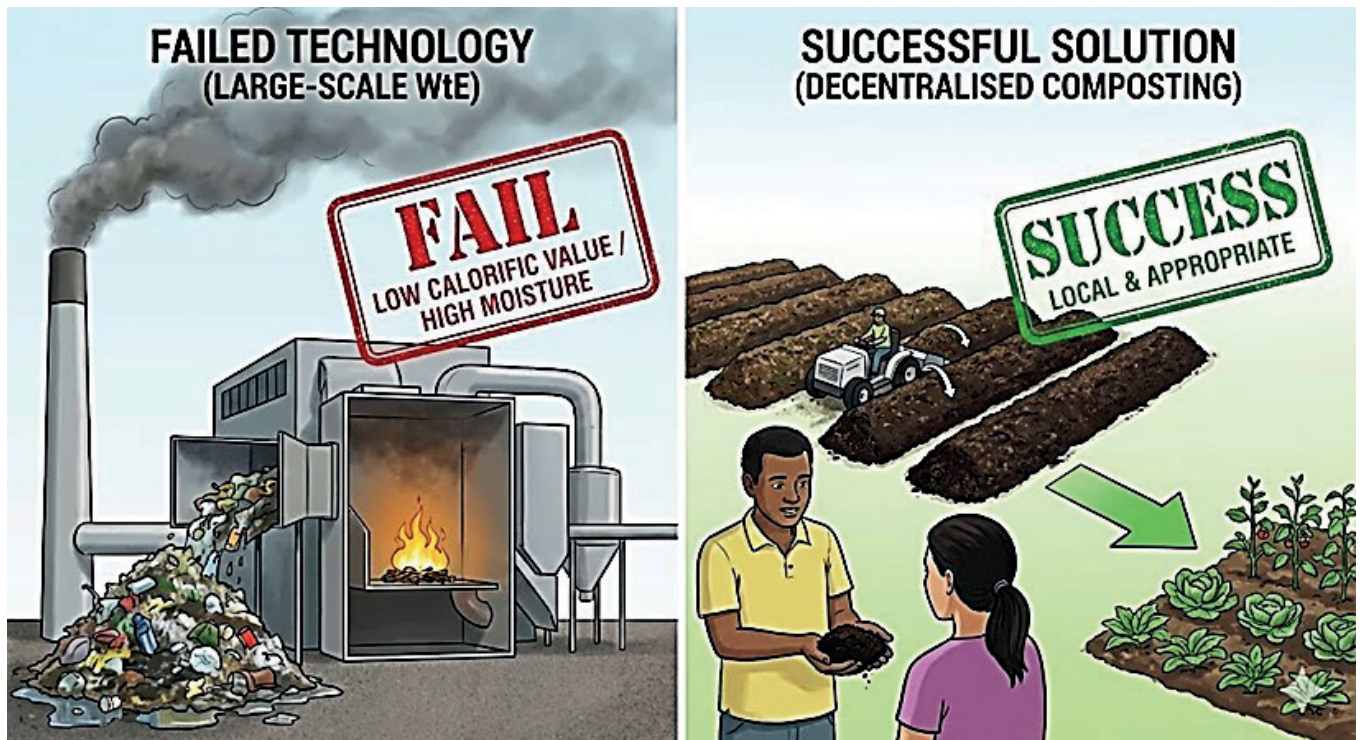


Figure 2: Contrasting Outcomes of Waste Processing Technologies in Indian Cities

Financial Reforms and the Agency Problem

Stricter policies call for ‘ring-fenced’ SWM accounts. This is essential because, in many ULBs, the revenue collected from waste is absorbed into the general municipal fund, which is often used to plug gaps in other departments like payroll or water supply. Without a dedicated budget, long-term investments in processing plants are impossible.

The financial bottleneck is also tied to how contracts are structured. Historically, ‘tipping fee’ contracts paid private operators based on the weight of waste delivered to the dumpsite. This created a perverse incentive: the more waste an operator dumped, the more money they made. There was no incentive to segregate or process.

To address this, the 2016 Rules suggest ‘Output-Based Contracts’. Under this system, operators are paid based on the amount of compost produced or the percentage of waste diverted from the landfill. However, this requires a level of monitoring - using GPS, RFID tags on bins, and IoT-enabled weighbridges - that most ULBs are not yet equipped to handle. The ‘Agency Problem’ arises when the goals of the private contractor (profit) are at odds with the goals of the municipality (environmental sustainability), and the municipality lacks the tools to enforce the contract (Ahluwalia & Patel, 2018, p. 89)⁷.

Social Sensitivity: The Informal Sector Integration

One of the most significant existing situations in India is the presence of a vast informal waste-picking economy. Millions of people survive by scavenging recyclables from the streets and dumpsites. They are the primary recyclers of the nation, diverting nearly 20% of waste at no cost to the taxpayer.

Stricter policies mandate their formalisation. This is not just a social imperative but an administrative one. When a private contractor takes over a city’s waste collection, they often displace these informal workers, pushing them further into poverty and losing their specialised knowledge of recycling.

The bottleneck here is ‘institutional invisibility’. Most ULBs do not have a registry of waste pickers. Integrating them into ‘Material Recovery Facilities’ (MRFs) requires a change in municipal mindset - moving from seeing them as a nuisance to seeing them as skilled partners. Success stories, such as the SWaCH cooperative in Pune (functioning since 1993), show that when waste pickers are integrated, segregation rates go up and municipal costs go down. However, replicating this requires a high degree of social sensitivity and a move away from purely ‘mechanised’ solutions that ignore the human element (Chikarmane, 2019, p. 12)⁸.

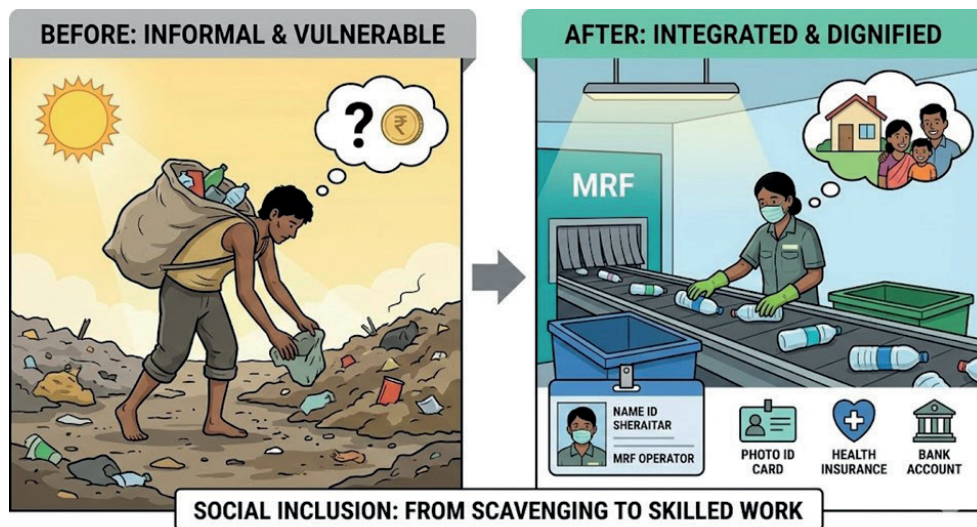


Figure 3: Integration of the Informal Sector into Formal Municipal Solid Waste Systems

The Roadmap to Administrative Firmness

To bridge these gaps, stricter policies must be backed by data-driven governance. Self-reported data from ULBs can no longer be relied upon. Independent audits and ward-level segregation scores are necessary to create accountability.

- **Enforceable Segregation:** ULBs must move beyond ‘awareness’ to ‘enforcement’. This includes a clear schedule of fines that is applied consistently, regardless of political affiliation.
- **Rationalised User Charges:** Waste collection is a service. Implementing a fair, tiered user charge system ensures that the ‘polluter pays’ and that the system becomes self-sustaining.
- **Digital Monitoring:** The use of technology is non-negotiable. Real-time monitoring of collection vehicles and processing plants reduces the scope for contractual fraud and ensures that waste is actually being treated.

While the Solid Waste Management Rules, 2016 provide a comprehensive regulatory framework, their uneven outcomes across cities reflect persistent structural bottlenecks in implementation. Table-2 presents a situational analysis linking these bottlenecks with corresponding policy responses and governance implications for Indian ULBs. The table highlights that challenges such as mixed waste collection, financial fragility, ineffective contracting models, and the marginalisation of informal waste workers are not isolated failures but interlinked systemic issues. Crucially, the analysis shows that stricter policy instruments - such as enforceable segregation, output-based contracts, and ring-fenced finances - can only succeed when supported by appropriate state-level oversight and institutional strengthening. In this sense, stricter waste management policies must be understood not as standalone regulatory prescriptions, but as governance instruments whose effectiveness is contingent upon administrative capacity, political backing, and inter-institutional coordination.

Table 2: Existing Bottlenecks and Governance-Oriented Policy Responses in Indian Cities

Core Policy Area	Existing Situations & Bottlenecks	Recommended Stricter Policy Instrument	Governance Implication for Indian ULBs
Source Segregation	Mixed waste at source; lack of trust due to downstream mixing; limited enforcement	Mandatory 3-way segregation with spot fines and differential user charges	Requires political backing at state level and decentralised enforcement at ward level; not feasible through awareness campaigns alone
Waste Processing	Over-reliance on WtE; low-quality compost; underutilised decentralised facilities	Mandatory processing targets with technology choice linked to waste composition	ULBs must shift from infrastructure procurement to outcome-based planning , supported by state technical cells
Landfill Management	Active dumping at non-engineered sites; landfill fires; leachate contamination	Time-bound biomining and prohibition of fresh waste dumping	Demands state pollution control board oversight , as most ULBs lack enforcement capacity
Financial Viability	Low cost recovery; SWM funds merged with general municipal accounts	Ring-fenced SWM accounts and rationalised user charges	Essential for medium and large ULBs ; smaller towns may need state-level pooled financing mechanisms
Contractual Monitoring	Tipping-fee contracts incentivising dumping; weak monitoring	Output-based contracts with digital verification	Requires state-supported digital platforms ; unrealistic to expect standalone ULB implementation
Informal Sector Integration	Displacement of waste pickers; loss of recycling efficiency	Mandatory registration and inclusion in MRF operations	Best handled through municipal – SHG - cooperative models ; success depends on local social context rather than uniform national templates

Conclusion

Taken together, the comparative assessment of technologies (Table-1) and the situational policy analysis (Table-2) illustrate that India's waste management challenge is fundamentally one of governance alignment rather than regulatory intent. Bridging the gap between policy ambition and operational reality requires differentiated strategies that reflect urban scale, institutional capacity, and social context.

The transition of Indian Municipal Solid Waste Management from a state of neglect to one of scientific rigour is hampered by a complex web of bottlenecks. The 'Existing Situation' is one of mixed waste, failed WtE plants, financial instability, and a marginalised informal workforce. However, the path forward is clear. By focusing on the fundamentals - source segregation, decentralised processing, and the formalisation of waste pickers - Indian cities can achieve the targets set by the 2016 Rules. Administrative firmness in enforcing these rules must be balanced with the social sensitivity required to change the habits of a billion people. Only then can the policy vision of a 'Clean India' be realised in its true, circular sense.

References

1. Ministry of Environment, Forest and Climate Change (MoEFCC). (2016). *Solid Waste Management Rules, 2016*. The Gazette of India. [pp. 14-40].
2. Sharholi, M., et al. (2008). *Municipal solid waste management in Indian cities - A review*. Waste Management, 28(2). [pp. 459-467].
3. NITI Aayog. (2021). *Waste-wise Cities: Best Practices in Municipal Solid Waste Management*. [pp. 40-65].
4. Ministry of Housing and Urban Affairs (MoHUA). (2021). *Circular Economy in Municipal Solid Waste Management: A Strategy Paper*. [pp. 22-45].
5. Central Pollution Control Board (CPCB). (2022). *Annual Report on Implementation of Solid Waste Management Rules, 2016*. New Delhi. [pp. 12-25].
6. Planning Commission. (2014). *Report of the Task Force on Waste to Energy (Vol. I)*. [pp. 25-40].
7. Ahluwalia, I. J., & Patel, U. (2018). *Solid Waste Management in India: An Assessment of Resource Recovery and Environmental Impact*. ICRIER. [pp. 45-92].
8. Chikarmane, P. (2019). *Integrating Waste Pickers into Municipal Processes*. WIEGO Policy Brief No. 19. [pp. 5-18].

MoRTH Issues Circular on Settlement Agreements in Highway Projects

The Ministry of Road Transport and Highways issued a circular dated February 25, 2026, prescribing a standard format for settlement agreements in national highway projects. The move aims to bring uniformity and legal clarity in settlement arrangements between project authorities and contractors in highway development projects.

Source : <https://morth.nic.in/backend/documents/uploaded/Circular%20dated%2025-02-2026.pdf>

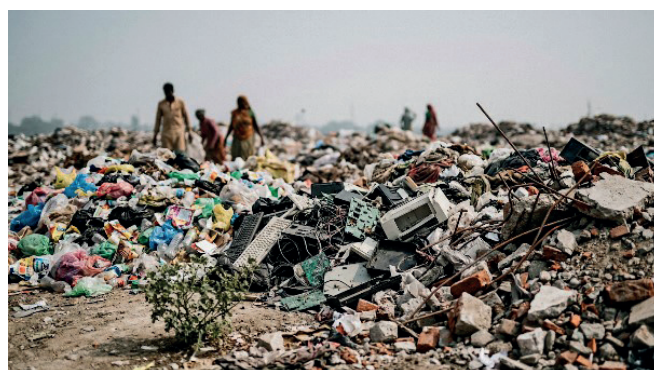
The 7 Habits of Highly Effective Waste Management: Turning India's Waste Crisis into a Strategic Business Opportunity



Pranav Sinha
ESGPace
Founder & CEO

Introduction

India generates 170,338¹ tonnes of solid waste every single day (as per 2022 data), that is equivalent to 14,000 trucks per day. But what most analyses miss is that the municipal solid waste headline - alarming as it is - tells only part of the story. India simultaneously produces 7.9 million tonnes of hazardous waste annually from over 47,000² industrial units. E-waste generation reached 1.75 million tonnes³ in financial year (FY) 2023-24, up 73% in just five years, with 57% of it sitting unprocessed. The country generates an estimated 26,000 tonnes of plastic waste per day⁴ - about 9.3 million tonnes annually⁵, but a 2024 study in Nature suggests the real figure could be three times higher, making India the world's largest plastic polluter. Biomedical waste from nearly 400,000⁶ healthcare facilities runs at over 775 tonnes per day. Battery waste is poised to surge exponentially as India's Electric Vehicle (EV) fleet and the contribution of solar and wind to the power mix scale. Every year, another 340 million tonnes⁷ of fly ash pour out of thermal power plants every year, as do another 53 million metric tonnes⁸ (per annum) of steel slag, from the rapidly expanding iron and steel industry - both non-hazardous industrial waste streams that, if designed into construction from the start, become valuable resources rather than an environmental liability.



Each of these waste categories demands distinct treatment, recycling, and disposal pathways. Each has its own regulatory framework - Solid Waste Management (SWM) Rules, Hazardous and Other Wastes Rules, E-Waste Rules, Battery Waste Management Rules, Plastic Waste Rules, Biomedical Waste Rules - and its own infrastructure gaps. Yet in boardrooms and on project sites, management of all non-hazardous industrial wastes has long been treated as a monolith, lumped under the suitably ambiguous term 'solid waste' and delegated to the local waste contractors, with scarcely a thought regarding the final fate of such wastes.

That era is ending. The convergence of the SWM Rules 2026, expanded Extended Producer Responsibility

(EPR) mandates across plastics, e-waste, batteries, certain hazardous and other wastes (e.g. non-ferrous metals, spent acid, used oil); the recently passed Environment (Construction & Demolition) Waste Management Rules 2025 (C&D Wastes Rules 2025); and tightening Business Responsibility and Sustainability Report (BRSR) disclosure requirements means that waste management across all categories has moved from compliance afterthought to a material business risk.

Drawing from Stephen Covey's timeless framework, here are seven habits that distinguish organisations getting waste management right - whether the waste stream is municipal, hazardous, electrical and electronic, or biomedical.

Habit 1: Segregate at Source - Be Proactive

Source segregation is the single highest-leverage intervention across every waste category. Without it, everything downstream - composting, recycling, reprocessing, waste-to-energy - becomes exponentially harder. Yet, according to the National Sample Survey Office (NSSO) only 43% of urban households currently practise it for municipal waste. The new SWM Rules 2026 mandate four-stream segregation at source. This change in the regulations is a step in the correct direction, but it is just that — the first of many steps. Its success will lie in the degree to which the law is adhered to in letter and spirit by citizens, as they navigate their daily lives.

Consider the contrast with biomedical waste. India's healthcare facilities are required to segregate into four colour-coded categories - yellow for infectious waste, red for contaminated recyclables, blue for glassware and white for sharps. During COVID-19, when biomedical waste surged from 619 tonnes per day (TPD) to over 800 TPD⁶, the facilities that had rigorously maintained segregation protocols managed the spike. Those that had not, became vectors for secondary contamination. The e-waste picture is worse: an estimated 57% of India's 1.75 million tonnes³ remains unprocessed, sitting in household drawers and storage rooms

because consumers have no easy channel for proactive separation.

Indore's transformation from rank 149 to India's cleanest city⁹ for seven consecutive years began with one decision: achieve 100% source segregation across all 85 wards, extending to six categories, including e-waste and domestic hazardous waste. Everything else - the Bio- Compressed Natural Gas (Bio-CNG) plant, the ₹14.45 crore revenue from waste, the 60% reduction in vector-borne disease - was built on that foundation.

Habit 2: Design for Circularity - Begin with the End in Mind

Effective waste management must start at the design stage, not at the dump site. The Construction and Demolition (C&D) Wastes Rules 2025 mandate recycling targets escalating to 100% by FY 2028-29, with mandatory use of recycled materials in new construction rising to 25% by FY 2030-31. However, the circularity principle is equally transformative for battery wastes; the Battery Waste Management Rules 2022 require producers to incorporate minimum percentages of domestically recycled lithium, cobalt, and nickel in new batteries starting FY 2027-28, essentially forcing manufacturers to design closed-loop supply chains from inception.

Non-hazardous industrial waste offers the most immediately realisable circularity opportunity. India's thermal power plants generated 340 million tonnes of fly ash⁷ in FY 2024-25 alone. Designed for incorporation into cement and road construction from the outset, this "waste" becomes valuable feedstock. Tata Steel's Industrial By-products Management Division proves the point: a dedicated profit centre with ₹10,000 crore annual turnover (per Tata Steel's Corporate Disclosures, June 2025), handling 14+ million tonnes of what used to be industrial waste (steel slag). The lesson is straightforward - if you design circularity into the system, waste becomes a product line and revenue generator.

Habit 3: Prioritise the Waste Hierarchy — Put First Things First

The SWM Rules 2026 formally codify India's waste hierarchy:

Prevention → Reduction → Reuse → Recycling → Recovery → Disposal

Yet most Indian waste management still inverts this - jumping straight to disposal or, at best, recovery. While the SWM Rules, 2016 and the Hazardous and Other Wastes Rules, 2016 also acknowledged the need for waste hierarchy-based design for waste management, the SWM Rules, 2026 are the first to add an explicit provision regarding imposition of environmental compensation (and application of the 'polluter pays' principle), for violation of regulatory requirements.



Adhering to the waste hierarchy is especially critical for hazardous waste, where the consequences of defaulting to disposal are severe. For the 7.9 million tonnes of hazardous waste that India generates annually, it has a chronic shortage of treatment infrastructure - just 18 integrated treatment, storage, and disposal facilities (TSDFs), 88 hazardous waste incinerators, and a mere two engineered landfills nationwide². Co-processing in cement kilns has emerged as a recovery-level solution, but the highest-value intervention remains prevention through cleaner production. For plastic waste, the hierarchy makes the case for the Single-Use Plastic (SUP) ban as a prevention measure - yet the ban covers only 19 identified items, roughly 11%⁴ of single-use plastic waste by volume. The upstream hierarchy steps

of prevention and reduction remain critically under-invested.

ITC Limited demonstrates what disciplined hierarchy application looks like: 18 consecutive years as solid waste recycling positive, 99.8% waste recycled across all streams, including hazardous chemicals and packaging plastics (per their Sustainability Report). As per Infosys Environmental, Social, and Governance (ESG) Vision 2030, the information technology (IT) services giant achieves a 95% landfill avoidance rate covering everything from municipal waste to e-waste from IT operations. These are not merely CSR showcases. They represent measurable cost savings from systematically applying the waste hierarchy to every stream.

Habit 4: Formalise the Informal - Think Win-Win

India's 1.5 to 4 million waste pickers¹⁰ are the unsung backbone of its municipal recycling system, largely responsible for a 60% plastic recycling rate - far above the global average of 14%. Any effective waste management strategy must integrate, not displace, these workers.

But the formalisation challenge is far more dangerous for e-waste and battery waste. Over 90% of India's e-waste is handled through informal channels using hazardous methods - acid baths to extract gold and copper, open burning of cables and manual dismantling without protection. In Delhi alone, an estimated 25,000 workers¹¹, including children, operate in crude e-waste dismantling units. Lead-acid batteries tell a similarly grim story, with over 90% recycled by informal smelters, as per WRI India, causing widespread lead contamination. The E-Waste Rules 2022 and Battery Waste Rules 2022 mandate EPR-based formal channels, but until the economics of formalisation work for informal operators - through fair pricing, skills training, and accessible collection infrastructure - the informal sector will dominate, carrying its full burden of health and environmental costs.

Pune's Solid Waste Collection and Handling (SWaCH) Cooperative - India's first wholly-owned cooperative

of waste pickers, with 3,900+ members¹² (70% women) - shows that formalisation can be win-win: it saves the city approximately ₹120 crore annually while providing dignified livelihoods. On the e-waste front, Ecoreco's partnership with the National Skills Development Corporation to train informal recyclers in scientific dismantling offers a replicable model for bridging the formal-informal divide.

Habit 5: Embrace Technology - Synergise

Technology is the force multiplier that makes all other habits scalable. Artificial Intelligence (AI) powered sorting now achieves 90%+ material recovery at 30-50% lower cost. Smart bins equipped with Internet-of-Things (IoT) sensors have demonstrated 32% improvement in collection route efficiency. India hosts approximately 292 solid waste management tech startups.

But the technology imperative is equally urgent across other waste streams. Biomedical waste management made a quantum leap during COVID-19 when the Central Pollution Control Board (CPCB) launched the COVID19 BMW mobile application for real-time tracking of infectious waste. Within a year, over 8,000⁶ healthcare facilities were onboarded, and today 208 of 218 Common Biomedical Waste Treatment Facilities operate with centralised barcode tracking and continuous emission monitoring. For plastic waste, CPCB's mandate for barcode and Quick Response (QR) code traceability on all packaging creates an unprecedented digital chain of custody. The EPR portals for e-waste and batteries similarly replace paper-based compliance with auditable digital trails.

The revenue case is already proven. RecycleKaro, a formal e-waste recycler, generated USD 25 million¹³ in sales in FY 2024-25 by recovering precious metals - gold, silver, platinum, palladium - from electronic waste through advanced hydrometallurgical processes.

Habit 6: Turn Waste into Revenue - Sharpen the Saw

The most effective waste management systems are

not cost centres - they are revenue generators. Indore Municipal Corporation earned ₹14.45 crore⁹ from waste in FY 2022-23, including ₹8.5 crore from carbon credit sales and ₹2.52 crore from its Bio-CNG plant royalty. It issued an \$87 million green bond⁹ in 2023 - a record for Indian municipalities.

The most compelling proof that waste management can be big business - not just civic housekeeping - comes from Re Sustainability Ltd. (ReSL), formerly Ramky Enviro Engineers Limited. In 2018, global private equity (PE) firm KKR acquired a majority stake in what was then the largest-ever buyout of an Indian environmental services firm, valuing the business at over USD 1 billion¹⁴. That bet has paid off. ReSL reported consolidated Earnings Before Interest, Taxes, Depreciation, and Amortisation (EBITDA) of INR 1,120 crore (approximately USD 125 million) in FY 2023, with its industrial waste management vertical alone commanding a valuation exceeding USD 1 billion, per publicly available data. When a global private equity firm values an Indian waste management company at that scale, the "waste to wealth" narrative ceases to be a government slogan and becomes an investable thesis.

The revenue logic extends powerfully across specific waste categories. E-waste is, quite literally, a goldmine - one tonne of waste circuit boards contains gold at concentrations 10 to 250 times¹⁵ that of natural ore, alongside recoverable silver, copper, and palladium. India's 322 registered e-waste recyclers hold an authorised processing capacity of over 220,000 tonnes per year, and the domestic e-recycling sector is projected to reach approximately ₹ 17.26 billion¹⁶ by 2032. For non-hazardous industrial waste, cement companies across India already co-process thousands of tonnes of paint sludge (and other energy dense wastes) as supplementary fuel, and millions of tonnes of fly ash and slag as supplementary raw material, simultaneously reducing costs and carbon intensity. India's circular economy is projected to generate a market value exceeding USD 2 trillion¹⁷ and create close to 10 million jobs by 2050, per the Union Environment Minister's statement at the 12th Regional

3R and Circular Economy Forum (March 2025) - but only for organisations that treat waste as a value stream, not an externality.

Habit 7: Report, Disclose, Improve — Seek First to Understand

What gets measured gets managed. The Securities and Exchange Board of India's (SEBI) BRSR framework now requires the top 1,000 listed companies to report waste generation across eight categories - plastic, e-waste, biomedical, construction and demolition, battery, radioactive, other hazardous, and other non-hazardous. Value chain ESG disclosures from FY 2025-26 mean that waste performance is becoming a supply chain qualification criterion, not just a corporate reporting exercise.

The reporting imperative is now category-specific and enforceable. Hazardous waste generators must maintain online manifests - Gujarat's Extended Green Node system tracks over 18,000 industrial facilities in real time. Battery waste producers must register on CPCB's EPR portal, report quarterly, and demonstrate achievement of recycling targets, with environmental compensation penalties for shortfalls. For biomedical wastes, 15,355 show-cause notices⁶ were issued to defaulting healthcare facilities in 2021 alone. Across every waste category, the era of unreported, untracked waste generation is ending.

Sterlite Technologies' achievement of Zero Waste to Landfill certification from Intertek - covering all waste streams, including hazardous process chemicals and e-waste from manufacturing, not just a narrow single-stream certification - exemplifies what comprehensive disclosure and improvement looks like in practice. It is this breadth of coverage that differentiates in global supply chain assessments.

The Habit That Binds Them All

Effective waste management is not a single initiative or a compliance checkbox. It is a system of interconnected habits that must operate across every waste stream, not just the most visible one.



Municipal solid waste fills the headlines and is most visible across Indian landscapes, but hazardous and other industrial wastes from 47,000+ manufacturing units pose severe risks with grossly inadequate TSDF infrastructure. E-waste grows at 73% over five years, with 90% still handled through dangerous informal methods. Battery waste will surge as India's EV ambitions scale, demanding entirely new collection and recycling systems. Plastic waste leaks into ecosystems despite a well-intentioned SUP ban that barely addresses a tenth of the problem. Biomedical waste, stress-tested by the pandemic, has improved its tracking systems but still faces treatment capacity gaps. And non-hazardous industrial waste - the quiet giant - offers the most immediately available circularity opportunity if corporations design for circularity from the start.

The regulatory trajectory across all these streams is clear and accelerating: SWM Rules 2026, C&D Waste Rules 2025, expanded EPR for plastics, e-waste, select hazardous and other wastes, and batteries, and tightening BRSR disclosure norms. Waste management obligations and costs will rise significantly across every category. The firms that treat this as a strategic opportunity, applicable to hazardous, non-hazardous industrial wastes and biomedical waste as much as to municipal solid waste, will define the next era of Indian infrastructure and industrial development.

The question is not whether to act, but how quickly.

References

1. Central Pollution Control Board (CPCB), Annual Report on Solid Waste Management, FY 2021-22. Cited

- in Government of India Rajya Sabha reply, February 2024. URL: https://cpcb.nic.in/uploads/MSW/MSW_AnnualReport_2020-21.pdf
2. CPCB, National Inventory of Hazardous Wastes Generating Industries & Hazardous Wastes Management in India, 2023-24. URL: https://cpcb.nic.in/uploads/hwmd/Annual_Inventory2023-24.pdf
3. Down To Earth, "India's E-Waste Surges By 73% in 5 Years," December 2024, based on CPCB data. URL: <https://www.downtoearth.org.in/waste/indias-e-waste-surges-by-73-in-5-years>
4. CSIRO, National Circular Economy Roadmap for India (December 2023); Meijer, L.J.J. et al., Nature (2024), cited in CenFA analysis; Down To Earth, "How Bad Is India's Single-Use Plastic Crisis?" <https://www.cenfa.org/how-dubious-data-fading-tech-shape-indias-global-plastic-stance/>
5. Down To Earth, "India Leads Global Plastic Pollution," September 2024; citing Cottom, Cook & Velis, Nature (September 2024). URL: <https://www.downtoearth.org.in/waste/india-tops-plastic-pollution-rankings-emitting-a-fifth-of-global-plastic-waste>
6. Frontiers in Environmental Science, "Upsurge in Biomedical Waste Due to COVID-19 in India," 2022; CPCB Annual Report on Biomedical Waste Management, 2021 (393,242 HCFs, 15,355 show-cause notices). URL: https://cpcb.nic.in/uploads/Projects/Bio-Medical-Waste/AR_BMWM_2021.pdf
7. Central Electricity Authority (CEA), Report on Fly Ash Generation FY 2024-25: 340.11 million tonnes. PIB Press Release, Government of India. URL: <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2160714>
8. Down To Earth, "Inner Steel," February 2025; citing SAIL/Kumar et al. (2019). 53 MT steel slag from 150 MT steel production. URL: <https://www.downtoearth.org.in/energy/inner-steel>
9. Indore Municipal Corporation, Swachh Survekshan Performance Data 2014–2024; US EPA/Global Methane Initiative Case Study; green bond issuance (2023). URL: https://globalmethane.org/documents/Indore_Case_Study.pdf
10. International Alliance of Waste Pickers / WIEGO, "Organising and Integrating the Informal Recycling Sector in the Solid Waste Management Sector – India," May 2025. URL: <https://globalrec.org/2025/05/20/organising-and-integrating-the-informal-recycling-sector-in-the-solid-waste-management-sector-india/>
11. CSE India, "E-Waste Management in India: Challenges and Agenda." URL: <https://www.cseindia.org/content/downloadreports/10593>
12. CenFA, "The SWaCH Cooperative Model of Pune," November 2025. 3,900+ members; world's largest waste picker-led cooperative. URL: <https://www.cenfa.org/the-swach-cooperative-model-of-pune-the-yes-in-my-back-yard-model-of-waste-management/>
13. Rest of World, "The Dirty Truth Behind the E-Waste Recycling Industry," September 2025. URL: <https://restofworld.org/2025/india-e-waste-recycling-electronics/>
14. Economic Times, "KKR to split Re Sustainability, sell industrial waste management business," 08 February 2024. URL: <https://economictimes.indiatimes.com/news/company/corporate-trends/kkr-to-split-re-sustainability-sell-industrial-waste-management-business/articleshow/107534030.cms>
15. Multiple peer-reviewed sources: ScienceDirect (Tan et al., 2017); IOM3/Royal Mint (165g/tonne PCBs); C&EN (10× ore concentration). URL: <https://www.sciencedirect.com/science/article/abs/pii/S0304389420330028>
16. Economic Times, "KKR to split Re Sustainability, sell industrial waste management business," 08 February 2024. URL: <https://economictimes.indiatimes.com/news/company/corporate-trends/kkr-to-split-re-sustainability-sell-industrial-waste-management-business/articleshow/107534030.cms>
17. India Ratings and Research (Ind-Ra), cited in IBEF, February 2025. URL: <https://ibef.org/news/e-recycling-sector-to-reach-rs-1-726-33-crore-us-198-52-million-by-2032-at-cagr-of-13-52-india-ratings-and-research-ind-ra>

About ESGPace: ESGPace is a specialist ESG consulting firm founded by Pranav Sinha, who has over 20 years of experience in sustainability, ESG, and Environment, Health, and Safety (EHS) consulting across 17 countries in Asia, the Middle East, Africa, Europe, and North America. Pranav and ESGPace focus on operationalising sustainability intent and driving on-ground improvements in ESG performance and outcomes.

Waste Management Policies in India: Policy Gaps, Implementation Challenges, and Pathways for Effective Governance



Pravinjith K P
Managing Director
Ecoparadigm

Abstract

India has developed one of the most extensive regulatory architectures for Municipal Solid Waste (MSW) governance in the Global South, anchored in the Solid Waste Management Rules and reinforced by the Swachh Bharat Mission – Urban. The framework mandates source segregation, lifecycle accountability, scientific processing, and Extended Producer Responsibility (EPR). However, implementation outcomes remain uneven, with persistent landfill dependence, suboptimal material recovery, and inconsistent segregation compliance across urban jurisdictions.

This article argues that India's waste governance underperformance stems not from regulatory inadequacy but from institutional misalignment. Although the legal framework is robust, implementation is constrained by weak alignment between statutory mandates, administrative capacity, fiscal systems, and enforcement credibility. Comparative city-level analysis shows that regulatory ambition without calibrated enforcement often results in compliance formalism rather than substantive behavioural change. Variations across municipalities indicate

that governance discipline rather than technological sophistication largely explains differential outcomes.

The study conceptualises India's waste management system as a case of “capacity–mandate asymmetry,” where statutory obligations exceed institutional readiness. Positioned within global circular economy transitions, the paper argues that enforceable traceability systems, incentive realignment, and formal integration of informal waste economies are essential for systemic transformation. It concludes by proposing a sequenced governance reform pathway to translate regulatory architecture into operational circularity.

Keywords: Solid Waste Management; Policy Implementation; Urban Governance; Circular Economy; Extended Producer Responsibility; India

Introduction

India's urban waste management challenge has intensified over the past two decades due to rapid urbanisation, rising incomes, and changing consumption patterns. Urban India currently generates over 60 million tonnes of municipal solid waste annually, with projections indicating significant

increases by mid-century. Waste composition is also evolving, with growing shares of plastics, multilayer packaging, sanitary waste, and embedded hazardous materials.

Ineffective waste management generates substantial environmental and public health externalities. Open dumping and poorly managed landfills contribute to groundwater contamination, vector-borne diseases, and methane emissions, while inadequate segregation undermines recycling and composting systems. Waste management therefore represents a critical test of India's urban governance capacity.

India has established a comprehensive regulatory framework through the Solid Waste Management Rules and the Swachh Bharat Mission – Urban. These policies mandate source segregation, door-to-door collection, scientific processing, landfill management, and defined stakeholder responsibilities. Despite this regulatory clarity, mixed waste collection and underperforming infrastructure persist, indicating a structural gap between policy design and implementation.

This paper addresses three questions:

- Why does policy implementation lag despite regulatory comprehensiveness?
- What explains the success of certain Indian cities?
- How can policy reforms enable scalable and sustained implementation outcomes?

The analysis situates India's experience within broader policy implementation literature, highlighting governance and political economy constraints.

Analytical Framework

The study adopts qualitative policy analysis based on regulatory review, government reports, academic literature, and city-level case studies. Instead of evaluating specific waste technologies, the analysis focuses on governance mechanisms influencing implementation outcomes. As shown in Figure 1, the OECD-recommended pathway highlights the sequential stages required for effective policy implementation reform.

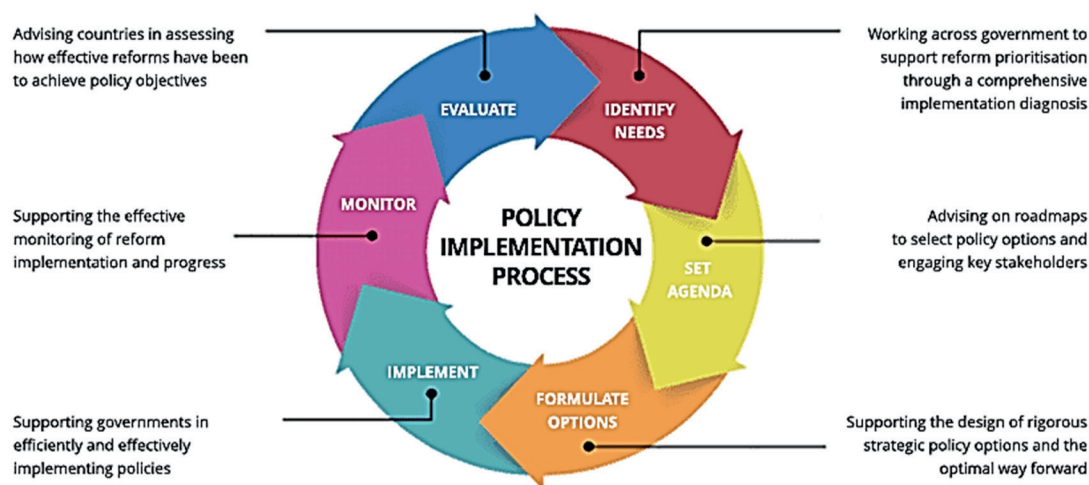


Figure 1: Depicts the OECD-recommended pathway for policy implementation reform.

The framework examines three interdependent dimensions:

- Administrative Capacity:** Staffing levels, technical expertise, financial autonomy, planning capability, and data systems within implementing agencies,
- Incentive Alignment:** Economic and behavioural incentives affecting households, bulk waste generators, contractors, and producers.
- Accountability and Enforcement:** Monitoring

particularly Urban Local Bodies (ULBs).

systems, audit mechanisms, penalty certainty, and political oversight.

Weakness in any one dimension can undermine policy outcomes even when formal regulations are strong.

India's Waste Management Policy Architecture

India's waste governance framework consists of national rules introduced primarily in 2016, including the Solid Waste, Plastic Waste, E-Waste, Construction and Demolition Waste, and Bio-Medical Waste Management Rules. These regulations define stakeholder responsibilities, mandate source segregation, prescribe processing standards, and emphasise Extended Producer Responsibility for select waste streams.

Policy implementation is decentralised. Urban Local Bodies manage municipal waste systems, state governments provide oversight and technical support, and the central government establishes regulatory standards and financing support through national missions.

Although the framework aligns with global best practices, implementation often assumes administrative and financial capacity that many municipalities lack. This mismatch between regulatory ambition and institutional capacity remains a central challenge.

Policy Gaps and Reform Priorities in India's Waste Management System

1 Enforcement and Regulatory Compliance Gap

Despite strong regulatory provisions, enforcement remains weak due to institutional capacity constraints, fragmented monitoring systems, and limited compliance verification. ULBs frequently lack adequate staffing, technical expertise, and financial resources. Similarly, State Pollution Control Boards face operational limitations in inspection and enforcement. As a result, large volumes of waste continue to be openly dumped or landfilled despite regulatory mandates.

2 Source Segregation and Collection System Failure

Source segregation is essential for effective recycling and processing. However, segregation rates remain low due to weak enforcement, limited infrastructure, and operational inefficiencies. In many cities, segregated waste is mixed during transportation because dedicated collection systems are absent. This contamination reduces recycling efficiency and undermines downstream processing.

3 Landfill Dependence

Landfills remain the dominant disposal pathway due to insufficient processing infrastructure and the absence of legally binding landfill diversion targets. Unlike advanced waste systems, India lacks landfill taxation mechanisms or strict diversion requirements, limiting incentives for material recovery.

4 Informal Sector Exclusion

India's recycling economy relies heavily on informal waste workers who recover significant quantities of recyclable materials. However, they remain largely excluded from formal regulatory frameworks. This reduces material traceability and creates socio-economic vulnerabilities. Integrating informal workers into municipal waste systems could significantly improve recycling efficiency and governance outcomes.

5 Weak Implementation of Extended Producer Responsibility

EPR provisions under the Plastic Waste Management Rules and E-Waste Management Rules assign producers responsibility for waste recovery. However, implementation remains weak due to limited monitoring, reliance on self-reported compliance data, and inadequate traceability systems.

6 Infrastructure and Financial Constraints

Processing infrastructure such as Material Recovery Facilities, composting plants, and

recycling units remains insufficient relative to rising waste generation. Municipal systems are financially constrained, relying largely on public funding with limited cost-recovery mechanisms.

7 Data and Institutional Coordination Gap

Waste data in India remains fragmented and inconsistent. Responsibilities are distributed across multiple agencies, creating coordination challenges and weak accountability. The absence of integrated digital monitoring systems limits effective planning and regulatory oversight.

Explaining Success: Evidence from Indian Cities

City-level experiences demonstrate that waste management outcomes depend primarily on governance discipline, financial structuring, and behavioural compliance rather than technological sophistication.

Disaggregated waste generation data at household or generator level, as evidenced by the pilot IOT project SEWAC at Sompura panchayath, Karnataka, which also secured the runner-up position at Smart city 2021 and mentioned by the United Nations 2025. This is currently being adopted at the HSR ward of Bengaluru. The daily data acquired gives valuable insights into per capita generation, waste segregation, and behaviour trends (Figure 2).



Figure 3: Integration of rag pickers into work at the Plastic Waste Collection Centre in Indore.

Source: <https://www.smartcityindore.org/solid-waste/>

Indore illustrates governance-led reform through strong leadership, real-time monitoring, and strict enforcement (Figure 3). Pune demonstrates the benefits of integrating waste pickers into formal service delivery systems. Alappuzha and Ambikapur show the viability of decentralised waste processing combined with strict segregation enforcement (Figure 4).

Financial sustainability has been strengthened in Surat and Panaji through structured user-fee systems. Targeted investments in Bhopal and legacy waste biomining in Gorakhpur highlight the benefits of strategic capital deployment.

Innovations in Vijayawada and Tirupati demonstrate context-specific circular economy approaches, while



Figure 2: Real-Time Segregated Waste Monitoring System by Ecoparadigm.

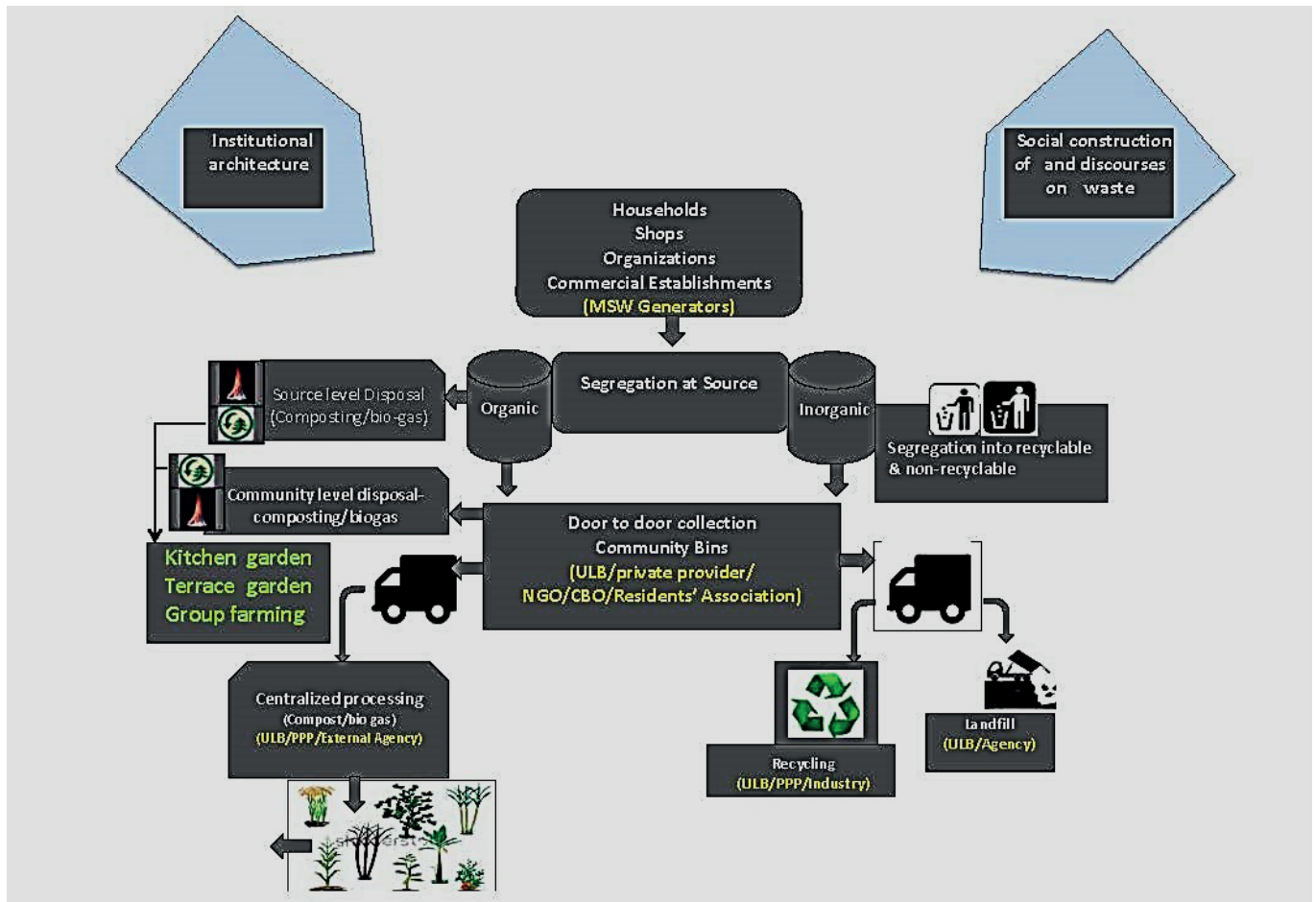


Figure 4: Overview of decentralised waste chains in Kerala.

Source: <https://riojournal.com/article/31430/>

decentralised dry waste management initiatives in Bengaluru and terrain-adapted systems in Shillong emphasise the importance of local design adaptation. Structured public-private partnerships in Ahmedabad illustrate effective risk-sharing frameworks.

Overall, successful SWM systems in India depend on institutional coherence, predictable financing, enforcement capacity, and sustained public participation as shown in Figure 5.

International Policy Benchmarks

Comparative experience from Germany, South Korea, and Japan highlights the role of enforcement certainty, waste pricing mechanisms, and long-term policy continuity. Germany's EPR regime internalises waste costs into product pricing, South Korea's pay-as-you-throw system links waste generation directly to financial incentives, and Japan demonstrates the importance of stable policy frameworks and strong social compliance.



Figure 5: Haritha Karma Sena: Women Keeping Kerala Litter-Free.

While direct policy transfer to India is constrained by capacity and equity considerations, targeted adaptation of waste pricing pilots, enforcement-driven EPR systems, and sustained public awareness programmes could improve policy outcomes.

Toward an Implementation-Oriented Reform Pathway

Policy reform should prioritise governance strengthening rather than infrastructure expansion. Key measures include:

- Establishing national and state waste data systems with standardised reporting.
- Strengthening enforcement through predictable penalties and performance incentives.
- Formalising informal sector participation in waste recovery systems.
- Piloting waste pricing mechanisms with safeguards for low-income households.
- Linking financing to performance outcomes rather than asset creation.

Reforms should follow a phased timeline: data and enforcement improvements within 1–2 years, financial sustainability reforms within 3–5 years, and broader circular economy integration within 5–10 years.

Policy Recommendations: Driving Circular Waste Transition

India's waste system must transition from disposal-based management to circular resource governance. As shown in Figure 6, the circular economy concept proposed by the European Environment Agency promotes the continuous use of resources by minimising waste and maximising material recovery. A national digital waste tracking system should be developed to ensure material traceability and regulatory accountability. Binding landfill diversion targets should reduce disposal to below 50% by 2030 and below 10% by 2040, supported by landfill taxation and regulatory disincentives.

EPR frameworks must introduce verifiable recovery targets supported by digital monitoring. Simultaneously, expanding decentralised processing infrastructure and integrating informal workers are essential to achieve 100% scientific waste processing by 2035.

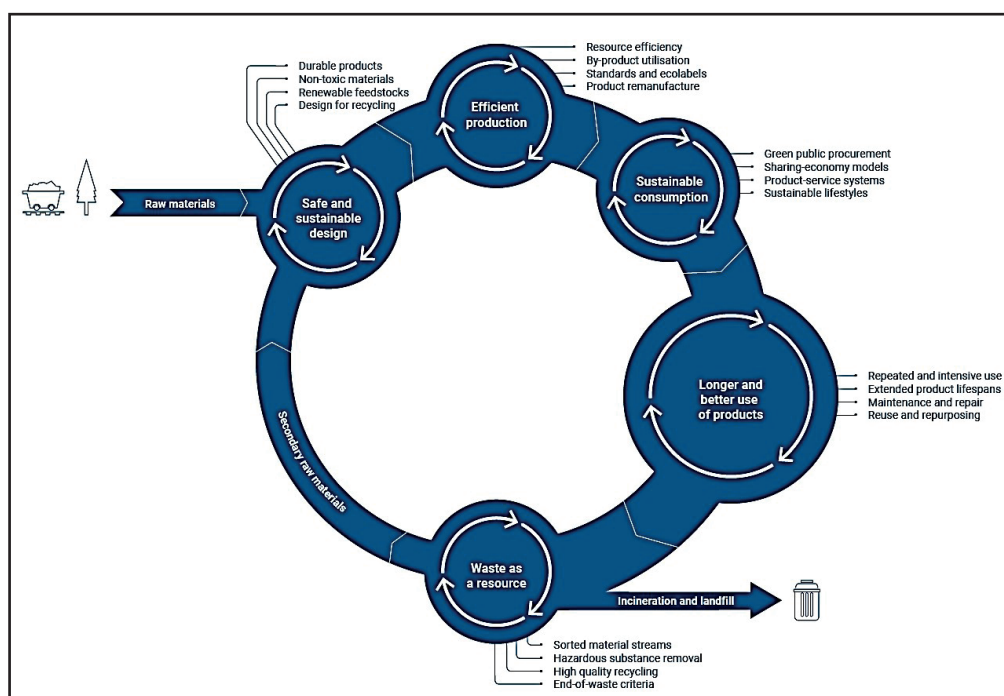


Figure 6: Circular economy concept proposed by the European Environment Agency

These reforms could enable over 75% recycling and 90% landfill diversion by 2040, transforming waste into a resource stream while reducing environmental and climate risks.

1. Sectoral Regulatory Architecture

India's circular economy transition is currently driven through sector-specific regulations targeting high-impact material streams.

- a. E-Waste Management Rules mandate EPR obligations, recycling targets, and digital compliance mechanisms.
- b. Plastic Waste Management Rules impose EPR obligations, recycled content requirements, and restrictions on specific single-use plastics.
- c. Vehicle Scrappage Policy promotes formal recycling of end-of-life vehicles.

These measures reflect gradual institutionalisation of lifecycle responsibility and resource recovery.

2. Institutional Coordination

The NITI Aayog Circular Economy Cell facilitates coordination across ministries and develops sectoral roadmaps focusing on e-waste, battery recycling, construction waste management, industrial symbiosis, and resource efficiency.

Circular economy strategies are increasingly linked with industrial policy instruments such as Production Linked Incentive schemes.

3. Integration with National Missions

Circular economy principles are also embedded within broader sustainability initiatives.

The Swachh Bharat Mission – Urban promotes the 3R framework through improved waste segregation and processing infrastructure. The National Action Plan on Climate Change integrates resource efficiency and cleaner production strategies.

4. Sub-National Initiatives

Several states are developing regional circular economy initiatives.

- a. **Maharashtra** promotes treated wastewater reuse in industry and agriculture.
- b. **Karnataka** is advancing circular construction practices emphasising resource-efficient building materials.

These initiatives demonstrate emerging decentralised leadership.

5. Structural Challenges

Despite progress, several structural challenges persist:

- a. Absence of a unified national circular economy law with binding targets.
- b. Enforcement disparities across regions.
- c. Limited integration of informal waste workers.
- d. EPR frameworks covering only select sectors.
- e. Insufficient market-based incentives such as deposit-return systems and recycled content mandates.

6. Strategic Policy Priorities

To accelerate circular economy transition, India should:

- a. Enact a National Circular Economy Law establishing binding targets and monitoring systems.
- b. Expand EPR obligations across additional sectors.
- c. Introduce market-based policy instruments including deposit-return systems and green procurement.
- d. Develop national dashboards and standardised circularity metrics.
- e. Integrate informal waste workers through formal recognition and cooperative models.
- f. Support innovation through circular economy finance and SME incentives.

7. Implementation Pathways for Metropolitan Cities, Cities, and Towns

Effective municipal solid waste management requires operational strategies tailored to

settlement size, administrative capacity, and waste generation characteristics. Although the Solid Waste Management Rules establish uniform regulatory obligations, implementation approaches must vary across metropolitan regions, medium-sized cities, and smaller towns.

a. Metropolitan Cities

Large metropolitan areas generate high volumes of heterogeneous waste streams and therefore require structured, large-scale operational systems.

Key actions include:

- i. **Ward-Level Processing Networks:** Establish multiple Material Recovery Facilities and

decentralized processing units across wards to reduce transport distances and increase material recovery.

- ii. **Dedicated Segregated Transport Systems:** Ensure that segregated waste streams are transported separately through specialised vehicle fleets and route planning.
- iii. **Legacy Dumpsite Remediation:** Implement large-scale biomining and scientific landfill remediation programmes to eliminate accumulated waste liabilities.
- iv. **High-Capacity Processing Infrastructure:** Develop large composting, bio-methanation, and recycling facilities capable of handling metropolitan waste volumes (Figure 7).



Figure 7: Biogas plant designed by Ecoparadigm in Nashik.

b. Medium-Sized Cities

Medium-sized urban centres generally generate moderate waste volumes but face constraints in financial and administrative resources. Efficient system design is therefore essential.

Key priorities include:

- i. **Neighbourhood-Level Organic Waste Processing:** Promote decentralised composting or bio-methanation systems at ward or community level.

- ii. **Structured Collection Networks:** Design predictable and scheduled door-to-door collection systems that maintain segregation integrity.
- iii. **Regional Recycling Linkages:** Develop logistical linkages with regional recycling markets to ensure consistent material recovery.
- c. **Small Cities and Towns**

Smaller towns typically generate lower waste volumes and can manage waste through simpler decentralised systems.

Recommended measures include:

- i. **Community-Level Composting:** Establish local composting units for biodegradable waste generated within residential clusters
- ii. **Cluster-Based Infrastructure:** Develop shared waste processing facilities across nearby towns to optimise infrastructure costs.
- iii. **Appropriate Collection Systems:** Use smaller vehicles and flexible collection routes suited to local settlement patterns.
- d. **Governance Priorities Across Urban Settlements**

Across all categories of urban settlements, municipalities must prioritise operational consistency and compliance with segregation and processing requirements. Clear institutional responsibilities, reliable collection systems, and appropriate processing infrastructure are essential to ensure that segregated waste is effectively processed and landfill disposal is progressively reduced.

Adopting differentiated operational models aligned with local waste volumes and institutional capacity can significantly improve municipal solid waste management performance across India's urban system.

Discussion

India's waste governance gap is primarily institutional rather than regulatory. While the Solid Waste Management Rules and EPR provisions provide a

strong policy foundation, implementation is uneven because statutory mandates exceed municipal capacity in many jurisdictions.

Three structural dynamics explain this gap:

First, decentralised governance produces capacity-mandate asymmetry, where uniform regulations confront uneven municipal capability.

Second, incentive misalignment persists because landfill disposal often remains the lowest-cost option. Weakly enforced EPR systems risk symbolic compliance rather than genuine accountability.

Third, enforcement credibility remains limited. Where inspection regimes are predictable and performance incentives are applied, segregation and recycling rates improve significantly.

Informal waste workers remain central to material recovery despite limited institutional integration. Their structured inclusion is essential for traceable circular systems.

Overall, regulatory expansion without aligned incentives, administrative capacity, and enforcement credibility tends to produce formal compliance rather than substantive transformation.

Conclusion

India's municipal solid waste governance framework is not deficient in statutory design. The country has comprehensive regulations, clearly defined stakeholder responsibilities, and articulated circular economy objectives. However, regulatory ambition has outpaced institutional capacity, creating a persistent implementation gap.

The study demonstrates that waste governance outcomes depend on the interaction between administrative capacity, incentive structures, and enforcement credibility. Where these factors align, significant improvements can occur within existing legal frameworks.

Transformative reform requires a sequenced strategy that includes:

- a. Establishing digital traceability systems for lifecycle accountability.
- b. Introducing binding landfill diversion targets supported by economic instruments.
- c. Strengthening municipal fiscal autonomy linked to performance outcomes.
- d. Integrating informal waste workers into formal recovery systems.
- e. Expanding and enforcing EPR through transparent verification.

Strengthening enforcement credibility and incentive alignment is therefore essential to convert India's regulatory architecture into a functioning circular governance regime.

References

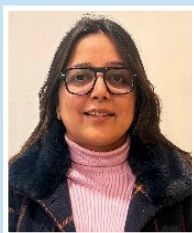
- 1) Government of India. 2023. Swachh Bharat Mission – Urban 2.0 Guidelines. Ministry of Housing and Urban Affairs, New Delhi.
- 2) Ministry of Housing and Urban Affairs. 2020. Manual on Municipal Solid Waste Management. Government of India.
- 3) NITI Aayog. 2021. Resource Efficiency and Circular Economy Industry Coalition (RECEIC): India's Circular Economy Framework.
- 4) World Bank. 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Washington, DC.
- 5) United Nations Environment Programme. 2015. Global Waste Management Outlook. Nairobi.
- 6) United Nations Environment Programme. 2024. Composting Solid Organic Waste from Municipal Sources in West Asia – A Technical Guide for Decision Makers and Practitioners. Nairobi.
- 7) European Commission. 2020. A New Circular Economy Action Plan for a Cleaner and More Competitive Europe. Brussels.

- 8) Joshi, R., and Ahmed, S. 2016. Status and challenges of municipal solid waste management in India: A review. Cogent Environmental Science, 2(1).
- 9) Gupta, N., Yadav, K., and Kumar, V. 2015. A review on current status of municipal solid waste management in India. Journal of Environmental Sciences, 37.
- 10) Wilson, D. C., Velis, C., and Cheeseman, C. 2013. Role of informal sector recycling in waste management in developing countries. Habitat International.
- 11) Velis, C. A. 2017. Waste pickers in global waste management. Waste Management & Research.
- 12) Vogt, R., Stubbusch, A., Lakshmi, K. V., Arora, K., Shekhar, A. R., Chandran, K., Pravinjith, K. P., and Khanam, A. (2019). *Resource and climate protection through integrated waste management projects in emerging economies and developing countries - Example India* (Final Report, TEXTE 05/2019, Project No. 3715 33 313 0). Umweltbundesamt (German Environment Agency).
- 13) Schröder, P., et al. 2019. Circular economy in developing countries: Approaches and challenges. Chatham House Research Paper.
- 14) Asian Development Bank. 2020. Solid Waste Management in India: Issues and Opportunities.
- 15) Centre for Science and Environment. 2020. Managing Municipal Solid Waste: A Review of Achievements under SBM-Urban.

About Ecoparadigm

Ecoparadigm is a six-time National Award-winning environmental engineering and sustainability consultancy established in 2006, in Bangalore, with over two decades of industry experience. It develops cutting-edge solutions tailored to clients' unique needs in the field of Wastewater, Rainwater, Lake Rejuvenation, Solid Waste, Net Zero Audits, Power, and the Energy sector, delivering sustainable outcomes for both clients and the planet. The main motto of the company is to help customers optimise their utilisation of resources and conserve the environment.

Reforming Solid Waste Management in India: Strategy, Structuring, and Circular Transformation



Era Singla

Director - Strategy and Transactions
Ernst & Young LLP

Introduction: The Scale of the Challenge

Solid Waste Management (SWM) in India has evolved from being a municipal sanitation function to one of the most complex urban infrastructure challenges facing the country. Rapid urbanisation, industrialisation, rising incomes, and changing consumption patterns have significantly increased both the volume and complexity of waste generated in cities and towns. According to various national estimates, urban India generates more than 1.5 lakh tonnes of municipal solid waste daily¹, which translates to over 55-60 million tonnes annually as per CPCB estimates, a figure that continues to grow year on year.

However, infrastructure development, institutional capacity, and behavioural change have not kept pace with this growth. Many Urban Local Bodies (ULBs) continue to rely on outdated collection systems, mixed waste handling, and unscientific dumping practices. Dumpsites on city peripheries have turned into mountains of legacy waste. According to the Central Pollution Control Board (CPCB), nearly 2,500 dumpsites across India collectively contain about 25 crore metric tonnes of accumulated legacy waste², occupying over 15,000 acres of urban land contributing



Photo 1: Bhalswa Landfill Site, Delhi

to groundwater contamination, methane emissions, fires, and public health risks. Legacy waste at urban dumpsites such as Bhalswa (Refer Photo1) in Delhi has been associated with groundwater contamination in adjacent areas, rendering nearby water sources unsafe for consumption and compounding environmental and public health risks.

Solid waste management today is not merely an environmental or sanitation issue; it is intrinsically linked to climate change, urban resilience, public health, resource efficiency, and sustainable economic growth. Addressing this challenge requires rethinking the entire waste value chain - from generation and segregation to treatment, recovery, and final disposal.

However, this transformation must be guided by a clear strategic hierarchy rather than incremental infrastructure additions.

In this context, the principle of the **3Rs - Reduce, Reuse, and Recycle** - provides the foundational framework. By prioritising reduction at source, encouraging reuse, and recycling unavoidable waste into productive resources, the 3Rs shift the focus from disposal to value creation. Reduction at source, through segregation and responsible consumption, remains the most effective and sustainable intervention.

India must now transition from a linear “collect - transport - dump” model to a circular “segregate - process - recover - reuse” model.

The Structural Gaps in India’s SWM Ecosystem

The Swachh Bharat Mission (Urban) has significantly improved awareness and service coverage across cities, with door-to-door waste collection coverage reported at over 85–90% in urban areas under SBM-U 2.0. However, fundamental structural weaknesses in India’s solid waste management ecosystem persist. The sector’s challenges today extend beyond infrastructure deficits and reflect deeper institutional, operational, and financial constraints.

1. Inadequate Segregation at Source

Despite mandates under various Government of India (GOI) guidelines and rules, source segregation remains inconsistent till now (Refer Photo 2),



Photo 2: Insufficient Source Segregation

with mixed waste collection still common across households and commercial establishments. Weak enforcement and limited behavioural incentives reduce compliance, directly impacting compost quality, Refuse Derived Fuel (RDF) value, and overall processing efficiency.

2. Collection and Transportation Inefficiencies

Although door-to-door coverage has improved, operational inefficiencies persist due to poor fleet management, lack of route optimisation, limited digital tracking, and weak coordination between collection layers. Since collection and transport can account for 60-70% of SWM operating costs, inefficient logistics significantly affect financial sustainability and service reliability.

3. Limited Scientific Disposal Capacity

A shortage of engineered sanitary landfills forces many cities, to rely on unscientific **dumps** for the disposal of waste rejects, perpetuating environmental and public health risks. Land constraints, public resistance, and high capital requirements further delay the development of compliant disposal infrastructure.

4. Weak Regulatory Enforcement

Although the Government of India has created a comprehensive framework covering segregation, bulk waste generators, processing standards, and landfill norms, enforcement remains uneven across cities. Penalties for non-segregation are rarely applied consistently, and compliance by bulk waste generators is often weak due to limited monitoring capacity.

Fragmented reporting systems, absence of real-time compliance tracking, and inadequate institutional accountability dilute regulatory effectiveness. Weak enforcement not only undermines service standards but also affects the financial and operational viability of processing facilities by compromising feedstock quality and contractual performance benchmarks.

5. Underperformance of Processing Infrastructure

Many composting, bio-methanation, and Waste

to Energy (WtE) plants operate below capacity due to inconsistent feedstock quality, inflated waste projections, weak market linkages, and delayed payments. While India has an installed capacity of ~250 MW of WtE, the plant viability remains highly dependent on effective segregation, assured waste supply, and robust contractual safeguards. In several cases, the focus on asset creation has overshadowed lifecycle sustainability. Weak project preparation, inadequate demand assessment, and poorly structured contracts result in idle capacity, feedstock variability, and revenue uncertainty.

6. Institutional and Contractual Challenges

Many ULBs face capacity gaps in project preparation, procurement design, PPP structuring, and contract management. Most of the ULBs face challenges in implementation of solid waste management projects due to lack of technical know-how. Effective PPP structuring requires clear allocation of risks related to waste quantity and composition, tipping fees, land availability, and regulatory approvals. Financial models must incorporate lifecycle costs, revenue assumptions, and contingency provisions. Without bankable project structures and transparent risk allocation, private participation remains limited and projects struggle to achieve financial closure.

7. Financial Stress

Solid waste management constitutes a significant share of municipal expenditure yet cost recovery mechanisms remain weak. User charges are often nominal, poorly structured, and inadequately collected, while revenue streams from recyclables, compost, RDF, and energy remain underleveraged. Dependence on grants without lifecycle financial planning undermines long-term sustainability. Institutional and contractual weaknesses further compound financial stress.

Ultimately, the recurring pattern across cities reflects a shift toward building infrastructure without adequately designing financially and

institutionally sustainable systems. Addressing this requires integrated planning, performance-based procurement, disciplined financial structuring, and sustained lifecycle governance.

Reforming Procurement and Implementation Frameworks

1. Governance Framework: SWM Rules, EPR and State Policies

India's solid waste management landscape is guided by an evolving environmental and regulatory framework, including the Solid Waste Management Rules, 2016 (and subsequent amendments), Extended Producer Responsibility (EPR) regulations for plastic, e-waste and other waste streams, and locally notified municipal byelaws. Several state governments have also formulated dedicated waste management policies and implementation strategies to strengthen compliance and improve service delivery. EPR shifts accountability upstream by mandating producers and brand owners to take responsibility for the collection, recycling, and environmentally sound disposal of post-consumer waste. However, translating these regulatory provisions into effective on-ground outcomes requires strong procurement design, structured contracts, and accountable implementation mechanisms.

2. Moving Beyond Infrastructure-Centric Procurement

Historically, many SWM projects were procured under EPC models, prioritising asset creation over lifecycle outcomes. That often resulted in the infrastructure lacking robust O&M frameworks, clear risk allocation, performance monitoring, and accountability. India is gradually shifting toward performance-based contracting (Refer Figure 1), though the transition remains uneven. Contracts are increasingly linking payments to measurable KPIs such as door-to-door collection coverage, source segregation rates, processing efficiency, landfill diversion, and environmental compliance. This shift strengthens accountability while reinforcing

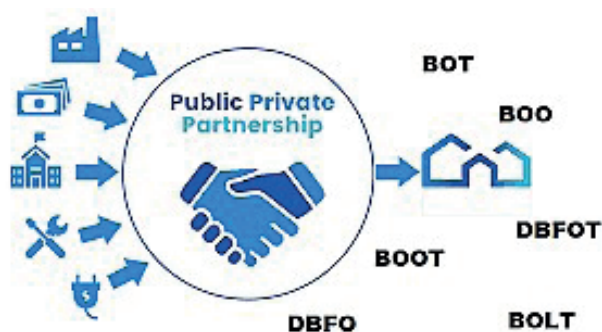


Figure 1: Overview of Key Public-Private Partnership (PPP) Models

the 3R hierarchy - reducing waste at source, enabling reuse and recycling through performance-linked service delivery.

Each contract presents unique contextual challenges; therefore, structuring must be tailored to local waste characteristics, scale, and institutional capacity.

3. Decentralised Waste Management Models

Decentralised models refer to ward or community-level waste management systems where segregation, processing, and resource recovery are carried out locally, reducing dependence on centralised facilities. These models - particularly for ULBs generating less than 50 TPD allow waste to be segregated, processed, and monetised locally. Given the higher organic fraction and recyclable recovery potential in such towns, the 3R approach becomes highly effective in minimising landfill dependency. However, it is important to note that segregation at source is the foundation of a successful SWM system and the first step in operationalising the 3Rs, as without segregation, mixed waste reduces processing efficiency and increases environmental risks.

The **Ambikapur model in Chhattisgarh** (refer Photos 3,4 & 5) stands out as a pioneering example of decentralised waste management and implementation of the 3R principle. The city implemented Solid and Liquid Resource Management (SLRM) centres at ward levels,



Photos 3 & 4: SLRM model-based Project

operated by women's self-help groups. The SLRM model was designed as part of an alternate approach to scientific disposal of municipal solid waste - 35 TPD of waste collected was segregated in 17 categories and 5 m³ per day of biogas was generated with 8-10 TPD compost prepared. The waste was segregated into multiple categories, composted locally, and recyclables were monetised. The city achieved high segregation rates and eliminated open dumping.



Photo 5: SLRM Centre, Ambikapur

Key lessons from this case include:

- Community participation is critical
- Decentralised infrastructure reduces transportation costs
- Livelihood integration enhances sustainability
- Strong IEC (Information, Education, and Communication) campaigns drive behavioural change

4. Cluster-Based Integrated Solid Waste Management Models (ISWM)

Where decentralised systems are not viable, cluster-based ISWM models provide scale efficiencies while retaining performance accountability. By aggregating waste from multiple ULBs, clusters enable financially viable, KPI-driven service delivery - aligned with landfill diversion and resource recovery goals. Haryana's cluster-based waste management model (Refer Photo 6) serving 33 ULBs across five clusters is a pioneering example demonstrating how state-level aggregation, structured PPP frameworks, and defined performance standards can operationalise recycling, RDF recovery, and energy generation under the 3R hierarchy.

One of such cluster is **Sonepat-Panipat cluster Model in Haryana** generating about 8 MW of electricity and processes over 700 TPD of waste.



Photo 6: Waste to Energy Plant- Sonepat

In the Sonepat-Panipat cluster Model in Haryana, the 3R framework is embedded through structured segregation, material recovery, and energy generation pathways. Recyclable fractions are channelled to recovery streams, combustible waste is converted into RDF and utilised for energy production. This integrated approach reduces disposal volumes while maximising resource recovery across the cluster.

Key interventions included:

- Prioritisation of unencumbered land for processing and disposal infrastructure.
- Coordinated effort between the State Government, Selected Bidder and ULBs for environmental clearances, tariff determination, PPA signing, etc.
- Early initiation of land lease agreements to avoid implementation delays.
- Establishment of dedicated project monitoring mechanisms with technical expertise.
- Integration of IT-based monitoring systems and performance-linked KPIs in contracts.

Beyond infrastructure creation, the state emphasised structured procurement, performance benchmarking, and coordinated monitoring. The approach strengthened decision-making and improved service outcomes, contributing to Haryana's improved ranking in Swachh Survekshan.

The Haryana Cluster Model case demonstrates that challenges such as land constraints, financial viability, and technical capacity can be addressed through state-level aggregation, structured PPP design, and integrated planning.

5. Digital Monitoring and Governance Reform

For performance-driven and cluster-based systems to succeed, digital oversight is indispensable. Technology acts as the backbone of accountability, enabling real-time monitoring of segregation, collection, processing efficiency, and contractor

compliance - thereby reinforcing the 3R ecosystem.

State-level dashboards and MIS platforms enable centralised monitoring of:

- GPS-based vehicle tracking
- Segregation levels
- Processing efficiency
- Contractor performance
- Citizen grievance redressal

Several cities in Haryana already track 80-90% of their fleets digitally under Swachh Bharat Mission (SBM) initiatives, demonstrating scalability.

One of the best examples of such robust monitoring is the **Karnal cluster ISWM project of Haryana**. Karnal cluster covers 18 ULBs and generates ~638 TPD of waste, showcasing how digital governance strengthens waste management outcomes.

GIS mapping, RFID tagging, and live vehicle tracking (Refer Photo 7) ensure 100% door-to-door collection in the cluster. A centralised dashboard generates real-time performance reports, enhancing transparency and oversight.

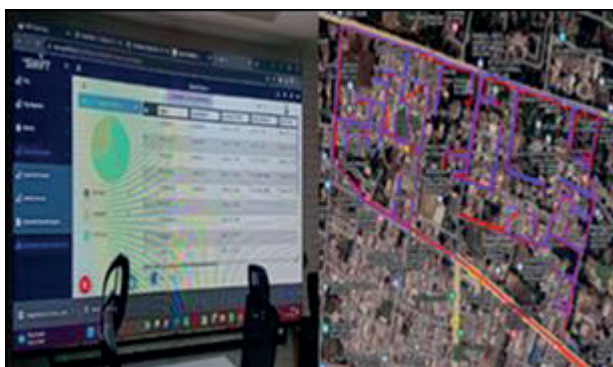


Photo 7: Location Based Mapping

Waste is transported to Material Recovery Facility (MRF) centres for segregation; recyclables are sold, combustible fractions converted to RDF for cement plants, and wet waste composted into nutrient-rich manure. By integrating digital systems with resource recovery pathways, the cluster operationalises all three pillars of the 3Rs - reducing landfill burden, promoting recycling, and converting organic waste into value.

6. Bulk Waste Generator Compliance

Bulk Waste Generators (BWGs) including institutions, hotels, hospitals, commercial establishments, and large residential complexes - generate a disproportionate share of urban waste. Enforcing on-site segregation and decentralised processing is critical to strengthening the 3R chain at source.

Mandatory composting or bio-methanation of wet waste significantly reduces pressure on municipal systems and landfill volumes. Compliance must be supported by structured monitoring, defined service standards, enforceable penalties, and digital tracking platforms.

Industry best practice requires BWGs to segregate waste at source and treat wet waste on-site, ensuring that only residual, non-recyclable fractions enter the municipal system.

The **3Rs** provide the solution pathway **reducing** waste at source through segregation, enabling **reuse**, and ensuring **recycling** through decentralised, bulk-level, and cluster-based processing systems. When supported by performance-based procurement, digital monitoring, and structured governance frameworks, this approach shifts India's waste management paradigm from disposal-driven to resource-efficient and financially sustainable systems.

Institutional Capacity and Stakeholder Engagement

Infrastructure alone cannot solve SWM challenges. Institutional capacity building and stakeholder engagement are equally critical to operationalising the 3Rs across the waste value chain.

Key priorities include:

- Training municipal staff in contract management
- Strengthening enforcement mechanisms
- Engaging ward committees and resident welfare associations
- Partnering with NGOs and community groups
- Integrating informal waste pickers into formal systems

Stakeholder engagement must explicitly embed the 3R framework - educating citizens, waste generators, and institutions to reduce waste at source, segregate responsibly, promote reuse, and channel recyclables into recovery streams.

In this context, EPR plays a critical role by shifting part of the waste management burden upstream to producers and brand owners. Under EPR regulations, producers are required to ensure collection, recycling, and environmentally sound disposal of post-consumer waste, particularly plastics. Effective enforcement of EPR strengthens recycling ecosystems, supports material recovery markets, and complements municipal systems in advancing circular economy objectives.

Public awareness campaigns (Refer Photos 8-11) must therefore move beyond slogans to sustained behavioural change, transforming waste generators and producers alike into accountable participants in a circular and resource-efficient ecosystem.



Photos 8 – 11: An innovative IEC concept - “Chhota Bheem-Captain Clean” was launched in Chhattisgarh

Financial Sustainability and Circular Economy Opportunities

At its core, the circular economy reframes waste not as a liability, but as a resource stream capable of generating economic value. By recovering materials, energy, and nutrients, solid waste management systems can transition from cost centres to value-creating ecosystems aligned with the 3R hierarchy.

In this context, long-term financial sustainability cannot rely solely on grants. Diversified revenue streams and structured cost recovery mechanisms are essential. Potential avenues include user charges linked to defined service levels, tipping fees from bulk waste generators, and revenues from recyclables and compost. Additional income can be generated through RDF supply contracts with cement and industrial units, energy sales from waste-to-energy and biomethanation plants, and emerging instruments such as carbon credits and climate finance.

EPR (Refer Figure 2) further strengthens this financial ecosystem by mandating that producers and brand owners finance and ensure the collection and recycling of post-consumer waste, particularly plastics and e-waste. Effective implementation of EPR not only reduces the fiscal burden on ULBs but also supports formal recycling markets, improves material recovery rates, and reinforces circular economy objectives.



*Figure 2: Extended Producer Responsibility
– the game changer*

Resource recovery markets - spanning recycling, compost, and energy create business opportunities for private enterprises, startups, and enable informal sector integration. Simultaneously, India's growing ESG investment ecosystem offers avenues to mobilise green financing for scalable and sustainable waste infrastructure.

Emerging Business Opportunities

Solid waste management presents significant opportunities across multiple emerging sectors, including recycling enterprises, green energy generation, and structured compost marketing networks. Technological advancements such as AI-based sorting systems are improving material recovery efficiency, while data analytics platforms are enabling smarter waste tracking and operational optimisation. In parallel, ESG-linked infrastructure financing is creating new avenues for sustainable investment in waste management projects.

EPR has catalysed new business models within the recycling ecosystem. Under India's Plastic Waste Management Rules, producers and brand owners must ensure collection and recycling of plastic waste through authorised recyclers. This has formalised recovery markets, improved traceability through digital portals, and created structured revenue streams for recyclers, while shifting financial responsibility upstream and easing the burden on ULBs.

1. Case Study: ITC's Plastic Waste Neutrality and EPR-Driven Recycling Model

ITC Limited has emerged as a leading example of EPR implementation in India. Under the Plastic Waste Management Rules, the company has developed a nationwide post-consumer plastic collection and recycling ecosystem through partnerships with local waste collectors, aggregators, and authorised recyclers.

Through its "Wellbeing Out of Waste" (WOW) programme, ITC has established source segregation and dry waste collection networks

across multiple cities, integrating informal waste pickers into formal recovery chains. The company has consistently reported collecting and sustainably managing plastic waste equivalent to, or exceeding, the amount of plastic it introduces into the market, achieving plastic waste neutrality.

By leveraging EPR compliance as a strategic opportunity rather than a regulatory burden, ITC has strengthened material traceability, supported recycling enterprises, and contributed to circular economy outcomes. This model demonstrates how structured EPR implementation can catalyse private investment, formalise recycling markets, and reduce pressure on municipal waste systems.

The principles discussed above are not merely theoretical. Across India, structured policy reform, EPR implementation, PPP design, and coordinated state-level interventions have begun demonstrating scalable results. The case studies mentioned earlier in this article illustrate how integrated planning and transaction-led implementation can translate strategy into measurable impact, moving the sector from compliance-driven waste management to investment-ready circular economy systems.

Way Forward: Towards Integrated and Accountable Waste Systems

India's solid waste management challenge is significant, but it is not insurmountable. The way forward lies in shifting from fragmented, infrastructure-led responses to integrated systems anchored in accountability, sustainability, and stakeholder ownership.

The foundation of this transformation must be the **3Rs - Reduce, Reuse, and Recycle** (Refer Figure 3). Segregation at source is non-negotiable. Without it, downstream investments in composting, recycling, and energy recovery cannot deliver optimal outcomes. The 3Rs reframe waste from a disposal burden to a resource stream within a circular economy.

Equally critical is the transition to performance-based procurement and well-structured PPP frameworks.

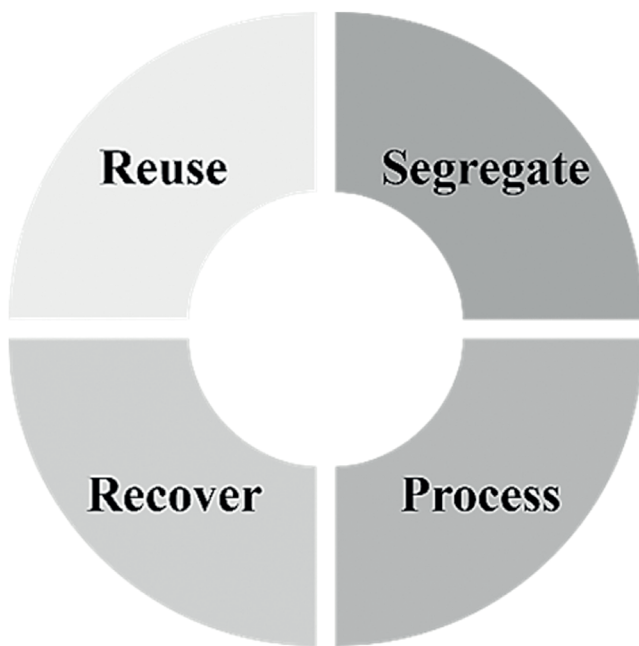


Figure 3: 3Rs – Reduce, Reuse & Recycle

Contracts must move beyond asset creation to embed measurable KPIs, clear risk allocation, lifecycle performance benchmarks, and transparent payment mechanisms. Bankable and outcome-driven project structures are essential to attract credible private participation and ensure long-term viability.

Digital monitoring and governance reforms must act as the backbone of this system. State-level dashboards, GPS-enabled tracking, standardised performance indicators, and grievance redressal platforms enable real-time oversight, transparency, and data-driven decision-making. Technology must support proactive management rather than reactive reporting.

Finally, no system can succeed without community participation and stakeholder alignment. Waste generators, bulk waste producers, informal sector workers, private operators, regulators, and civil society must operate within a shared accountability framework. Sustained behavioural change and local ownership are central to durable reform.

Solid waste management is therefore not merely about managing waste - it is about designing resilient, circular, and performance-oriented urban systems capable of supporting future generations.

References

1. <https://www.ceew.in/publications/how-can-indian-cities-boost-sustainable-solid-waste-management-practices?>
2. <https://www.pib.gov.in/PressReleasePage.aspx>

Delhi High Court Upholds Tender Clause Disqualifying Bidders Facing Economic Offence Proceedings

The Hon'ble Delhi High Court in *M/s Dhanvine Engineering Pvt. Ltd. v. Delhi Jal Board* (decided on February 5, 2026) upheld the validity of a tender condition introduced by the Delhi Jal Board disqualifying bidders against whom an FIR or charge sheet alleging corruption, fraud, or economic offences relating to DJB contracts was pending. The Court held that tendering authorities may prescribe additional eligibility conditions to safeguard the integrity of public procurement, particularly in projects involving critical public infrastructure such as sanitation systems. It further observed that the impugned clause was a risk-management measure rather than a punitive debarment and did not amount to pre-conviction punishment. The judgment reiterates the limited scope of judicial review in tender matters and affirms the discretion of public authorities to frame eligibility criteria aimed at ensuring transparency and integrity in infrastructure procurement.

Source: https://www.verdictum.in/pdf_upload/74805022026cw10192026101603watermark-1770632.pdf

Screening Model for Evaluation of MSW Treatment Technologies with Special Context to Indian Conditions



Dr. Alok Kumar
General Manager- Environment



Ganesh Kumar Singh
Dy. General Manager-Environment

TATA Consulting Engineers Ltd.

Abstract

Municipal Solid Waste (MSW) management is a major challenge for Metropolitan and large cities and towns of India. The estimated generation of solid waste in the year 2021-22 was 170,000 tonnes per day (approx. 62 million tons annually) as per a Press release from the Central Pollution Control Board (CPCB). It is the responsibility of the municipal corporations and Urban Local Bodies (ULBs) of the concerned cities to provide proper MSW treatment and management facilities. However, in most of the cities, Municipal Solid Wastes are not treated properly in an integrated manner, despite the claim being made to utilise its energy and material.

In this paper, an effort has been made to formulate screening criteria for MSW treatment technologies which would provide a foundation to develop a way to manage and treat solid waste while giving importance to environmental sustainability, economics, regulatory compliance, and costs associated with MSW treatment and its management.

Keywords: Municipal Solid Waste, Screening, Sustainability, MSW Treatment

Introduction

The current pace of urbanisation, industrialisation,

consumerist societies, and waste generation pose formidable challenges to global sustainability in many ways. With the unplanned urbanisation and rapid growth of middle-class families with changing lifestyles, most of the Asian countries are facing the mammoth challenge of managing urban waste¹. There is no reliable national-level data on the technical or financial aspects of waste management in India. Therefore, in the present paper, fair approximations are made for different figures.

The scale of the problem, however, is evident with the country's annual generation of municipal solid waste falling in the range of 50 to 60 million tonnes. The volume is likely to be doubled by 2035, which may double further by 2055. The scale will be perhaps more comprehensible at the level of the individual city. Mumbai today generates about 7,000- 8000 tons per day (TPD) and Delhi generates about 10,000 to 12,000 TPD. These figures clearly indicate that the growth of MSW in the urban centres has outpaced the ongoing population growth of recent years.

Different waste treatment options are available with various levels of problem solving and resource recovery facilities. All the waste management technologies have some benefits and limitations when applied in field conditions. There is no single treatment technology

available that can solve the waste management problem comprehensively. Therefore, it is important to integrate different waste management technologies in a strategic manner to achieve sustainable waste management objectives (Schunke 1999)².

It is difficult to select a particular technology for sustainable waste management decision or policy making processes without knowing the pros and cons of different technologies including their impacts on the environment. Due to lack of available information on impacts from technology, the decisions made may not be the correct one and that might pose adverse and critical situations in the future. Therefore, it is important to know the different energy efficient and viable technologies. A comparative study for different options that could be a guiding tool for decision making processes are presented in this study.

Considering the above facts, the present study proposes a model for screening and evaluation of various MSW

treatment technologies in Indian conditions. The same can be used for selection of possible integrated treatment options. This paper describes a model considering multiple criteria to be developed and evaluate alternative waste treatment technologies for the treatment of municipal solid waste. The evaluation is based on Indian legal requirements, while covering technical, environmental, and cost considerations.

Choice of Technology

In order to assess various options of Municipal Solid Waste (MSW) treatment technologies, relevant information was collected from available sources, both through review of literature, discussions, and field observations. Waste processing technologies based on waste qualities can be broadly divided into three categories, (refer Table 1).

- Thermal Technologies
- Biological/ Chemical Technologies
- Physical Technologies

Table 1: MSW Treatment Technologies Considered

Sr. No	Technology	Details
1.	Thermal Processing Technologies	✓ Incineration (Mass Burn) ✓ Pyrolysis ✓ Gasification Plasma Arc Thermal Treatment
2.	Biological Processing Technologies	✓ Composting • Vermi -composting • Windrow Composting • Static Aerated Pile Composting • In Vessel Composting ✓ Bio methanation ✓ Bioreactor Landfill
3.	Physical Processing Technologies	✓ Pelletisation ✓ Refuse Derived Fuel (RDF)

1 Thermal Processing Technologies

1.1 Incineration

This method, commonly used in developed countries, is the most suitable for MSW having high calorific value with a large component of paper, plastic, packaging material, pathological wastes, etc. It can reduce waste volumes by over

90 per cent and convert waste into innocuous material, with energy recovery³. The method is relatively hygienic, noiseless, and odourless, and land requirements are minimal. The plant can be located within municipal city limits, reducing the cost of waste transportation with the provision of reduction for air pollutants.

1.2 Pyrolysis/ Gasification/ Plasma Arc

Pyrolysis and gasification processes are established for homogenous organic matter like wood, pulp, etc., while plasma pyrolysis vitrification is a technology for disposal of hazardous waste like radioactive wastes, etc. It has been in use in countries like Russia for about two decades. Toxic materials get encapsulated into a vitreous mass, which is relatively much safer to handle than incinerator/ gasifier ash. In all these processes, besides net energy recovery, proper destruction of the waste is also ensured. These processes, therefore, have an edge over incineration.

2 Biological Processing Technologies

2.1 Composting

Composting is the decomposition of organic matter by microorganisms in warm, moist, aerobic, and anaerobic environments. Composting of MSW is the most simple and cost-effective technology for treating the organic fraction of MSW. Waste is built up to rotting windrows which are either self-aerated, or the air is pressed or sucked through the windrows (in order to meet the oxygen demand

for the aerobic degradation processes). The aim is to reduce the volume as much as possible as well as the contamination through leachate and gaseous emissions, if any.

2.2 Biomethanation

Anaerobic digestion is one of the favourable organic waste management options which have higher resource recovery potentials. Biological process of anaerobic digestion is taking place in the absence of oxygen with the help of microbes. Its application to the organic fraction of MSW is more recent and less extensive. It leads to biogas/ power generation in addition to production of compost (residual sludge). This method provides a valuable addition to the aerobic (composting) process and offers certain other clear advantages over composting in terms of energy production/ consumption, compost quality and net environmental gains. This method is suitable for kitchen wastes and other putrescible wastes, which may be too wet and lacking in structure for aerobic composting. Studies have been done of various Bio-methanation plants across India and estimates done of the potential of Bio-CNG from urban MSW in India⁴.

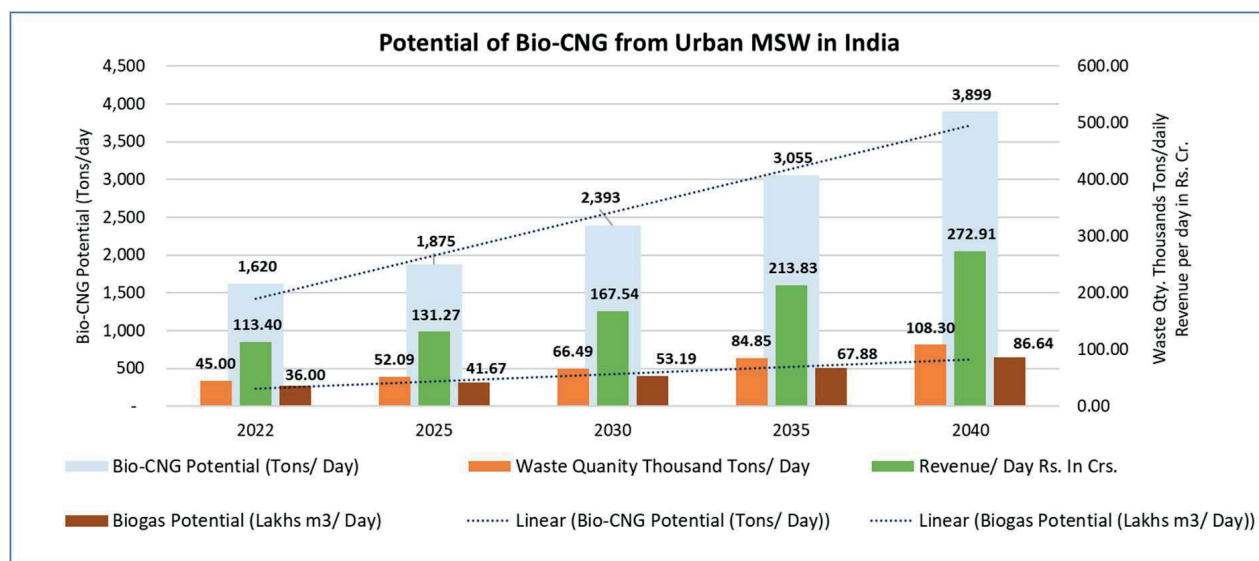


Figure 1: Potential of Bio-CNG from Urban MSW in India

2.3 Bioreactor Landfill

“Bioreactor landfill” allows active landfill management based on an understanding of the biological, chemical and physical processes involved. It focuses on enhancing the degradation processes to stabilise the waste and aims to bring forward the inert state of a landfill in a relatively short time. It basically utilises a landfill as a bioreactor to treat and stabilise the waste rather than merely as a ground fill.

3. Physical Processing Technologies

3.1 Pelletisation/ Refuse Derived Fuel (RDF)

It is basically a processing method for mixed MSW, which can be very effective in preparing enriched fuel feed for thermal processes like incineration or industrial furnaces. As pelletisation involves significant MSW sorting operations, it provides a greater opportunity to remove environmentally harmful materials from the incoming waste prior to combustion. The process, however, is energy intensive and not suitable for wet MSW / during the rainy season.

Methodology for Screening and Evaluation Criteria for Technologies

Different technologies have been tried in different parts of the country at different points of time and on different scales of operation. Some of them have failed outright whereas some have had limited success on overall techno-economic parameters including marketing and product pricing (Sharholly et.al. 2008). Therefore, it is necessary to have an effective screening mechanism considering suitable criteria to find out the best suited technology/ system which would be a techno-economically viable solution.

A framework (evaluation model) has been developed (Table-2) after reviewing the available national and international literature and the best practices pertaining to MSW management and exploration of the concept of sustainable provision of this basic service. This framework is based on the study objectives and the available background information on performance of the various technologies actually installed and operated for processing municipal solid waste, especially in India.

Table 2: Evaluation Criteria for Screening of Technologies

Sr. No.	Evaluation Criteria	Parameters
I	Basic Requirements	• Modularity • Scalability • Upgradability • Flexibility / Ease of Operation
II	Primary Screening	• Techno-economic viability for given waste material • Compliance with applicable laws including environmental and health (EHS) • Long term sustainability • Reliability under expected variations • Quantum of process rejects, extent of landfill diversion and total land requirement for the project • Social acceptability and public perception
III	Secondary Screening	• User friendly (operator friendly) • Skill set requirement (technical, financial, managerial)
IV	Commercial Evaluation	• Capital Cost • O & M cost/ Energy cost/ labour (manpower) cost/ land cost/ payback tariffs

1. Basic Requirements

Before screening the various technologies, it needs to be ensured that the basic requirements such as modularity, scalability, flexibility in operation, and upgradeability are fulfilled.

1.1 Modularity

Plants should be phased/ modular, enabling capacity additions at intervals (8–10 years) without systemic disruption. This mitigates demand-supply mismatches and supports staged funding.

1.2 Scalability

Technologies must perform across varying daily throughputs and seasonal composition shifts typical of Indian cities, especially during monsoon (moisture spikes) and festivals (volume spikes).

1.3 Flexibility

Systems should absorb external/ internal changes - feedstock variability, climate, and market shifts - via resilient material handling, process tuning, and expansion provisions.

1.4 Upgradeability

Designs should support process optimisation, component upgrades, and capacity enhancements (e.g., adding pre-sorting or drying units, gas upgrading skids, or improved emissions controls).

Technological Evaluation

2. Primary Screening

The primary screening of the technologies considered are based on a set of crucial issues and performance indicators as mentioned in the Table-2, which allow technologies to be assessed for suitability under the given circumstances.

a) Techno-economic viability for the given waste material:

It is important to assess the suitability of technology to properly address the issue of its appropriateness to local conditions, including waste characterisation, and operational capacity. For the purpose, it is crucial to

evaluate the techno-economic viability of the given waste material that should include technical viability, capital investment, operation and maintenance cost, possibility of accrual from carbon revenue, etc.

Apart from technical viability, financial viability is very important for overall techno-economic viability without which a project cannot be sustainable for a long term, especially if Private sector participation is considered. The following components need to be included:

- Capital investment on civil structure and provision of other infrastructure facilities
- Capital investment on plant and equipment purchase including foreign exchange requirement for import, if any.
- Capital investment on vehicle and mobile equipment required for material movement.
- Cost of regular operation and maintenance of the facility (fixed and variable costs, which include interest on capital, depreciation, manpower, establishment and utility cost, etc.)
- Major repair/ replacement of plant and equipment at the end of every 8-10 years
- Revenue accrual through sale of various recycled/ recovered products (such as compost, biogas, power, RDF, etc.)
- Market risks in terms of product sale.
- Revenue accrual prospects through sale of CERs.
- Leakage through use of fossil fuel with respect to calculation of carbon revenue.
- Market risks in terms of carbon revenue.

b) Compliance with applicable laws including environmental and health (EHS):

The applicable rules are the Municipal Solid Wastes (Management and Handling) Rules, 2026 (SWM 2026 Rules). These rules stipulate various waste processing technologies like composting, incineration, refuse derived fuel

(RDF), energy recovery or any other process based on state-of-the-art technology approved by CPCB and prescribed standards to comply as per Schedule IV. The selected technologies should thus meet the compliance criteria prescribed in the rules.

c) Long term sustainability:

Long term sustainability of any project is important for justifying investment, be it from the public or private sector. For a service sector like MSW management, sustenance of the project is extremely important for the public, health and the environment. Long term sustainability of a MSW management project requires that the following be addressed:

- Extent of product recovery
- Product quality
- Market prospects of the products and byproducts
- Investment vs. revenue accrual

d) Reliability under expected variations:

The reliability pertaining to solid waste management (SWM) treatment system is its ability to absorb expected variations with reasonable process efficiency. Reliability of technology is ascertained by collecting data on failures and successes, for operating units in India and abroad. For setting reliability, the technologies need to be graded for each of the key aspects - Proven, Yet to be Proven, and Unproven.

The categorisation would benchmark the performance of different treatment technologies at national and international level. The minimum cut off level considered for reliability is, at least two successful installations followed by commercial operation of that technology for a minimum of one year in India.

e) Quantum of process rejects, extent of landfill diversion and total land requirement for the project:

The extent of process rejects is an important consideration in making a choice of technology.

It is one of the main reasons for the popularity of incineration (mass burn). Among the other factors is the processing time, which is also the least in case of thermo-chemical systems like mass burn. With growing disenchantment with mass burn, the focus is shifting to a combination of technologies to minimise total process rejects because the rejected material from one process becomes the raw material for the other. For example, a combination of composting and RDF can significantly reduce total process rejects that maximise landfill diversion.

The extent of process rejects/ residues and the land requirement for different processing technologies are listed in Table 3.

Table 3: Process Remnants from MSW Treatment Technologies

Sr. No.	Technology	Value (%)
1.	Composting	20 – 30
2.	Biomethanation	25 – 40
4.	RDF	25 – 30
5.	Incineration	8 – 12
6.	Composting + RDF	10 – 15

Land/ area requirement for waste treatment and disposal is a significant factor while making selection of technology. The footprint of MSW processing technologies and land requirement to house them is a significant constraint in urban conditions, where the pressure on land is very high. Therefore, the technology which requires lesser land should be preferred over the technologies requiring more land area.

f) Social acceptability and public perception:

For SWM, public participation and acceptance is the key for success. The health and environmental risks of waste management have been the subject of controversy due to the NIMBY factor. Social acceptance is a major criteria, while suggesting a treatment technology at any location. Technology should

be widely accepted by the public; only then the chances of the project being successful would be good.

For conducive public perception and social acceptability, the following points must be taken into consideration:

- Interactive planning involving the public and civil society.
- Appropriate planning of the system, keeping in view all the environmental norms.
- Proper execution of the project facility.
- Standard Operating Procedure (SOP) must be followed without resorting to any short-cuts.
- Observation of all safety norms so that neither the workers nor the surrounding environment is adversely affected due to any unforeseen incident. That would enable the project to have a good name and be perceived as acceptance for the neighbourhood.
- Employment potential for the local persons.
- Sustained awareness generation for the public that would encourage interaction.

3. Secondary Screening

In the secondary screening, software filters are proposed:

- User (Operator) friendly operations and maintenance.
- Skill-set requirement (from the planning and designing to operations and maintenance stages).

User/ operator friendly technology is linked to viability, and long-term sustainability as well. Skill-set requirement is another important issue, because there is acute shortage of properly qualified and experienced (actual hands-on experience, not academic) personnel in the waste management sector. As the sector is growing, there is a trend of increasing attrition.

In the first stage of screening, the selection is narrowed down by applying various suitability filters. In the second stage, measurement of the performance of the selected technologies in terms of input required and output received are considered. The criteria considered for secondary screening are:

- Need for auxiliary fuel, and
- Marketing of end products (Energy/ fuel/ compost/ slag).

Need for auxiliary fuel: The high organic content of the MSW in India indicates that a self-sustaining combustion reaction cannot be obtained from MSW. The waste needs to be supplemented with auxiliary fuel for incineration (mass burning). Moisture content and calorific value are the key factors to determine the feasibility of thermal treatments.

Marketing of end products (Energy/ fuel/ compost/ slag): Effective marketability of end products (thermal energy in the form of steam /power/ fuel oil/ gas/ RDF/ compost material) is a crucial factor to determine project viability and needs to be tied-up in advance with the respective technologies. There are technologies having the capability of recovering recyclables, converting waste into intermediate fuel products (e.g., biogas, syngas, steam) efficiently using the fuel products and other byproducts on-site for power generation. End products generated from processing of the waste should meet all regulatory standards and should not create harm to the environment. The end product generated preferably should have continuous demand in the market. Technology providers should have firm agreements and institutional arrangements with the company/ agency/ industry, which will off take the end product on a continuous basis.

4. Commercial Evaluation

The decision to implement any particular technology needs to be based not only on its technical viability but also on its economic viability, sustainability, as well as environmental implications. Keeping in view the local conditions and the available physical

and financial resources, the key factors considered as the criteria of commercial evaluations are:

- Energy requirement and prices/ buyback tariff for energy purchase,
- Cost of alternatives, land price and capital and labour costs,
- O&M cost, energy generation, payback period and tipping fees, and
- Capabilities and experience of the technology provider.
- The monetary aspect identifies the relation between technical or environmental standards of the treatment technology compared to the costs (i.e. the trade-off between monetary aspects and advantages in other areas).

The costs considered fall into two basic categories, capital costs and recurrent costs. Capital costs are incurred at the beginning of the project between its inception and its completion on the ground and also include:

- Cost of planning and designing the works,
- Construction costs,
- Supervision costs, and
- Overheads.

In some cases, facility financing costs, land cost, debt charges or interest on loan repayment are also associated with Capital cost.

Operation and Maintenance costs or recurrent costs are the costs incurred after execution of the project for its routine operations and maintenance which include manpower cost, miscellaneous expenses, administrative expenses, routine maintenance cost, electricity and fuel consumption charges, sanitisation treatment, inoculants, additives, etc. SWM collection equipment has a short life, but operation and maintenance costs are substantial.

Waste recycling, composting, waste-to-energy, may generate operating revenues or at least reduce the cost of treatment of waste. Such programmes provide tangible financial benefits from recovered materials and conserved energy, and additional benefits from avoided costs of land filling. Further, they help in increasing the life of a landfill facility.

The summary of cost estimates, land and electricity requirements for different treatment technologies are provided in Table 4.

Table 4: Summary of Land, Energy Requirement and Cost for MSW Treatment Technologies for 100 TPD MSW

Sr No.	Technology	Land Requirement (acres)	Capital Cost (Crores)*	Operation & Maintenance Cost/ annum** (Crores)
1.	Composting	5	15	0.75
2.	Biomethanation/ Anaerobic Digestion	4	24	1.2
3.	Composting + RDF	8	26	1.3
4.	Incineration/ WtE	5	24	1.2

*The tentative cost for year 2026 is considered by taking 5.77% per annum escalation on the cost mentioned in SBM 2.0 Guidelines (published in Oct-2021).

**5% of Total Capital Cost is considered for the O&M

Evaluation of Technologies: Screening Matrix

The appropriateness of technology is decided if it passes the set basic requirements - modularity, scalability, upgradability and flexibility; the primary screening parameters - suitability for the MSW characteristics, regulatory acceptability, reliability,

environment impact (air, water, land, biodiversity) and social impact/ public acceptance; and the secondary screening parameters - need for auxiliary fuel, end product market (energy/ compost/ash) and various auxiliary parameter assessment. Commercial viability was also assessed based on parameters like capital cost, land, energy and labour requirement, O&M cost, energy generation, and end product marketing.

Based on the screening criteria proposed in this paper, a screening matrix has been proposed to evaluate all the existing and popular MSW technologies on the same

scale and result of screening exercise summarised in Table 5.

Table 5: Technology Screening Matrix

Screening Parameters		MSW Treatment Technologies							
CO		BM + CBG	CO + RDF	IN	PY	GA	PA	BL	
Basic Requirements	Modularity	M	H	M	H	H	H	H	M
	Flexibility	H	H	H	H	H	H	H	H
	Upgradeability	H	H	H	H	H	H	H	L
	Scalability	H	H	H	H	H	H	H	H
Primary Screening	Regulatory Acceptability	H	H	H	H	H	H	H	N
	Suitability	H	H	H	L	L	L	L	H
	Reliability	H	H	M	L	L	L	L	M
	Env. Impact	M	H	M	M	H	H	H	L
	Public Accept.	H	H	M	M	M	M	M	L
Secondary Screening	Need for Auxiliary fuel	-	-	-	M	-	-	-	-
	End Product	H	H	H	H	H	H	H	M
Remarks		H	H	H	H	L	L	L	L
Commercial Evaluation	Land Requirement	L	M	L	H	Low preference has been given to thermal treatment technologies (Pyrolysis, Gasification, Plasma Arc & Bioreactor Landfill)			
	Capital Cost	H	L	M	L				
	O & M Cost	L	M	M	M				
	Energy Requirement	M	M	M	L				
	Manpower Requirement	L	M	M	H				
	Energy Generation	-	M	H	H				
Remarks		√ (M)	√ (H)	√ (H)	√ (M)				

Legend:

CO: Composting, BM with CBG: Biomethanation with Compressed Biogas, RDF: Refuse Derived Fuel, IN: Incineration, PY: Pyrolysis, GA: Gasification, PA: Plasma Arc, BL: Bioreactor Landfill

H: High matrix rating, M: Medium matrix rating, L: Low matrix rating, N: Not accepted

√: Viable, X: Not Viable

Note:

All weightages (H, M, and L) are given on matrix ratings

L: Low matrix in the screening criteria will get eliminated at the first stage itself.

N: Regulatory acceptance will result in non-selection of technology

Medium and High Matrix Rating: Technologies are selected after first stage screening

It is clear from the evaluation in Table 5 that the overall technology winners which satisfy the overall criteria are Composting + RDF and Biomethanation with weightages (H), followed by Composting and Incineration technologies with weightages (M). However, other thermal treatment technologies (Gasification, Pyrolysis, and Plasma Arc) can also be used but have been given low preference. To clarify, the overall criterion is based on the efficiency of the waste

treatment technology as per the evaluation under four broad categories: Technical, Regulatory Compliance, Environmental and Monetary. They are further broken down into lower-level criteria. Besides, the term efficiency is meant to describe the overall merit of the treatment technologies rather than being a measure for the effectiveness at converting input into outputs.

No single technological option can provide a complete solution for waste management. The choice of technology for treatment of the wastes needs to be done carefully after considering the following factors:

- a) Mixed form of MSW
- b) Excess moisture content in MSW, and
- c) Low Calorific Value

The composition of the MSW plays a crucial role in determining and deciding the appropriate technology to be used for its treatment.

Conclusion

Overall technology winners are Composting + RDF & Biomethanation as (H), followed by Composting and Incineration technologies considered as (M), which satisfy the overall criteria. All treatment technologies claim to be reasonable to a certain extent as far as technical, environmental and economic criteria are concerned. The decision pertaining to which waste treatment technology may be the best or most appropriate can thus only be made within certain boundary limits. However, the decision requires to be on the basis of reliable data and information together with a good understanding of the decision-making process, during which all important aspects should be taken into consideration. The important aspects are not only the technology as given above but also the building and closing down phases of the treatment plant, the input material, the output of the treatment process, the recovery process and disposal of the output, etc.

The evaluation guidelines are another step in the right direction to establish a sensible and responsible waste management concept. Further investigation, research,

and refinements could be based on practical experience of available case studies of waste management practices using the applicable environmental regulations and guidelines.

Acknowledgement

This paper is based on various projects carried out by TATA Consulting Engineers Limited for several cities and ULBs under the Swachh Bharat Mission (SBM) programme.

References

- 1) What a Waste 2.0- A Global Snapshot of Solid Waste Management to 2050, World Bank Group, 2018
- 2) U. Schunke, (1999) An Evaluation Guideline for Waste Treatment Technologies, Master of Management Studies (in Technology) Thesis, VUW.
- 3) Report of the Task Force on Waste to Energy, Planning Commission 2014, Chairman- Dr. K. Kasturirangan
- 4) TCE studies as a Reference
- 5) Municipal Solid Waste Management (MSW) Rules 2016, Ministry of Environment & Forest and Climate Change (MoEFCC), Government of India, 2016
- 6) Municipal Solid Waste (MSW) Manual, Centre for Public Health Engineering and Environment Organization (CPHEEO), Ministry of Housing and Urban Affairs (MoHUA), Government of India
- 7) CSE, (2007), Publication 'Down to Earth', Center for Science and Environment, New Delhi, India, <http://www.downtoearth.org.in/> (accessed August 2007)
- 8) Kumar, S. and Gaikwad, S. A. (2004), "Municipal Solid Waste Management in Indian Urban Centres: An Approach for Betterment", Urban Development Debates in the New Millennium, Edited by K. R. Gupta, Atlantic Publishers & Distributors, New Delhi, pp.100-111.
- 9) Sharholly, M., Ahmad, K., Mahmood, G., Trivedi, R.C. (2008) Municipal solid waste management in Indian cities-A review. *Waste Management*. **28**(2), 459-467.
- 10) The World Bank Publication (2008), Improving Municipal Solid Waste Management in India (A Sourcebook for Policy Makers and Practitioners), Da Zhu, P. U. Asnani, Chris Zurbrugg, Sebastian Anapolsky and Shyamala Mani,

Economic Analysis of Solid Waste Management and Biogas Plant - a Case Study



Kousik Ahmed¹
Environmental Specialist



Md. Rucunuzzaman²
Deputy Project Director



A.K.M. Shamsuzzoha³
Project Manager



Dr. S K Bagui⁴
Sr. QCME/ATL



Md. Saidur Rahman⁵
Environment & Safety Engineer

^{1,4} ICT, IRD, Sheladia, ADSL, K S Consultants JV; ^{2,3}RHD, Dhaka, Bangladesh; ⁵CSCEC7-SPECTRA JV Dhaka Sylhet Project, Dhaka, Bangladesh

Abstract

Solid waste management is widely recognised as a critical environmental challenge, yet when properly managed, waste can become a valuable resource. Poor waste management significantly undermines urban environmental sustainability. This paper presents a case study of the construction of the Dhaka Sylhet Project (210 km), where organic waste generated at a labour camp is utilised to operate a 3.2 m³ biogas plant since 2023.

Temporary labour camps established during large-scale infrastructure projects produce substantial quantities of organic solid waste, particularly in rural areas where formal municipal waste management systems are very limited. Improper disposal of the waste can lead to environmental pollution, public health risks, and greenhouse gas emissions. Despite its importance, sustainable and context-specific waste management solutions for construction camps remain under-documented.

The labour camp generated approximately 2,200 kg of kitchen waste per month. The segregated organic waste

was treated in a 3.2 m³ biogas plant through anaerobic digestion. The system processed around 75 kg of waste per day, producing biogas equivalent to 3.54 kg of Light Petroleum Gas (LPG) daily, thereby replacing nearly 50% of monthly LPG consumption. That resulted in monthly fuel cost savings of approximately USD 100, with a simple payback period of less than one year (11.4 months). Additional benefits included improved waste hygiene, reduced odour and vector nuisance, and the production of nutrient-rich bio-fertiliser.

The Economic Internal Rate of Return (EIRR) was 114 %, i.e., the construction of the biogas plant at the contractor's temporary labour campus was economically very viable.

Introduction

Solid waste is non-liquid waste generated by households, small businesses, and institutions within cities, and its uncontrolled disposal can harm the environment and human health (Baawain et al, 2017)¹. It has a significant impact on the environment and public health (Deabrah et al 2021)². Waste generation is increasing globally, making proper waste management

activities more difficult. Solid Waste Management (SWM) can be defined as the collection, transport, resource recovery, and disposal of waste, including supervision and aftercare of disposal sites such as landfills (European Council, 1991)³.

Management of SW is now an integral part of environmental governance (Das et al., 2019)⁴ and it has become a major environmental problem in urban areas, especially in the Global South (GS) where treatment facilities, infrastructure and financial limitations are inadequate (Alam & Qiao, 2020)⁵. In a significant part of GS cities, the SW disposal is crude dumping, with partial or uncontrolled materials treatment and resource recovery (Das et al., 2019)⁴. This situation poses several sustainability issues, including resource depletion, environmental pollution, and public health concerns (Ghosh et al., 2023; Singh et al., 2023)^{6,7}. In the 1990s, SW governance could not be effectively managed and disposed of without local stakeholders' active participation. By the end of the decade, international financial institutions and donor agencies had called on policymakers to develop sustainable SW management solutions.

It is widely accepted that the management of solid waste is a global problem. This problem is even more pronounced in developing countries such as Nigeria, Nepal, and Bangladesh where solid waste management is a major concern. Adeyemi et al. (2001)⁸ observed that solid waste constitutes a major problem in most developing countries. Adeyemi added that waste management is one of the most intractable problems facing city administrators and environmental agencies. Ogwueleka (2009)⁹ reported that solid waste management is by far one of the greatest challenges facing environmental bodies in the country. As a result of the management challenges, Adefemi & Awokunmi (2009)¹⁰ reported a breakdown of law and order in relation to waste management. They observed that urban centres are experiencing an increased rate of environmental deterioration as a result of indiscriminate dumping of solid waste. Omuta (1987)¹¹ noted that one notable flaw in waste management administration in developing countries is the unavailability of a proper

waste management policy. His view is that for waste management to work, various aspects of government services such as engineering, urban planning, geography, economics, public health and law among others must be brought together under a proper policy to deliver an effective waste management system.

Poor management of solid waste collection and disposal can result in the leachate contaminating the surface water or the groundwater. That poses serious risks, especially if the waste contains toxic substances or if nearby water sources are used for drinking or domestic purposes. In hot climates, the accumulation of large amounts of dry waste can also create a fire hazard, producing smoke and threatening nearby buildings and residents. Living in unhygienic and cluttered surroundings can demoralise people, reducing their motivation to maintain or improve their environment. Moreover, waste tends to attract more waste, encouraging unhygienic behaviour and further deteriorating community cleanliness.

Bangladesh is currently investigating renewable energy sources, particularly solar panels and biogas plants (Rana et al., 2021)¹². As an agriculture-based country, Bangladesh has enormous potential for implementing biogas technologies. Currently, Bangladesh has nearly 100,000 biogas plants and more than 58,000 plants are financed and monitored by the Infrastructure Development Company Limited (IDCOL).

Biogas technology is not complex, it's rather quite simple, easy to operate, and therefore, acceptable to common people. Besides, raw materials can be made easily available and are also relatively cheap, economical, and affordable. Biogas also has a different aspect – that of economic benefits since it provides gas, electricity and fertiliser to the household. However, the cost of digesters has been the most significant limitation in biogas operations. Because of the decline in subsidies, new biogas plants have decreased substantially every year, leading to the shift of fuel used from biogas to coal (Qiu et al., 1990)¹³.

Previously, renewable energy was treated as economically unviable (Rana et al., 2021)¹². It

has nonetheless been deemed technologically and economically feasible in the light of the full package of economic and environmental benefits (Bahauddin and Salahuddin, 2012)¹⁴.

Solid waste management can be divided into six key components: generation; storage; collection; transportation; treatment and disposal.

Summary of Literature Review

Based on the literature review, the following points are highlighted:

- Solid waste management impacts on the environment and public health;
- Waste generation is increasing; it needs proper waste management;
- Investigating renewable energy sources, particularly solar panels and biogas plant; and
- Renewable energy was earlier considered being as economically nonviable.

Sources of Solid Waste

The main sources of solid waste are: medical centres; food stores; feeding centres; food distribution points, slaughter areas, warehouses, agency premises, markets and domestic areas.

Appropriate solid waste management strategies may vary for institutional, communal and domestic sources, depending on types and volumes of waste. Waste from medical centres pose specific health hazards.

Type and Quantity of Solid Waste

The type and quantity of waste generated ii varied greatly. The main factors affecting these are: the geographical region (developed or less-developed country or region); socio-cultural practices and material levels among affected population; seasonal variations (affecting types of food available); volume and composition of waste may change over time); and the packaging of food ration.

The different categories of solid waste generated at the construction site and the labour camps are:

Organic waste: Waste from the preparation of food, marketplace, etc.

Combustibles: Paper, packaging for relief items, wood, dried leaves, etc. (high organic and low moisture content)

Non-combustibles: Metal, tin cans, bottles, sand, stones, etc.

Ashes/ dust: Residue from fires . for cooking,

Bulky waste: Tree branches, tyres, etc.

Dead animals: Carcasses of domestic animals and livestock.

Hazardous waste: Oil, battery acid, and medical waste.

Construction waste: Roofing, rubble, broken concrete, etc.

Biogas Plant

A biogas plant has three major components:

- Reception Area;
- Digester (or fermentation tank); and
- Gas Holder.

The Reception Area is where the raw materials arrive and are prepared for anaerobic digestion. Each type of biomass has a different fermentation process, so the overall length of the biogas production process varies depending on the raw materials used. Hence, it is not uncommon to use pre-treatments in industrial biogas plants to accelerate fermentation and increase the production of biogas.

Some of the most popular biomass choices are crop residues, municipal and industrial sewage, agricultural material, livestock manures, seaweed, food-processing, paper wastes, etc.

The Digester is an air-tight, waterproof container with an inlet for feeding the biomass. Agitators shift the biomass periodically to free the gases and prevent

the formation of layers. The digester also includes a pipe that enables the digestate to be removed after the fermentation is over.

The Gas Holder is an airtight container, preferably made of steel, that collects the gas generated during fermentation. It is provided with a gas outlet that permits the biogas to come out of the system and produce energy and heat.

The process is shown schematically in Figure 1.

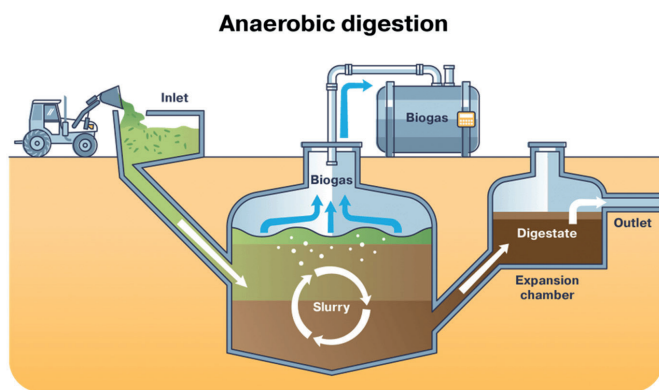


Figure 1: The Bio Digester Process

Objectives and Scope of the Present Study

A case study has been adopted for justification of the investment for the construction of a biogas plant for a labour campus of the Dhaka Sylhet Project, Bangladesh. The objectives and scope for the study are:

- Collection of organic waste per day;
- Disposal of organic waste;
- Uses of organic waste in a biogas plant;
- Determination of the initial construction cost of the biogas plant; and
- Economic analysis/ viability of a biogas plant.

Case Study

Site Description (Case Study Area: DS-08 Corridor)

The case study area is located along the Dhaka–Sylhet National Highway (N 2), under the Improvement of

Dhaka–Sylhet National Highway Project, Lot DS-08. The contract package covers a road section extending from the Sayestaganj Bypass BM Filling Station to Bahubal Square Textile, between chainage 134+600 km and 151+000 km, with a total length of 16.4 km. The project involves upgrading the existing two-lane highway into a four-lane highway with service lanes on both sides, aiming to improve regional connectivity, traffic safety, and economic activities in the Habiganj district.

The DS-08 corridor connects several important towns and growth centres in Habiganj, including Sayestaganj, Chunarughat, Madhabpur, Mirpur Bazar, Lakhai, Chalta Bazar, and Bahubal. Biogas plant is shown in the map in Figure. 2.



Figure 2: Location Map of Biogas Plant of DS-08

The Dhaka–Sylhet Corridor Road Investment Project involves large-scale construction activities with multiple labour camps and associated facilities established in predominantly rural settings under 13 contract lots. These basecamps generate a significant volume of solid waste, particularly organic kitchen waste from labour accommodation.

At the construction basecamp of Dhaka Sylhet (D S)-Lot 08, approximately 2200 kg of organic waste per month is generated from five labour sheds, primarily consisting of food scraps and biodegradable materials. In the rural context, the absence of formal municipal waste collection systems makes conventional disposal practices challenging and environmentally

unsustainable. Initially, after commencement, improper management of organic waste was leading to odour nuisance, vector breeding, groundwater contamination, and public health risks for the basecamp.

Solid Waste Management Strategy

Reduce

Waste minimisation at source is promoted through:

- Awareness training for camp residents and kitchen staff on food planning and portion control;
- Segregation of organic and inorganic waste at the point of generation;
- Reduction of single-use packaging materials in camp supply procurement; and

These measures help limit unnecessary waste generation and improve the efficiency of downstream waste handling.

Reuse

Wherever feasible, reusable materials are segregated and reused within the camp or handed over to authorised recyclers. The materials include:

- Reuse of plastic containers for non-food purposes;
- Reuse of cardboard and sacks for storage and transport; and
- Safe reuse of cooking water (where hygienically appropriate) for cleaning or gardening.

Recycle/ Resource Recovery (Biogas System)

As a key best practice initiative, a small-scale biogas plant has been installed at the construction basecamp to manage organic kitchen waste.

The key features include:

- Daily collection of segregated organic waste from labour sheds;
- Controlled feeding of biodegradable waste into the biogas digester;

- Anaerobic digestion of organic waste to produce biogas;
- Utilisation of biogas as a supplementary cooking fuel in the basecamp kitchen; and
- Collection of digested slurry, which is safely reused as organic compost for landscaping and plantation activities within the camp premises.

This system converts waste into useful energy, significantly reducing the volume of waste requiring disposal and minimising environmental pollution.

Technical and Economic Analysis on 3.2 m³ Biogas Plant of DS-08

This paper is prepared on the basis of the project information provided for a 3.2 m³ household/commercial biogas plant with technical and supervision support from Grameen Shakti. The objective is to document the plant description, design, expected gas production, material requirements, and an economic comparison between LPG-based cooking and biogas-supported cooking. The typical photograph of the plant is shown in *Figure-3*.



Figure 3: Biogas Plant of DS-08

Description of the Biogas Plant

The biogas plant is designed to utilise kitchen waste (75 kg/day) along with the initial cow dung charging to produce renewable biogas for cooking. The plant produces biogas equivalent to 3.5 kg of LPG per day, reducing dependency on commercial LPG. In addition to gas, the system produces bio-fertiliser as a valuable by-product.

- Plant Capacity: 3.2 m³
- Daily Feedstock: 90 kg kitchen waste
- Daily Gas Production: Equivalent to 3.5 kg LPG
- By-product: Bio-fertiliser (slurry)

Land Requirement

The approximate area required for setting up a biogas plant is 7 m × 4m = 28 m².

Expected Gas Production Analysis

Daily LPG Equivalent: 3.5 kg

Monthly LPG Equivalent (30 days): 105 kg

Materials Required for Construction

The approximate quantum of material required for the construction of a biogas plant are First Class Brick: 2000 nos; Aggregate: 40 cft; Cement: 24 bags; Sand: 100 cft; MS Rod: 30 kg; PVC Pipe 15 cm diameter: 3m; Biogas Stove: 1 no; Gas Valve: 2 nos; Polythene sheet: 1 kg; Cow Dung: 3600 kg.

Economic Analysis

The detailed project cost is worked out and shown in Table 1.

Table 1: Initial Construction Cost of Biogas Plant

Sl. No.	Item Description	Quantity	Unit Rate (BDT)	Cost (BDT)
1	First Class bricks	2000 No	15/No	30,000
2	Aggregates /Khoa /Septin	40 cft	225/cft	9,000
3	Cement	24 Bag	515/Bag	12,360
4	Sand (FM-1.5)	100 cft	36/cft	3,600
5	MS Rod (8/10 mm)	30 kg	90 Tk/kg	2,700
6	PVC Pipe 15 cm (6" dia)	10 ft	350/ft	3,500
7	Centre Pipe 60 cm (6" dia)	1 Pc	600/Pc	600
8	Biogas Stove (Single)	2 Pc	2,000/Pc	4,000
9	Gas Valve	3 Pc	500/Pc	1,500
10	Polythene Sheets	1 kg	120/kg	120
11	Acrylic Plastic Paint (Berger)	2 Liter	450/L	900
12	3/4" Hose Pipe (Lata Pipe)	100 ft	25/ft	2,500
13	Plain Sheet (18 Gauge) for inlet box	As required	300/meter	1,000
14	Earth digging (2 pits + filling)	As required	labour cost only	1,500
15	Fittings materials	As required		1,000
16	Cow dung for primary charging	As required	free/nominal	3600
17	Others	As required		1,000
18	Sub-Total Cost A (Sl 1 to Sl 17) =			78,880
19	Initial Construction Cost			20,000
20	Design fees of Supervision Consultants			10,000
21	Sub-Total Cost B (Sl 18+19+20)			108,880
22	Overhead and Profit @15% Sub-Total Cost B			16,332
23	Final Cost (Financial)			125,212
24	Final Cost (Financial) (Say)			125000 (say)

Construction and Annual Operation Cost

Construction cost of the biogas plant in terms of Bangladesh Taka (BDT), i.e., Financial Cost = 125,000 = USD 1000 (125BDT=1 USD)

Monthly Savings: Cost of use of LPG gas is reduced to 12,000 BDT, Annual Savings: 144,000 BDT = USD 1150

Life Cycle analysis and Economic analysis have been carried out. The plant was installed in 2023, and the project is expected to be completed in 2028 or 2029. Thus, the biogas plant will be used for five years.

The total Financial Cost is BDT 125,000. The Economic Cost is 90 % of the Financial Cost = $125000 \times 0.90 =$ BDT 112,500.

The Annual Operation Cost calculated is BDT 24,690, and thus the monthly cost is BDT 2,060/Month. Considering Escalation rate and Discount rate @ 6 % and 12 % per annum respectively, it is, 0.5 % and 1 % monthly (approximately). Assuming usable period of five years (although the biogas plant's life period is longer) the Net Present Value (NPV) and Economic Internal Rate of Return (EIRR) were calculated. NPV works out to be BDT 219,871, and the saving BDT 405,590 after recovery of the initial cost in 5 years.

EIRR is determined @ discount rate when “(Saving – NPV)” is zero. It is found to be 0.03 (approximately 0). This has been calculated using a discount rate of 9.57 % (Monthly) and EIRR is found to be $9.57 \times 12 = 114$ % (Say).

The construction of the biogas plant in the temporary campus is found to be economically highly viable and thus, justified. *This type biogas plant construction will be very useful for the Medical college hostels, Engineering College hostels, labour, officers residential colony of the industry where cooking is done every day for 100 to 1000 or more students /people and long- term return can be gained and it will be viable financially.*

Additional Benefits of a Biogas Plant

The additional benefits are a reduction of fossil fuel (LPG) consumption by 50%; proper management of kitchen waste, production of organic bio-fertiliser; reduction of greenhouse gas emissions; improved energy security.

Environmental and Social Benefits

The biogas-based solid waste management system provides multiple benefits, such as:

Environmental Protection: Reduces open dumping and burning of organic waste. Minimises methane emissions from uncontrolled decomposition and prevents soil and groundwater contamination.

Resource Efficiency: Converts waste into renewable energy. Produces nutrient-rich compost, reducing the need for chemical fertilisers, health and safety; reduce odour, fly nuisance, and vector breeding improves hygiene conditions in labour camps.

Community and Sustainability Benefits: Demonstrates environmentally responsible construction practices. Serves as a replicable model for waste management in rural construction sites.

Institutional Arrangement and Monitoring: The Contractor's Environmental, Health & Safety (EHS) team members are responsible for the operation, maintenance, and monitoring of the biogas plant.

Regular training is provided to kitchen staff members and labourers on waste segregation and safe handling. Monthly records are maintained on: quantity of organic waste collected, including biogas production and utilisation, slurry reuse and disposal.

Conclusion

The National 3R Strategy (2010) plans to change the way waste is managed in Bangladesh by adopting a “Reduce, Reuse, Recycle” approach instead of the current “end-of-pipe” method of disposal. The strategy recognises waste as a non-recovered resource and plans

to achieve the “elimination of open dumping by 2015.” The strategy requires source segregation, encourages public-private partnerships, and seeks to integrate the informal sector into the formal waste management system.

The strategy is driven by the “Polluter Pays Principle,” Green Purchasing, and the creation of a National 3R Focal Point. The strategy gives high priority to waste reduction and recycling over disposal and thus aims to reduce environmental degradation, greenhouse gas emissions, and promote a sustainable economy through incentives such as tax concessions for green technology. Connecting Organic Waste to Biogas Production “The National 3R Strategy” connects organic waste management to energy security through biogas production, which is made possible by the fact that a substantial amount of Bangladesh’s municipal waste is organic in nature.

The strategy recommends the production of biogas from this waste through anaerobic fermentation, which yields clean energy (60-70% methane) for cooking, lighting, and powering electricity. Some examples of this conversion in Bangladesh are:

Agricultural Initiatives: The National Domestic Biogas and Manure Program (IDCOL), which aims to establish 60,000 domestic biogas plants from agricultural residues and manure. **Commercial Power Generation:** A private sector project in Kapasia, Gazipur, uses rice husks to produce biogas-based electricity, which is provided to rural households not connected to the national grid. **Urban & Housing Policy:** The strategy recommends that new residential areas be designed to include space for biogas plants, which will address waste management and bio-fertiliser production simultaneously.

The implementation of a 3Rs-based solid waste management system, supported by a small-scale biogas plant, reflects the contractor’s commitment to sustainable construction practices under the Dhaka–Sylhet Corridor Road Investment Project. This approach effectively addresses the challenges of

managing approximately 2200 kg/month of organic waste in a rural context and aligns with ADB safeguard requirements, national environmental regulations, and international best practices.

This initiative represents a good practice example of integrating environmental protection, resource recovery, and occupational health considerations into construction camp management.

The scope of the work is very limited and project-specific, therefore, limited conclusions may be drawn from this study. However, the following conclusions may be drawn:

- Solid waste in the form of organic waste from the kitchen poses an environmental hazard in rural areas where the contractors’ labour camps are established. This waste is used in a biogas plant. It reduces environmental hazards.
- It reduces the LPG Consumption by 50 %, and the yearly savings are around BDT 1, 44,000 (USD 1150). The construction of a 3.2 m³ biogas plant is calculated and found to be BDT 125,000, i.e., the construction cost will be recovered within the first year of operation, i.e., 11.4 months.
- Net Present Value (NPV) has been determined for five years and the benefit (Saving-Expense) is found to be BDT 405,593 after recovery of initial cost and operation cost in 5 years. The Construction of a biogas plant is economically viable;
- Economic Internal Rate of Return (EIRR) has been determined and found to be 114 %, which is more than 12 %. The biogas plant is economically highly viable; and
- It has several benefits namely environmental protection, resource efficiency, community and sustainability benefits and institutional arrangement and monitoring.

References

- 1) Baawain, M., Al-Mamun, A., Omidvarborna, H., Al-Amri, W., 2017. Ultimate composition analysis of municipal solid waste in Muscat. J. Clean.

- Prod. 148, 355–362. <https://doi.org/10.1016/j.jclepro.2017.02.013>.
- 2) Debrah, J. K., Vidal, D.G., Dinis, M. A. P., 2021. Raising awareness on solid waste management through formal education for sustainability: A developing countries evidence review. *Recycling* 6 (1), 6. <https://doi.org/10.3390/recycling6010006>.
 - 3) European Council. (1991). Council Directive 91/156/EEC of 18 March 1991 amending Directive 75/442/EEC on waste. *Waste Official Journal*, L 078, 32–37. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A31991L0156>.
 - 4) Das, S., Lee, H.S., Kumar, P., Kim, K.i., Lee, S.S., Bhattacharya, S.S., 2019. Solid waste management: Scope and the challenge of sustainability. *J. Clean. Prod.* 228, 658–678. <https://doi.org/10.1016/j.jclepro.2019.04.323>.
 - 5) Alam, O., Qiao, X., 2020. An in-depth review on municipal solid waste management, treatment and disposal in Bangladesh. *Sustain. Cities Soc.* 52, 101775. <https://doi.org/10.1016/j.scs.2019.101775>.
 - 6) Ghosh, A., Kumar, S., Das, J., 2023. Impact of leachate and landfill gas on the ecosystem and health: Research trends and the way forward towards sustainability. *J. Environ. Manage.* 336, 117708. <https://doi.org/10.1016/j.jenvman.2023.117708>.
 - 7) Singh, D., Tembhare, M., Machhirake, N., Kumar, S., 2023. Impact of municipal solid waste landfill leachate on biogas production rate. *J. Environ. Manage.* 336, 117643. <https://doi.org/10.1016/j.jenvman.2023.117643>.
 - 8) Adeyemi, A. S., Olorunfemi, J. F., & Adewoye, T. O. (2001). Waste scavenging in Third World cities: A case study in Ilorin, Nigeria. *Environmentalist*, 21(2), 93-96. <https://doi.org/10.1023/A:1010655623324>.
 - 9) Ogwueleka, T. (2009). Municipal solid waste characteristics and management in Nigeria. *Iranian Journal of Environmental Health Science & Engineering*, 6(3), 173-180.
 - 10) Adefemi, S. O., & Awokunmi, E. E. (2009). The impact of municipal solid waste disposal in Ado Ekiti metropolis, Ekiti State, Nigeria. *African Journal of Environmental Science & Technology*, 3, 186-189.
 - 11) Omuta, G. E. D. (1987). Urban solid waste generation and management in Nigeria: Towards an environmental sanitation policy. *Habitat International*, 11(2), 77-87. [https://doi.org/10.1016/0197-3975\(87\)90058-0](https://doi.org/10.1016/0197-3975(87)90058-0).
 - 12) Rana, J., Kamruzzaman, M., Oliver, M.H., Akhi, K., 2021a. Financial and factors demand analysis of solar powered irrigation system in Boro rice production: a case study in Meherpur district of Bangladesh. *Renew. Energy* 167, 433–439.
 - 13) Qiu, D.X., Gu, S.H., Liange, B.F., Wang, C.H., 1990. *Diffusion and Innovation in Chinese Biogas Program*, 18. World Development Oxford, pp. 555–563.
 - 14) Bahauddin, K. M., Salahuddin, T. M., 2012. Prospect and trend of renewable energy and its technology: towards climate change mitigation and sustainable development in Bangladesh. *Int. J. Adv. Renew. Energy Res.* 1 (3), 156–166.

The CEAI team would like to thank Mr A P Mull, Ms Vandana Randhawa and Ms Jamini Goel for providing interesting snippets of information for this March 2026 edition of ViewPoint

Extended Producer Responsibility (EPR): A Strategic Instrument for Sustainable Waste Management and Circular Economy



Himanshu Tilwankar
Director
Envirotech Solutions

Abstract

Extended Producer Responsibility (EPR) has emerged as one of the most significant policy instruments for addressing the growing challenge of waste management in India. By shifting the responsibility of post-consumer waste from Urban Local Bodies (ULBs) to producers, importers, and brand owners, EPR seeks to internalise environmental costs, promote resource efficiency, and accelerate the transition towards a circular economy. This article examines the concept, regulatory framework, implementation models, and engineering relevance of EPR in the Indian context. Special emphasis is placed on the role of consulting engineers in designing, implementing, and strengthening EPR systems. Challenges in implementation and engineering and policy-oriented solutions are also discussed, making the article relevant for professionals engaged in infrastructure planning, environmental compliance, and urban development.

Introduction

“EPR is an environmental policy approach in which a producer’s responsibility for a product is extended to the post-consumer stage of a product’s life cycle.”¹ This rule makes companies responsible for managing

the waste their products create *after* consumers are done with them. Instead of it being only the city’s problem, the brand that made the product has to ensure it is collected and recycled properly. This is a major shift in how India handles waste.

EPR is not just an environmental rule; it is creating a whole new market for waste management systems, infrastructure, and compliance services. It directly affects projects in urban development, infrastructure planning, and environmental compliance.

Consider a plastic bottle or an old mobile phone. Traditionally, the local municipal corporation/ urban local body (ULB) would deal with discarding it. With EPR, the company that made that bottle or phone is financially and physically responsible for its end-of-life. That makes companies think about designing products that are easier to recycle. It is the “Polluter Pays” principle in action.¹

Concept and Evolution of Extended Producer Responsibility

Extended Producer Responsibility was first articulated by the Organisation for Economic Co-operation and Development (OECD) in the early 1990s.¹ The

central principle of EPR is that “producers should bear significant financial and/or physical responsibility for the treatment or disposal of products once they reach the end of their useful life.”¹

“The key principles underlying EPR include the Polluter Pays Principle, a lifecycle-based approach to product management, and the promotion of waste prevention through eco-design.”¹. By internalising environmental costs, EPR encourages producers to design products that are easier to reuse, recycle, or recover. Internationally, EPR has been successfully implemented in regions such as the European Union, Japan, and South Korea, particularly for packaging waste, electronic waste, and batteries. India has adapted these principles to suit its regulatory framework and socio-economic conditions.

Notified EPR Frameworks

India has adopted a waste-stream-specific approach, leading to multiple, interlinked regulations.

A. E-Waste (Management) Rules, 2022

The most advanced EPR regime, which replaces the 2016 rules.

- **Scope:** It Covers over 100 Electrical and Electronic Equipment (EEE) items, including solar PV modules/ panels.⁴
- **Key EPR Obligations:** Producers (including importers) must achieve annual EPR targets (a percentage of sales by weight) through: (i) Recycling via certified recyclers; (ii) Refurbishment; or (iii) Purchase of EPR certificates from the centralised portal. Strict RoHS (Restriction of Hazardous Substances) compliance is mandated.⁴
- **Innovation:** Introduces a **tradable EPR certificate mechanism** and mandates a dedicated escrow account/ bank guarantee for compliance assurance.

B. Plastic Waste Management (PWM) Rules, 2016 (Amended 2021, 2022, 2024)

EPR for plastic packaging was formalised in the 2021; 2022 and 2024 amendments.²

- **Scope:** Applicable to Producers, Importers & Brand Owners (PIBOs) of plastic packaging.²
- **Categorisation:** Four categories - Rigid, Flexible, Multi-layered Plastic (MLP), and Compostable Plastic.²
- **Key EPR Obligations:** PIBOs must register and fulfil annual EPR targets via recycling, end-of-life disposal, reuse, or certificate trading. The rules also phase out identified Single-Use Plastics (SUPs) and mandate **minimum recycled plastic content** in packaging, creating a pull-for-recycled material.²

C. Battery Waste Management Rules, 2022

A forward-looking framework for the booming battery sector, especially EVs.³

- **Scope:** All types of batteries -Electric Vehicle, Portable, Automotive, and Industrial.³
- **Key EPR Obligations:** Producers must collect and recycle/ refurbish waste batteries against progressive collection targets (70% by 2024-25, 90% by 2026-27). A landmark provision mandates the use of **minimum recycled content (cobalt, lithium, nickel, lead)** in new batteries, directly closing the material loop.³

D. Construction & Demolition (C&D) Waste Management Rules, 2024

It imposes significant responsibility on the generators of the waste.

- **Scope:** Waste generated from construction, re-modelling, repair, and demolition.⁶
- **Key Obligations:** Primary responsibility lies with the **generator** (like builders, contractors) to segregate, store, and ensure disposal at authorised processing facilities. Urban Local Bodies must provide collection mechanisms. Large generators must pay for collection and processing, internalising waste management costs.

E. Used Oil / Oil Waste (Spent Oil) EPR

It is governed by the **Hazardous and Other Wastes**

(Management and Transboundary Movement) Rules, 2016.

- **Scope:** Waste/ Used oil is classified as hazardous waste.⁷
- **Key EPR Obligations:** Generators (like automotive workshops, industries) must ensure safe storage and disposal only to authorised re-refiners or recyclers. While not targeting the *lubricant producer* directly, the rules create a chain of responsibility where sellers/ collectors must be authorised, and refiners must meet specified recovery standards.

F. Tyre Waste Management Rules, 2022

- **Scope:** All pneumatic tyres.
- **Key Proposal:** EPR obligation on producers/importers to ensure 100% collection and processing, primarily through registered pyrolysis units or material recyclers, with a move towards material recovery.⁸

Proposed and Draft EPR Frameworks

These signify the next phase of India's circular economy agenda, expanding EPR to new, complex waste streams.

A. Draft EPR Framework for Packaging (Beyond Plastic)

- **Scope:** Aims to cover all packaging materials - plastic, paper, glass, metal, and composite.
- **Key Proposals:** Will likely introduce material-specific recycling targets, mandate the use of recycled content, and create a unified, **centralised portal** for all packaging EPR compliance. This seeks to address the limitation of the current PWM Rules, which focus only on plastic packaging.

B. Draft Regulation on End-of-Life Vehicles (ELVs)

Often referred to as the **Vehicle Scrapping Policy**.

- **Scope:** Older, unfit passenger and commercial vehicles.

- **Key EPR-Linked Proposals:** While not a classic "producer responsibility" rule, it incentivises manufacturers to: (i) Offer discounts against "Scrapping Certificates", (ii) Set up Registered Vehicle Scrapping Facilities (RVSFs), and (iii) Use recycled materials from ELVs. It creates a market for certified scrapping and links to the E-Waste and Battery Rules for components.

C. Textile Waste: EPR on the Horizon

The **Draft Notification on EPR for Textile Waste** is under discussion.

- **Rationale:** To tackle the massive waste from pre- and post-consumer textiles and fast fashion.
- **Expected Framework:** Likely to impose responsibility on apparel brands and manufacturers for collection and recycling of textile waste, promoting fibre-to-fibre recycling and responsible disposal.

Converging Mechanisms

- A. **Digital Compliance:** All frameworks rely on **centralised online portals** (CPCB) for registration, filing returns, and trading EPR certificates.⁵
- B. **Market-Based Instruments:** The **tradable EPR certificate** mechanism (in e-waste, plastics) introduces flexibility and economic efficiency.^{1,2,5}
- C. **Progressive Targets:** All rules set escalating collection/recycling targets, providing a clear compliance roadmap.^{1,2,3,5}
- D. **Circular Economy Mandates:** Rules like Battery (recycled content) and proposed Packaging (recycled content) explicitly push for circular material flows.³

EPR Value Chain and Stakeholder Responsibilities

The EPR system operates through a multi-stakeholder value chain involving regulators, producers, service providers, and recyclers. Producers, importers, and brand owners are responsible for meeting prescribed

EPR targets and financing waste management activities. Producer Responsibility Organisations facilitate collective compliance by aggregating obligations and engaging collection and recycling agencies.

Collection agencies, aggregators, recyclers, and co-processors form the operational backbone of the EPR system. Urban Local Bodies provide interface support at the city level, particularly for integration with existing waste collection systems. Consulting engineers play a critical role in designing systems, preparing detailed project reports, conducting audits, and advising on compliance strategies.

EPR Implementation Models

India has adopted flexible EPR implementation models to accommodate the diversity of industries and waste streams. Under the individual EPR model, large producers manage their own waste collection and recycling systems. The collective EPR model involves pooled responsibility through Producer Responsibility Organisations and is commonly adopted by fast-moving consumer goods and packaging sectors.

“Credit-based EPR allows producers to meet their obligations by purchasing verified recycling credits, particularly for plastics and electronic waste. Take-back systems involve reverse logistics arrangements and are widely used for electronics and batteries. These models provide flexibility while ensuring regulatory accountability”.⁵

Role of Consulting Engineers in EPR

Consulting engineers play a pivotal role in translating EPR regulations into practical, implementable systems. Their contributions include the design of EPR-compliant collection and recycling infrastructure, preparation of feasibility studies and detailed project reports, and integration of EPR streams with municipal solid waste management master plans.

Engineers also support the development of digital monitoring and traceability systems, conduct third-party audits, and provide compliance advisory services to producers and Producer Responsibility

Organisations. EPR represents a convergence of environmental engineering, logistics planning, and regulatory compliance, areas where consulting engineers possess core expertise.

Integration of EPR with Municipal Solid Waste Management

Effective integration of EPR with municipal solid waste management systems can significantly reduce the financial and operational burden on Urban Local Bodies. High-value waste streams such as plastics and electronic waste can be diverted from landfills, improving material recovery rates and reducing environmental impacts.

Alignment with national programmes such as Swachh Bharat Mission 2.0 and climate-resilient city planning initiatives further enhances the benefits of EPR. Integrated planning enables cities to move towards resource-efficient and low-carbon waste management systems.

Critical Challenges

The critical challenges are:

- **Integration of the Informal Sector:** A massive workforce handles waste informally. Their inclusion as authorised collectors/ aggregators is crucial for system efficacy and social equity.
- **Infrastructure Gap:** Scientific recycling capacity, especially for complex waste (MLP, composites, textiles), lags behind regulatory ambition.
- **Enforcement & Transparency:** Preventing fraudulent EPR certificate trading and ensuring accurate waste traceability requires robust monitoring, auditing, and technology (like blockchain).⁵
- **Consumer Awareness:** Effective segregation at source remains weak, hampering collection efficiency.
- **Rule Harmonisation:** As products become complex (e.g., an EV has e-waste, battery, tyre, and future ELV components), streamlined compliance across rules is needed to avoid duplication.

Engineering and Policy Solutions

Strengthening EPR systems requires coordinated engineering and policy interventions. Standardised third-party audits and transparent digital monitoring systems can improve credibility and traceability.⁵ Integrating the informal sector through formal contracts and capacity-building initiatives can enhance collection efficiency and social inclusion.

The development of regional recycling hubs, lifecycle assessment-based EPR planning, and targeted capacity building for regulators and municipal officials are critical measures. Consulting engineers can play a central role in designing and implementing these solutions.

EPR and Circular Economy Linkages

Extended Producer Responsibility serves as a foundational mechanism for advancing the circular economy.¹ By promoting secondary raw material markets, eco-design, and closed-loop systems, EPR reduces dependence on virgin resources. In the infrastructure and construction sectors, the use of recycled materials contributes to resource conservation and sustainability.

Way Forward and Recommendations

Future efforts should focus on strengthening regulatory certainty and enforcement, expanding material coverage under EPR, and encouraging innovation in product design and recyclability. The role of consulting engineers in policy execution and system design should be further enhanced. Aligning EPR with national climate and sustainability goals will maximise its environmental and socio-economic benefits.

References

- 1) Organisation for Economic Co-operation and Development (OECD). (2001). *Extended Producer Responsibility: A Guidance Manual for Governments*.
- 2) Ministry of Environment, Forest and Climate Change, Government of India. (2016, amended 2022). *Plastic Waste Management Rules*.
- 3) Ministry of Environment, Forest and Climate Change, Government of India. (2022). *Battery Waste Management Rules, 2022*.
- 4) Ministry of Environment, Forest and Climate Change, Government of India. (2022). *E-Waste (Management) Rules, 2022*.
- 5) Central Pollution Control Board (CPCB). (2023). *Guidelines for Implementation of EPR*.
- 6) Ministry of Environment, Forest and Climate Change, Government of India. (2024) **Construction & Demolition (C&D) Waste Management Rules, 2024**
- 7) Ministry of Environment, Forest and Climate Change, Government of India. (2016) **Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016**
- 8) Ministry of Environment, Forest and Climate Change, Government of India (2022) **Tyre Waste Management Rules, 2022**

About Envirotech Solutions. It is a leading environmental consultancy based in Gurgaon, spearheaded by a seasoned environmental engineer with over 38 years of comprehensive expertise. The founder's background includes hands-on experience with Pollution Control Boards, top-tier FMCG industries, renowned environmental consulting firms, and academic roles at prestigious engineering colleges. It specialises in end-to-end environmental compliance, auditing, and impact assessments, alongside dedicated waste management solutions for solid, hazardous, plastic, and e-waste. It also offers forward-looking advisory services in Sustainability, ESG, BRSR reporting, and Carbon Footprint measurement. Trusted by industries and institutions alike, Envirotech Solutions is committed to driving ecological responsibility through innovative, compliant, and sustainable practices.

Garbage by Choice, Not by Chance: India's Solid Waste Management Crisis



Vandana Randhawa

Director and FIDIC Procurement Specialist
Legacy Law Offices LLP

Introduction

Dump sites in operation as well as the legacy waste dump sites occupy huge areas of valuable public lands and are the source of pollution for air, water and land which results in damage to the environment and affects public health. The emission of gases like methane and carbon dioxide and malodorous gases like hydrogen sulphide and ammonia, etc. have resulted in an intolerable, hazardous and unsafe environment for inhabitants in the vicinity of the dumps, severely affecting their quality of life and infringing upon their constitutional and human rights. In addition, considerable financial harm is caused to public health and environmental resources. This situation is not acceptable in a civilised society governed by rule of law. For victims of the situation, there is no governance¹.

India's solid waste crisis is frequently attributed to population growth, rapid urbanisation, and infrastructural stress. These explanations, while convenient, obscure a more fundamental truth - the accumulation of unsegregated waste, the persistence of open dumpsites, and the routine burning of garbage are not the result of regulatory absence. Rather, they are the consequence of sustained non-compliance within an existing and reasonably comprehensive legal framework.

From a governance perspective, the crisis reflects not just a legislative gap, but a failure of enforcement

discipline. Where legal obligations are repeatedly disregarded without consequence, waste ceases to be a municipal problem and becomes an indicator of institutional breakdown.

Waste Management and Constitutional Accountability

Indian legal jurisprudence has long been plagued by the issue of legacy wastes and the inability of legislation to deal with the same. The case of **Municipal Council, Ratlam v. Shri Vardhichand & Ors**² is an adequate example, where the Hon'ble Supreme Court dealt with the issue of a failure on the part of the Municipal Council to ensure basic facilities like public sanitation to the slum dwellers of Ratlam combined with the sheer callousness of the authorities to prevent the 'discharge from the nearby Alcohol Plant, of malodorous fluids into the public street', showing obliviousness to the statutory obligation envisaged under Section 123 of the M. P. Municipalities Act, 1961. A landmark judgment was resultantly pronounced, holding 'clean environment' to be a fundamental right under Article 21 of the Constitution of India, further holding that the financial inability cannot be taken as a defence by the authorities to avoid their duties towards the residents.

The precedent, alongwith the one pronounced in the case of **B.L. Wadhwa v. Union of India & Ors**³, underscored that where public nuisance and health

hazards persist, law must be enforced and that systemic ignorance rooted in administrative difficulty shall not suffice.

While the judgments have had positive impact, issues concerning an unhinged increase in solid waste continue to be an epidemic. So much so, that various government initiatives, rules, and policies like the Swachh Bharat Abhyan have remained inadequate, as dump yards continue to engulf cities and states.

Policies and the Inadequacy in their Implementation

The Solid Waste Management Rules, 2016, replaced the earlier 2000 regime and introduced a detailed, modern regulatory framework applicable across urban and rural areas. The Rules mandate source segregation of waste into biodegradable, non-biodegradable, and domestic hazardous categories. They require door-to-door collection, decentralised processing, establishment of material recovery facilities, and scientific landfilling in accordance with prescribed standards⁴.

The Rules also impose specific obligations on bulk waste generators, including institutions, hotels, markets, and residential complexes. Such entities are required to segregate waste at source and process biodegradable waste on-site where feasible. Local authorities are mandated to levy user fees, frame bye-laws for enforcement, integrate informal waste workers, and ensure remediation of legacy dumpsites within defined timelines.

Notwithstanding this clarity, compliance remains fragmented. Mixed waste collection continues in many cities despite the express mandate of source segregation. Processing and landfill infrastructure is frequently delayed. Enforcement against bulk waste generators is often selective or symbolic. Data reporting is inconsistent and, in some cases, unreliable.

Another recent enactment in the area of solid waste management, includes the Environment (Construction and Demolition) Waste Management Rules, 2025. The 2025 Rules expand the regulatory ambit by imposing

Extended Producer Responsibility (EPR) on waste generators, including developers of large construction projects, requiring them to meet defined recycling targets and manage waste in an environmentally sound manner. The Rules mandate real-time tracking of waste through digital systems, detailed waste storage and processing protocols, and clear recycling and utilisation targets that escalate over time, with the goal of achieving 100 per cent recycling of Construction and Demolition (C&D) waste by 2028-29⁵.

Furthermore, the Rules set minimum utilisation targets for recycled C&D materials in reconstruction and construction projects and require local authorities to establish intermediate waste storage and recycling facilities. These provisions are designed to close the gap between generation and processing capacity and to institutionalise accountability within the construction value chain. However, provided that the implementation and the actual impact of the Rules have been largely unreported, there may be a need for cautious optimism about the overall potential of such legislations, pending efficient enforcement measures.

An International Overview

Beyond domestic law and comparative regulatory practice, waste management is increasingly shaped by international conventions that treat uncontrolled waste not merely as a local environmental concern, but as a transboundary and systemic risk. These instruments reinforce the principle that waste governance is an obligation grounded in prevention, accountability, and international cooperation.

International experience suggests that effective waste management regimes are defined less by legislative novelty and more by enforcement discipline. The waste hierarchy established by the European Union legally discourages landfilling. The framework is designed to protect the environment and human health by emphasising the importance of proper waste management, recovery, and recycling techniques to reduce pressure on resources and improve their use⁶.

Additionally, the Basel Convention on the Control of

Transboundary Movements of Hazardous Wastes and Their Disposal establishes a foundational obligation on States to minimise waste generation at source and ensure environmentally sound management of waste within their jurisdictions. While the Convention is most often associated with cross-border movement of hazardous waste, its underlying logic is preventive. Parties are required to reduce waste generation, develop adequate disposal facilities, and avoid practices that merely shift environmental harm from one location to another. Persistent reliance on open dumping, unmanaged landfills, and informal disposal systems sits uneasily with these obligations.

Similarly, the Stockholm Convention on Persistent Organic Pollutants further reinforces this framework by requiring States to eliminate or restrict substances that pose long-term risks to human health and the environment. Open burning of mixed municipal waste, including plastics and electronic waste, directly undermines these objectives by releasing toxic pollutants into the air and soil. Where such practices persist, they raise concerns not only under domestic environmental law, but also under international commitments to pollution control and public health protection.

The combined effect of these conventions reflects an international consensus that waste management is inseparable from environmental protection, public health, and sustainable development. They impose obligations that extend beyond policy aspiration. They require States to build institutional capacity, enforce compliance, and prevent environmental harm at source rather than manage its consequences after the fact.

India, being a party to these conventions, has incorporated several of their principles into domestic regulations, including the Solid Waste Management Rules, 2016 and the Environment (Construction and Demolition) Waste Management Rules, 2025. Refer Table 1. However, as with domestic law, the effectiveness of international commitments depends on enforcement. Where municipal non-compliance, informal disposal, and regulatory inertia persist, treaty obligations risk becoming symbolic rather than operational.

Table 1: Solid Waste Management Laws

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, (adopted in 1989, came into force in 1992)

Stockholm Convention on Persistent Organic Pollutants, (adopted in 2001, came into force in 2004)

Solid Waste Management Rules, 2016, (replaced the earlier Municipal Solid Waste (Management and Handling) Rules, 2000)

Environment (Construction and Demolition) Waste Management Rules, 2025 (replaced the earlier 2016 Rules)

From an international law perspective, unmanaged waste is not merely a failure of local governance. It represents a breach of globally accepted environmental norms that increasingly demand accountability, traceability, and preventive action.

Need for an Efficient Solution

Waste generation used to be an unavoidable and unfortunate by-product of economic activity and growth. With modern technology and careful management, that cyclical link can be broken⁷.

India's solid waste crisis, however, is not a technological failure, nor is it a legislative one. Legal standards are clearly articulated. Even with many landmark judgments holding clean environment, pollution-free environment, and clean air, to be fundamental rights, the various judicial and policy interventions have remained largely inadequate. Frameworks including the Solid Waste Management Rules, 2016, and the Environment (Construction and Demolition) Waste Management Rules, 2025, are firmly in place and international commitments further reinforce the obligation to prevent environmental harm through effective waste governance. What remain deficient, however, are the measures for efficient enforcement.

Addressing the crisis requires a deliberate shift from tolerance of default to insistence on compliance. Source segregation must be enforced without exception. User charges must reflect real service costs. Legacy waste remediation must be tied to enforceable timelines, independent verification, and clear accountability. Bulk waste generators and project proponents must face meaningful consequences for sustained non-compliance.

Waste, ultimately, is a mirror of governance capacity. When laws are enforced consistently, waste reduces. When enforcement is indulgent, garbage accumulates. India's challenge is no longer to frame better rules, but to apply existing ones with institutional discipline. Until that transition occurs, landfills will continue to rise, not as by-products of growth, but as visible reminders of responsibility deferred.

References

- 1) In re: Compliance of Municipal Solid Waste Management Rules, 2016 and other environmental issues, O.A. No. 606/2018, before the National Green Tribunal, Principal Bench, New Delhi.
- 2) Municipal Council, Ratlam v. Shri Vardhichand & Ors, AIR 1980 SC 1622.
- 3) B.L. Wadhwa v. Union of India & Ors., AIR 2002 SC 1913.
- 4) https://cpcb.nic.in/uploads/MSW/Salient_features_SWM_Rules.pdf.
- 5) <https://www.corporateprofessionals.com/regulatoryupdate/environment-construction-and-demolition-waste-management-rules-2025/>.
- 6) <https://eur-lex.europa.eu/EN/legal-content/summary/eu-waste-management-law.html>.
- 7) Id.

Kadamvakvasti Gram Sabha passes resolution to tackle garbage crisis

In Pune, amid the ongoing student agitation against garbage dumping in the Mula-Mutha riverbed near the MIT Art, Design and Technology University campus, the Kadamvakvasti gram panchayat passed a resolution to address the issue of waste management and proposed setting up of a solid waste treatment project.

The student agitation against the dumping of garbage in the Mula-Mutha riverbed intensified after nearly 6,000 students of the MIT Art, Design and Technology University renewed their 'garbage bandh' protest when the deadline given to the local gram panchayat expired without concrete action.



Students gathered outside the main gate of the university and blocked tractors carrying garbage, preventing them from entering the campus area and proceeding towards the riverbed. According to protesters, large quantities of waste continue to be dumped daily along the river, raising serious environmental and health concerns.

The protest had been temporarily suspended earlier after students gave the local authority and gram panchayat time to resolve the issue. However, as no visible action was taken within the stipulated period, the students resumed their agitation demanding an immediate halt to dumping of garbage in the riverbed.

Amid the growing agitation, Haveli block development officer (BDO) Shekhar Shelar on March 13 issued a letter to the Lonikand and Kadamvakvasti gram panchayats and said that "improper garbage management in these peri-urban villages had created serious sanitation and health concerns, and emphasised the need for coordination between local agencies and gram panchayats to find a sustainable solution".

Source: Excerpts from Hindustan Times

Solid Waste Management: Producer and Policy Perspective



Dr. Vivek Agrawal

Secretary

Centre For Development Communication, Jaipur

After a decade of Swachh Bharat Abhiyan and promulgation of various rules in 2016, on waste management and achieving circular economy, new revised, improved, and comprehensive rules will come into force during 2026¹. The New Extended Producers Responsibility Rules for Paper, Metals, Glass Packaging and Sanitary products have come into force from 1st October 2025². The Ministry of Environment, Forest and Climate Change, Government of India has revised these rules after seeking stakeholders' opinion on the draft rules². By revision and introduction of new rules, the government is taking a leap forward to make the system more responsible and to create clarity on some of the ambiguous issues.

The major impact of comprehensive rules introduced in 2016 supported with systematic and dynamic initiatives is visible in the creation of infrastructure, enhanced services and increased awareness and attitude of every individual to adapt to better waste management practices³. The Swachh Bharat Mission involves all stakeholders with incremental targets of service delivery and upscaling interventions⁴. Besides, with continuous monitoring through Swachhata Sarvekshan and reporting mechanism, local bodies have become more responsible and answerable to the growing menace of waste⁵.

During the last decade, with change in lifestyle, newer types of waste streams have replaced the older ones.

Shopping behaviour has also changed drastically with more dependence on online shopping⁶. In this era of change, steep growth in online shopping, growing apathy towards use of plastic, more environmentally conscious behaviour and concern for mother earth have affected waste management significantly. As a result, consumption of packaging material has increased manyfold creating newer challenges⁷. Increased quantity of waste is not only of plastic but also of paper, glass, board, non-ferrous metal, etc. The Ministry of Environment, Forest, and Climate Change's new rules on Extended Producer Responsibility (EPR) for paper, glass, metal, and sanitary products mark a pivotal step toward a truly circular economy². These rules are not just a regulatory mandate but an incredible opportunity for industries to rethink their approach to packaging sustainability.

In the recent past, businesses have shifted from plastics to alternatives like paper and glass, often driven by public belief rather than scientific evaluation of environmental impact⁸. New rules challenge that paradigm, urging the industry to select materials based on their life cycle impacts and proper use cases. By emphasising recycling, use of recycled content, and end-of-life disposal, the rules intend to ensure that the materials are used for their environmental benefits, not assumptions⁹.

Moreover, this initiative aligns with global efforts to reduce virgin resource extraction, create green jobs, and foster innovations in waste management¹⁰. It encourages producers, importers, and brand owners to take ownership of their packaging material from cradle to grave. The result? A harmonised approach that helps the environment, promotes resource conservation, and creates economic opportunities. This is a significant leap forward for India's sustainable development journey.

Unfortunately, EPR rules do not cover the problem in a holistic manner. The Rules are focused on the packaging industry based on the assumption of having paper, glass, metal used for the purpose of packaging but have ignored significant indirect uses in events and other industries. The unscientific notion of these materials being environment friendly leads to non-judicious consumption patterns⁸. The Rules have limited impact on Producer, Importer and Brand Owners who introduce packaging made from glass, metal and paper including paper board as well as sanitary products into the market².

The newly introduced Solid Waste Management Rules 2026 have a transformative approach to accelerate the pace of Waste Management in India by adopting a more responsive and scientific approach, overcoming existing ambiguities, increasing its scope and coverage, and defining stakeholders with more clarity¹. With the promulgation of new rules, all the stakeholders including rural or urban, private or public, residential, industrial, or commercial, religious or archaeological, transport or defence and likewise will have to follow the Solid Waste Management Rules 2026¹. The Rules have specifically defined roles and responsibilities for waste producers, bulk waste producers, local body, and/or the concessionaire/ third party authorised by the local body involved in collection, segregation and transportation of solid waste, entities involved in sorting of recyclable/ non-recyclable waste at a Material Recovery Facility (MRF), besides all other stakeholders, making everyone responsive towards managing waste³.

In the earlier rules, bulk waste generators were mentioned without proper definition¹. The new rules have elaborately defined Bulk Waste Generators (BWG) as entities, irrespective of their ownership or uses but with any one of the following criteria¹:

- Buildings with a floor area of 20,000 sqm or above.
- Daily water consumption of 5,000 litres or more.
- Daily solid waste generation of 100 kg or more

In this regard, one major compliance fulfilment expected from Bulk Waste Generators is to get Extended Generator Responsibility (EGR) Certificate from local authorities by adhering to compliance norms¹. This ensures accountability and promotes sustainable waste management practices. In compliance with Extended Bulk Waste Generator Responsibility (EBWGR), BWGs will be responsible to ensure proper segregation, storage, and management of waste. They will also handle:

- Segregation of waste into four streams: wet, dry, sanitary, and special care waste.
- On-site processing of wet waste through composting, bio-methanation, or other approved methods.
- Handing over segregated waste to authorised collectors

After these rules come into force on April 1, 2026, online registration of Bulk Waste Generators will be a mandatory requirement¹. Every BWG will have to get registered on a centralised online portal and submit periodical compliance reports to the concerned local bodies. That will enable better accountability, promote resource recovery and recycling along with reduction in dependency over landfill³.

The new rules have also made it mandatory for Industrial units using solid fuel to use Refuse-Derived Fuel (RDF), Solid Combustible Fraction (SCF), or agri-residue sourced from solid waste plants¹¹. These rules have provided the duties of Industrial Units located within specified distances from RDF plants to make arrangements to replace their conventional solid

fuel requirement with CPCB-approved combustible fractions¹¹.

A major step to achieve sustainable waste management is to minimise landfill requirement which means that the least possible should go to final disposal⁹. The Rules have made a provision for this by introduction of a landfill user fee. BWGs will have to pay landfill user fees for non-recyclable waste, thus incentivising efficient waste processing and segregation¹.

The first comprehensive rules were brought out in 2000 and have been modified since 2014⁴). Since then, waste management has taken front seat with the launch of the ambitious Swachh Bharat Mission (SBM) as the topmost priority of the government⁴. It has resulted in the largest Sanitation and Behavioural change programme in the world⁴. These efforts have brought sanitation, waste management from a neglected area to the priority agenda. Prior to this, waste management was the sole responsibility of the urban local bodies³.

The program which started on a Mission mode, has expanded its horizon to the micro level of waste management and as a result, by each passing day a new dimension is added to the Mission⁴. The journey of SBM began with its first aim as to improve coverage and usage of toilets both in public and private areas. Every year, SBM moves with a new thrust⁴. SBM is now not limited to just the Urban area but has expanded to every inhabited area. It has a focussed approach on all aspects like Knowledge, Attitude and Practice. Nowhere in the world, such organised and well monitored intervention has ever happened. SBM has been under implementation for over 11 years now with a dynamic approach having major emphasis on citizen feedback⁴.

After a decade long innovative and successful interventions, the focus has shifted to replicate the best practices adopted by various municipalities or cities. Over successive editions of Swachh Sarvekshan, several cities have consistently shown exceptional performance, sustained high citizen engagement and positive feedback, and resilient governance processes,

even in the face of leadership transitions and operational challenges⁵.

During the past, cities used to collaborate with Sister Cities found in industrialised or developed countries. The basis of collaboration used to be either similar culture, origin, or funding support besides unwritten aims. However, the benefits of the sister cities remained limited to some delegation exchanges or funding to set up some facility. It did not work proactively and continuously for the betterment of the cities.

The latest addition in this direction is introduction of an innovative step “Swachh Shahar Jodi” (SSJ) which is a mentorship initiative under the Swachh Bharat Mission-Urban where high-performing cities (“mentor” cities) will pair with lower-performing cities (“mentee” cities) to share best practices in sanitation and waste management¹³.

To make the programme more sensible, practical, and replicable; two cities of the same state with several shared challenges and culture are to pair. To scale the impact of the proven approaches adopted by India’s cleanest cities over the years, the Swachh Shahar Jodi now aims to institutionalise structured mentorship, peer learning, and collaborative action between mentor cities and mentee cities from within the same State. Launched by the Ministry of Housing and Urban Affairs (MoHUA) in September 2025, the program aims to improve urban cleanliness through collaborative, 100-day action plans and peer learning, with the goal of uplifting mentee cities’ performance in the Swachh Sarvekshan rankings¹³.

The objective of the scheme is to improve sanitation and waste management in urban areas by using the ability of successful cities to help struggling ones. The aim is to support comparatively low performing cities in improving their Swachhata performance by drawing on the experience of mentor cities.

As an outcome, the initiative looks to accelerate urban transformation by fostering direct city-to-city collaboration and sharing of best practices to enhance overall urban cleanliness.

Conclusion

To conclude, the Swachh Bharat Mission is not limited to cleanliness but is a firm step to achieve better health. It has been a major Public Health intervention with significant impact on the environment and social development⁴. This initiative has enabled local bodies to develop institutional framework towards sustainable development. The unique Swachhta Survekshan is for a multi-pronged impact to make the Swachh Bharat Mission successful with the active engagement of the community at large⁵. In an indirect impact, survekshan has contributed positively to gear up the local bodies to act more professionally. The entire process aims at continued action, replication, and visible impact.

References

- 1) Ministry of Environment, Forest and Climate Change. Draft Solid Waste Management Rules 2026.
- 2) Ministry of Environment, Forest and Climate Change. Extended Producer Responsibility Rules for Paper, Glass, Metal Packaging and Sanitary Products (2025).
- 3) Central Pollution Control Board. Implementation Status of Solid Waste Management Rules.
- 4) Swachh Bharat Mission. Programme guidelines and progress reports.
- 5) Swachh Survekshan. Annual sanitation survey reports.
- 6) World Bank. E-commerce growth and consumption patterns in developing economies.
- 7) United Nations Environment Programme. Global Waste Management Outlook.
- 8) Organisation for Economic Co-operation and Development. Extended Producer Responsibility: Policy Guidance.
- 9) European Environment Agency. Circular Economy and Waste Reduction Policies.
- 10) United Nations. Sustainable Development Goals – Resource Efficiency.
- 11) Central Pollution Control Board. Guidelines for Refuse Derived Fuel Utilisation.
- 12) Ministry of Housing and Urban Affairs. NAMASTE and Swachhata Mitra Suraksha Challenge guidelines.
- 13) Ministry of Housing and Urban Affairs. Swachh Shahar Jodi Mentorship Programme.

Urban trash disposal to be mechanised under solid waste management scheme of SUDA

A comprehensive and mechanised project aimed at segregating, processing and disposing off large quantities of garbage under the solid waste management scheme of the state urban development agency (SUDA) was inaugurated in Malda recently.

The project, estimated to cost around ₹8 crore, will be implemented by a Delhi-based private agency selected through the SUDA's tender process and address the longstanding issue of accumulated waste in the municipal dumping grounds of the town.

Under the project, waste segregation and processing will be carried out at four dumping sites - three under the English bazar Municipality and one under the Old Malda Municipality.

With the launch of the project, around 1,000 tonnes of accumulated waste can now be segregated and processed each day mechanically. With the processing machine capable of segregating and treating around 50 tonnes of waste per hour, processed waste can become the raw material to produce organic fertilisers, stone chips and plastic dust for road construction and other purposes.

Source: Excerpts from The Telegraph

Circular Recycling of Organic Kitchen Waste in Construction Labour Camps



Kousik Ahmed¹

Environmental Specialist



Md. Rucunuzzaman²

Deputy Project Director



Amit Kumar Chakrabarty³

Project Manager



Dr. S K Bagui⁴

Sr. QCME/ATL

^{1,4} ICT, IRD, Sheladia, ADSL, K S Consultants JV, ^{2,3} RHD, Dhaka, Bangladesh, Dhaka Sylhet Project, Dhaka, Bangladesh

Abstract

The National 3R Strategy of Bangladesh promotes a transition from disposal-oriented waste management to a resource-efficient circular economy. Construction labour camps associated with large infrastructure projects generate significant quantities of biodegradable kitchen waste, which, when unmanaged, contribute to methane emissions, sanitation risks, and environmental degradation. This study presents an empirical case analysis from the Panchrukhi and Shaheprotap construction labour camp under the SASEC Dhaka–Sylhet Corridor Project, where segregated organic kitchen waste is recycled as fish feed through a community-based model. Using an Intergovernmental Panel on Climate Change (IPCC) compliant life-cycle boundary focused on avoided methane emissions, the study quantifies environmental, economic, and policy outcomes. The results indicate that diversion of 73 t/year of organic waste avoids approximately 123 t CO₂-eq/year under conservative default factors. The intervention reduces project waste management costs by BDT 72,000 annually while generating an estimated BDT 3.10 million/year in feed value for local aquaculture. The model demonstrates consistency with Bangladesh's National 3R Strategy and Nationally

Determined Contribution (NDC), offering a scalable circular solution for infrastructure-linked temporary settlements.

Introduction

Rapid infrastructure development in Bangladesh has led to the establishment of large construction labour camps, which are recognised as concentrated sources of institutional solid waste, particularly biodegradable kitchen waste (World Bank, 2018)¹. Inadequate management of such waste often leads to open dumping, odour nuisance, vector breeding, and methane emissions, especially in temporary camp settings (UN-Habitat, 2010)². To address these challenges, the Government of Bangladesh adopted the National 3R Strategy for Waste Management, emphasising reduction, reuse, and recycling as pathways toward sustainable development (Government of Bangladesh, 2010)³. This study evaluates a recycling intervention implemented at the Panchrukhi and Shaheprotap construction labour camp (Contract LoT DS-02) under the South Asia Sub-regional Economic Corridor (SASEC) Dhaka–Sylhet Corridor Road Investment Project, where organic kitchen waste is utilised as fish feed. The practice is assessed against national

policy objectives, environmental sustainability, social viability, economic feasibility, and climate change mitigation outcomes. The initiative exemplifies industrial symbiosis, where waste from one system (labour camp kitchen) becomes a resource for another (local fishery), reducing environmental externalities and enhancing resource efficiency (Ghisellini et al., 2016)⁴. Furthermore, the strategy prioritises recycling over disposal within the waste hierarchy, making this practice a higher-order waste management option compared to open dumping or landfilling (Government of Bangladesh, 2010)³.

Literature Review

Wheat bran, soybean and peanut cake are often used as feed ingredients, but cornmeal, bread, noodles, flour and biscuits are also applied to ponds for feeding freshwater fish in South China including Hong Kong (Lau et al., 2003)⁵.

Fishmeal replacement with fermented organic wastes, as fermentation is a strong tool for reducing the unwanted microbial load from biodegradable organic wastes. This is discussed herein. During fermentation, the substrate's protein also gets hydrolysed, and low molecular weight (less than 10 KD) proteins (peptides and amino acids) are produced, some of which have immunomodulatory effects and render increased palatability and digestibility in animals. Therefore, fermentation of protein resources probably enhances health parameters of fish (Kader et al. 2012)⁶. Fermented biodegradable organic wastes have been successfully used by several workers to replace Fish Meal (FM) in aquaculture feed formulation. Fermentation of organic wastes generated from fish industries and their recycling through aquaculture is gaining importance. A fermented fish-offal containing diet was able to replace 30% of Fish Meal.

The Lambung Village Community has a program to utilise organic waste in order to reduce environmental pollution. So far, utilisation of organic waste has been carried out only for making compost. However, it is expected that there will be a variety of products from the organic waste processing as raw material i.e. fish

feed could be used by fish farmers in Lambung Village (Mo et al. 2017)⁷.

Limited studies have evaluated decentralised organic waste recycling within temporary construction settlements in developing countries.

Summary of Literature Review

A limited literature review showed the following:

- Wheat bran, soybean and peanut cake are often used as feed ingredients;
- Corn meal, bread, noodles, flour and biscuits are also applied to ponds for feeding;
- Fermented organic wastes may be used for feeding fish; and
- A variety of products from organic waste processing are raw material for fish feed.

Objective and Scope of Present Study

Objectives

The primary objective of this study is to assess the techno-economic and environmental feasibility of recycling kitchen waste into aquaculture feed within construction labour camps. The main task of this present study is to determine if recycling kitchen waste into fish feed is a viable reality from Bangladesh's construction labour camps' organic waste, by adopting 5 actions as follows:

- Quantify organic waste generation;
- Evaluate the economic impacts of recycling waste as aquaculture feed;
- Estimate greenhouse gas mitigation using IPCC-compliant methodology;
- Assess alignment with Bangladesh's 3R Strategy and NDC framework; and
- Develop a scalable implementation framework for infrastructure projects.

Scope of the Study

This research focuses specifically on labour camps tied to medium-to-large infrastructure projects across Bangladesh. This study covers daily waste

generation rates, current disposal habits, pilot-scale feed production modelling, and the environmental/economic indicators of success. The brief scope of the present study is:

- Segregation of daily wastage from the Contractor's temporary camps;
- Collection of wastage for fish feeding material in production unit; and
- Convert these wastages to fish feeding, and
- Dispatch fish feeding to pond.

While the data is collected from specific sites in Bangladesh, the resulting framework is designed to be scalable and replicable for infrastructure projects nationwide.

Methodology

This study adopts a case-based analytical approach using primary site data collected from the Panchrukhi and Shaheprotap construction labour camps, including a number of labour sheds, kitchens, workforce size, and daily organic waste generation. Waste generation rates were estimated using standard per-capita organic waste coefficients for institutional facilities in Bangladesh. The Economic Analysis compares baseline waste disposal costs with post-recycling costs and estimates feed cost savings using prevailing fish feed market prices. Greenhouse Gas Emission reductions were calculated following the IPCC (2006)⁸ Guidelines for National Greenhouse Gas Inventories with the 2019 Refinement, applying default methane generation and oxidation factors. An oxidation factor of zero was assumed, consistent with unmanaged disposal conditions in a developing country. The system boundary includes organic waste generation, diversion, and avoided methane emissions from unmanaged disposal. Downstream emissions from feed processing and transport were also excluded.

The results are presented as per the Asian Development Bank's (ADB) climate co-benefit reporting requirements. The Study Methodology is shown in Figure 1. Typical photographs of waste collections are shown in Figure 2 and Figure 3. Photographs of fish

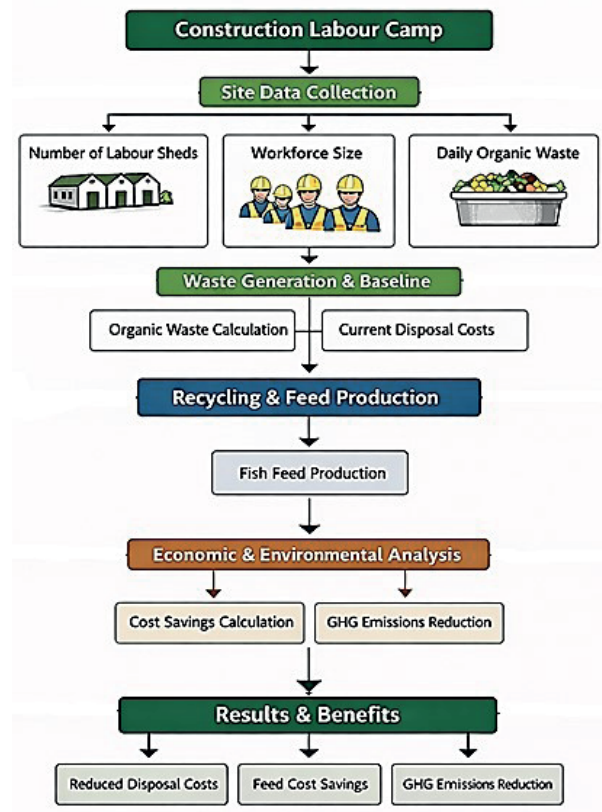


Figure 1: Study Methodology

meal provided at the pond by a local farmer are shown in Figure 4. A comparison between baseline vs current improved waste was carried out as per ADB Guidelines and is presented in Table 1.



Figure 2: Segregated Organic Waste at the Kitchen



Figure 3: Collection by local fish farmer



Figure 4: Fish meal is being provided at the pond by a local farmer



Table 1: Comparative Evaluation of Organic Waste Management Practices

Sl. no.	Parameter	Baseline Condition	Current Condition (Recycling Practice)
1	Waste segregation	No	Yes (at source)
2	Waste type handled	Mixed waste	Organic waste only
3	Collection system	Contractor-based	Community-based
4	Disposal method	Open dumping/ landfill	Recycling as fish feed
5	Monthly management cost	High	Low
6	Environmental risk	High	Low
7	Green House Gas (GHG) emissions	Methane generation	Methane generation avoided
8	Community involvement	None	Active
9	Policy compliance	Low	High (National 3R Strategy)

Results and Analysis

Site Profile and Waste Generation

The project road with a total length of approximately 17 km under Contract Package DS-2 starts from Design Chainage 18+000 at Sonpara Bus Stand to Chainage 35+000 near the BSCIC Industrial Area in Narsingdi,

which is a major industrial zone along this route. The works include the complete reconstruction of the existing road over the stretch. One of the important intersections, Shaheprotap Roundabout, lies at about Chainage 30+100. The Location Map is shown in Figure 5.

Project Area: Geographically, the project area is situated in the Dhaka Division and passes through two districts: Narayanganj District and Narsingdi District. It passes mainly through rural areas, besides some urban and semi-urban growth points in Narayanganj and Narsingdi districts. It is marked by a combination of natural and man-made environments. There are many water bodies such as ponds, small rivers, tributaries, distributaries, streams, and canals, situated adjacent to or in the vicinity of the road. Besides, there are some socio-cultural and community facilities like mosques, schools, colleges, educational institutions, medical facilities, hospitals, and training institutes situated in the project influence area.

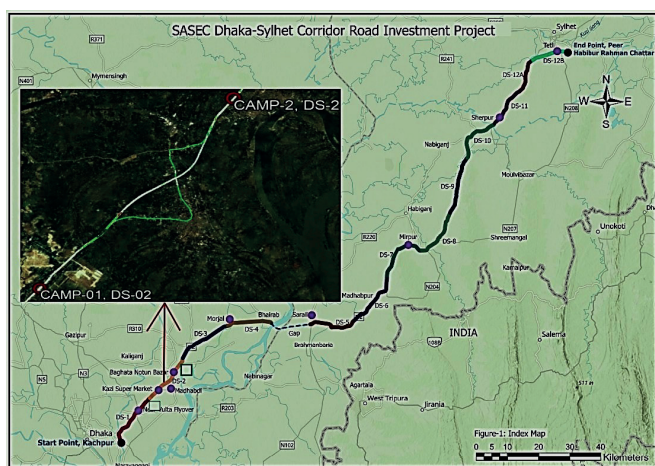


Figure 5: Location of the study area.

The construction labour camp established at two camp sites (Panchrukhi & Shaheprotap) accommodate approximately 1000 workers in 20 labour sheds and Engineers accommodation, supported by ten kitchens. Using an average organic waste generation rate of 0.2 kg/person/day, the camp produces approximately 200 kg of organic kitchen waste daily, equivalent to 73 tonnes annually. Under the improved system, waste is segregated at source and collected daily by local fish farmers for use as feed.

Daily organic waste generated: $1000 \text{ persons} \times 0.2 \text{ kg} = 200 \text{ kg/day}$

Annual organic waste diverted: $200 \text{ kg/day} \times 365 \text{ days} = 73.0 \text{ tons/year}$.

Economic Performance

The recovered organic fraction is assumed to partially substitute commercial grower feed (24–28% protein floating pellets), commonly priced at BDT 45–60/kg in Bangladesh. A conservative market-equivalent value of BDT 50/kg was adopted for valuation purposes. The direct nutritional equivalence was not laboratory verified; therefore, the estimated benefit reflects replacement value rather than exact nutrient substitution.

Prior to recycling, monthly waste management (organic waste) costs averaged BDT 10,000 due to collection, transportation, and disposal. Following the implementation of segregation and community-based recycling, the costs reduced to approximately BDT 4,000 per month, generating savings of BDT 6,000 per month. For fish farmers, the recovered waste replaces commercial feed valued at approximately BDT 50/kg, yielding feed cost savings of about BDT 300,000 per month.

Economic Benefit to Local Fish Farmers

Organic waste received from the labour camp kitchens averages **200 kg/day**. However, not all collected material is suitable for direct use as fish feed due to unavoidable processing losses. These losses arise due to:

- Removal of non-biodegradable contaminants (plastic fragments, packaging residues, etc.),
- Excess moisture reduction during sun-drying or fermentation,
- Sorting out inedible components (bones, large fibrous peels, spoiled fractions), and
- Handling and storage losses.

Based on field observations and comparable decentralised organic waste processing studies, a **15% material loss factor** is conservatively applied.

Therefore, the usable organic waste collected for fish feed $= 200 \text{ kg/day} \times (1 - 0.15) = \mathbf{170 \text{ kg/day}}$.

Realistic fish feed market price (Bangladesh): BDT 50/kg,

Equivalent feed value: $170 \times 50 = \text{BDT } 8500/\text{day} \approx \text{BDT } 255,000/\text{month}$.

Annual value: $8500 \times 365 = \text{BDT } 3,102,500/\text{year}$.

The feed costs, which typically account for 50–60% of aquaculture operational expenses, are reduced significantly.

Sensitivity Analysis

Waste generation rates in construction labour camps may vary due to changes in workforce size, food consumption patterns, kitchen management efficiency, and seasonal factors. To assess the robustness of the recycling intervention, a sensitivity analysis was conducted using low, base, and high organic waste generation scenarios. The analysis evaluates the implications for waste diversion, economic benefits, and Green House Gas (GHG) mitigation using conservative IPCC default factors. A sensitivity analysis was conducted to assess the robustness of emission reduction outcomes under varying per capita organic waste generation rates ($\pm 25\%$ from the base estimate of 0.20 kg/person/day). Under the conservative low-waste scenario (0.15 kg/person/day), annual waste diversion equals 54.75 t/year, resulting in approximately 92 tCO₂-eq/year of avoided emissions. Under the higher waste generation scenario (0.25 kg/person/day), annual diversion increases to 91.25 t/year, yielding approximately 153 tCO₂-eq/year of avoided emissions. These results demonstrate that the climate mitigation performance of the intervention remains substantial across plausible variability ranges in waste generation. Sensitivity Analysis of the economic benefits is presented in Table 2.

Table 2: Economic Benefits under Different Scenarios

Scenario	Feed Value (BDT/month)	Annual Community Benefit (BDT/year)
Low	225,000	2,737,500
Base	300,000	3,650,000
High	375,000	4,562,500

a) Sensitivity Interpretation

The sensitivity analysis indicates that the recycling intervention remains economically viable and environmentally beneficial across all scenarios. Even under conservative low-waste conditions, the system avoids approximately 123.0 tCO₂-eq/year, while providing substantial cost savings and community income. Under high-waste conditions, both economic and climate benefits increase proportionally, demonstrating the scalability of the intervention. Significantly, no scenario results in increased environmental risk or negative economic performance, confirming the robustness of the recycling model.

Waste Diversion: Even under the most conservative “Low” scenario, a single camp of 1000 people can divert over 73 tons of organic waste from landfills annually.

Economic Impact: The circular model generates a significant local economic value, ranging from BDT 3.19 million to BDT 4.56 million per year in fish feed value.

Climate Action: By preventing the anaerobic decomposition of kitchen waste, the project can mitigate between 45.9 tons and 73.6 tons of CO₂ equivalent per year, directly contributing to Bangladesh’s NDC commitments.

b) Policy and Implementation Implications

The results suggest that:

- The intervention is resilient to operational variability.
- Higher waste generation enhances climate and economic benefits without additional infrastructure.
- Conservative assumptions ensure no over-estimation of GHG co-benefits, consistent with ADB and IPCC guidance.

Climate Change Mitigation

Methane emissions were estimated using a Tier 1 simplified emission factor approach consistent with the

2006 IPCC Guidelines for National Greenhouse Gas Inventories and the 2019 Refinement (Volume 5: Waste). For unmanaged disposal sites in developing countries, a default methane generation potential equivalent to 0.06 t CH₄ per ton of wet organic waste was applied. This factor implicitly reflects default Degradable Organic Carbon (DOC), Methane Correction Factor (MCF), fraction of methane in landfill gas (F), and oxidation factor (OX = 0). Global Warming Potential (GWP) of methane was adopted as 28 (IPCC AR5).

For climate accounting, methane avoidance is calculated based on total organic waste diverted from unmanaged disposal (73 t/year), while economic valuation applies a conservative 15% preprocessing loss to account for sorting and moisture reduction.

Diverting 73.00 tons of organic waste annually avoids anaerobic decomposition and methane generation. Using IPCC (2006) default methane generation factors with AR5 GWP values:

$$\text{Methane avoided} = 73.00 \times 0.06 = 4.38 \text{ t CH}_4/\text{year}$$

$$\text{GHG reduction} = 4.38 \times 28 = \approx 123 \text{ tCO}_2\text{-eq/year.}$$

The summarised climate change benefits are shown in Table 3, and the Indicator Parameters are shown in Table 4.

Table 3: Climate Change Mitigation Co-Benefit Assessment

Parameter	Value
Organic waste diverted	73.00 t/year
Methane generation factor (IPCC default)	0.06 t CH ₄ /t waste
Methane avoided (73.0×0.06)	4.38 t CH ₄ /year
Global Warming Potential (CH ₄ , AR5)	28
GHG reduction (4.38 ×28)	≈ 123 tCO ₂ -eq/year

Assumption: Avoided open dumping and anaerobic degradation of organic waste.

Table 4: Summary of Indicator and Value

Sl. No.	Indicator	Value
1	Workforce	1000 persons
2	Organic waste generated	200 kg/day
3	Annual waste diverted	73.0 t/year
4	Usable feed fraction (85%)	170 kg/day
5	Annual usable feed	62.05 t/year
6	Community feed value	BDT 3.10 million/year
7	Project cost saving	BDT 72,000/year
8	Methane avoided	4.38 t CH ₄ /year
9	GHG reduction	≈ 123 tCO ₂ -eq/year

Environmental and Social Benefits

Recycling organic waste reduces unmanaged organic disposal by 73 t/year, reduces odour, prevents vector breeding, and improves sanitation within the labour camp, contributing to improved public health (UN-Habitat, 2010)³. Community involvement through local fish farmers strengthens public–private–community partnerships and enhances social acceptance of waste management interventions (UNEP, 2013)⁴.

Discussion

The findings demonstrate that recycling organic kitchen waste as fish feed operationalises key principles of the National 3R Strategy, including waste-as-resource, recycling prioritisation, and community participation. The initiative also exemplifies industrial symbiosis and circular economy approaches by linking construction activities with local aquaculture systems. Compared to conventional disposal practices, the intervention offers superior environmental performance, social acceptance, and economic efficiency.

Study Limitations

This study applies a Tier 1 IPCC methodology using default methane generation factors, which may not fully reflect site-specific degradable organic

carbon content or landfill management conditions. Nutritional equivalence of recycled kitchen waste to commercial aquaculture feed was not laboratory-tested; therefore, economic valuation assumes market-equivalent substitution rather than measured feed conversion performance. Transportation emissions and potential emissions from feed processing (drying/fermentation) were not included, rendering the GHG results conservative but partial. Future research should incorporate laboratory feed analysis, Tier 2 waste characterisation, and full life-cycle assessment.

Conclusion

The recycling of organic kitchen waste from the Panchrukhi and Shaheprotap construction labour camp as fish feed represents a technically feasible, economically viable, and environmentally sustainable application of the National 3R Strategy. The initiative delivers measurable cost savings, strengthens community livelihoods, and provides significant climate mitigation benefits. The findings suggest that decentralised organic waste recycling in construction labour camps offers measurable environmental and economic benefits and may be adaptable to other construction projects in Bangladesh and similar developing and developed country settings, subject to site-specific feasibility conditions. Based on the present study following conclusions may be drawn:

- Waste segregation, handling, collection, disposal saving, environmental risk, GHG emissions, etc. mentioned in Table 1 are very important parameters and should be used;
- Site-specific waste generation, economic parameters, economic performance and sensitivity analysis as shown in this present study, are useful aspects and should be considered for analysis;

- Benefit and sensitivity analysis of local fish farmers will be helpful to engage fish farmers in recycling kitchen organic waste; and
- Methane generation, methane avoided, global warming potential and GHG reduction contribute to climate change mitigation, including environmental and social benefits for the society.

References

- 1) World Bank. (2018). *What a waste 2.0: A global snapshot of solid waste management to 2050*. World Bank.
- 2) UN-Habitat. (2010). *Solid waste management in the world's cities*. Earthscan
- 3) Government of Bangladesh. (2010). *National 3R strategy for waste management*. Ministry of Environment and Forests.
- 4) Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, 114, 11–32.
- 5) Lau TSK, Lee JCW, Young L (2003). Pilot Project to Raise Awareness of the Ecological Importance of Pond-fish Farming in the Mai Po Inner Deep Bay Ramsar Site. World Wide Fund for Nature Hong Kong.
- 6) Kader A, Shunsuke K, Manabu I, Saichiro Y, Mahbuba B, Nguyen B, et al. Can fermented soybean meal and squid by-product blend be used as fishmeal replacements for Japanese Flounder (*Paralichthys olivaceus*). *Aquaculture Research*. 2012; 43:1427-1438.
- 7) Mo Y M, Man Y B, Wong M H 2017 *Journal Science of the Total Environment* 613 635-643.
- 8) IPCC. (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. IPCC.



Umesh Shrivastava
Executive Chairman
Holtec Consultants Pvt Ltd.

Ethics and Integrity in Engineering Consultancy

Engineering consultancy is a profession founded on trust. Clients entrust consultants with decisions involving large investments, public safety & security, robustness, environmental impact, and societal consequences so that they are built fit for the purpose intended and for their design service life albeit with regular maintenance. Bridges, power plants, cement factories, and other industrial facilities, as well as water systems, etc., designed by Consultants shape and influence the quality of human life. In such a context, apart from technical competence, what distinguishes a true professional organisation from a mere service provider are its commitments to ethics and integrity.

Ethics provides the framework of what is right and acceptable behaviour, while integrity ensures consistent adherence to those ethical principles even under pressure. In engineering consultancy, where commercial interests, competitive pressures, and other influences often come in conflict with professional judgment, ethics and integrity act as the moral compass.

Definitions of Ethics and Integrity

1 Ethics

Ethics refers to a set of moral principles or values that govern conduct. In a professional context, ethics defines what is considered fair and acceptable behaviour within a particular profession.

For engineering consultants, ethics involves:

- Acting in the best interest of society and the client
- Ensuring safety, quality, and sustainability
- Maintaining honesty in reporting and advice
- Avoiding conflicts of interest
- Respecting confidentiality, and
- Rejecting bribery, favouritism, and misrepresentation.

Professional bodies worldwide codify these principles into codes of ethics, providing guidance to professional conduct.

“Codes of ethics are not paperwork –they are safety systems for society”

2. Integrity

Integrity is the quality of being honest and having strong moral principles consistently in action. While ethics tells one what is right, integrity establishes whether one actually does it.

Integrity means:

- Doing the right thing even when it is difficult or costly
- Standing by professional judgment despite pressure

- Being truthful in communication and documentation
- Aligning actions with declared values, and
- Maintaining consistency between words and deeds.

In simple terms, ethics is the rulebook; integrity is the discipline to follow it.

“Without Integrity, skill becomes a liability”

Connection between Ethics and Integrity

Ethics and integrity are inseparable. Ethics without integrity becomes theoretical and hollow; integrity without ethics lacks direction. Ethics defines standards of right and wrong. Integrity ensures adherence to those standards in practice.

In engineering consultancy:

An ethical code may prohibit falsifying reports. Integrity ensures the engineer refuses to alter data even if the management or the clients demand it. Thus, ethics provides the moral map, while integrity is the moral engine that keeps the organisation moving along the right route on that map. Or in simple terms, ‘**Ethics = Rule Book**’ and ‘**Integrity = Inner compass**’. Together, they build credibility, trust, and professional honour.

Basic Tenets of Ethics and Integrity in Engineering Consultancy

The following core principles form the backbone of ethical engineering consultancy:

1 Responsibility to Society

Public safety, health, and welfare are paramount. Designs and recommendations must never compromise safety, security and robustness for cost or speed.

2 Competence

Continuous professional development is an ethical obligation. Accept only work within one’s domain of expertise.

3 Honesty and Truthfulness

Drawings, cost estimates, and performance data and reports must reflect reality.

4 Independence and Objectivity

Advice must be technically sound, unbiased and free from hidden financial or other influences.

5 Fairness and Impartiality

Treat clients, employees, suppliers, and competitors fairly. Avoid discrimination and favouritism.

6 Confidentiality

Protect client information except when disclosure is required by law or public safety concerns.

7 Transparency

Decisions, pricing and contractual arrangements should be open and justifiable.

8 Accountability

Accept responsibility for decisions and outcomes rather than shifting blame.

9 Respect for Environment

Design and advise with due consideration to environmental protection and sustainability.

10 Respect for the Profession

Avoid conduct that discredits the profession, such as bribery, plagiarism, or misrepresentation of credentials.

How can an Engineering Consultancy Company be Judged Ethical or Unethical?

Ethical judgment rests on consistent patterns of action, not isolated incidents. An organisation’s ethical character is revealed not by slogans but by behaviour.

1 Some Indicators of an Ethical Organisation:

- Has a written and enforced code of ethics
- Refuses unsafe or technically unsound projects
- Provides honest opinions even if unwelcome
- Encourages whistle-blowing without fear
- Pays fair wages and respects labour laws
- Avoids bribery and kickbacks, and
- Chooses long-term reputation over short-term profit.

2 Some Indicators of an Unethical Organisation:

- Alters technical data to please clients
- Uses bribery to secure contracts
- Exploits employees
- Neglects safety and environmental standards
- Treats compliance as a burden rather than a duty

- Project failures
- Demoralised staff, high attrition
- Loss of reputation
- Legal penalties
- Public harm and social distrust, and
- Blacklisting by clients

Unethical behaviour is thus economically and morally unsustainable.

Being Ethical or Unethical

1 Advantages of Being Ethical:

- Reputation and Trust - Trust is the most valuable asset of consultancy firms. They attract serious clients and repeat business.
- Sustainable growth
- Employee loyalty and pride
- Staff feel proud to work in principled organisations, reducing attrition and improving productivity.
- Build stability and resilience.
- Ethical behaviour minimises legal, financial, and reputation risks.
- Better decision-making
- Long- term profitability
- Help build safe infrastructure and responsible industry and
- Contribution to society

2 Implications of Being Unethical:

Unethical behaviour may lead to:

- Some faster contract awards
- Lower apparent costs
- Higher short-term margins

Conclusion

An organisation mentored by ethics and integrity becomes not merely a commercial entity but a respected and coveted institution. Engineering consultancy, more than most professions, shapes industrial productivity, public safety and environmental sustainability. When consultants act unethically, the consequences can be catastrophic - unsafe structures, environmental degradation and damage, wasted public funds, and depletion of trust.

Conversely, when organisations solemnly resolve to abide by ethical principles, they create workplaces of confidence, dignity and mutual respect. Clients feel assured, employees feel secure, and society benefits from worthy engineering solutions. Such organisations may face short-term handicaps or losses but they earn long-term stability, influence and honour.

“Ethics = The Rule-book”

“Integrity = The Inner Compass”

A future, where more and more engineering consultancy firms embrace ethics and integrity is not only desirable but necessary. It will create a happier place - professionally and socially - when success is measured not only by profits but by principles, ethics and integrity.

CEAI NEWS

❖ CEAI ACADEMY

Intensive Online Training Course on “Detailed Project Report (DPR) Preparation”

To address the rising demand for high-quality infrastructure in India’s highway sector, an **Intensive Online Training Course on “Detailed Project Report (DPR) Preparation”** was conducted from 10th of January, 2026 to 21st of March, 2026.

The intent was to shift the focus from simple documentation to a multidisciplinary, lifecycle-driven decision-making process to minimise cost overruns, safety hazards, and execution delays.

Spanning eleven instructional days, the curriculum provided a comprehensive exploration of technical, financial, and environmental modules led by industry experts.

KEY MODULES AND CONTENT OVERVIEW

Module	Core Topics Covered	Key Focus/Outcome
DPR Architecture	Scope definition, task sequencing, team roles, client oversight	Establishing structured DPR workflow and responsibilities
Bridge Design & Document Control	Bridge siting, span arrangement, General Arrangement Drawings (GAD), loading, structural behavior, document revision	Ensuring technical integrity, traceability, and contractual clarity in bridge design and documentation
Geometrical Design of Highways	Design standards, cross-section, alignments, superelevation, interchanges, quantity estimation, 3D design, BIM tools	Linking geometric design with safety, constructability, and operational efficiency
Hydraulic & Hydrological Investigations	River/catchment studies, rainfall/storm analysis, flood discharge estimation, scour depth	Designing hydraulically safe bridges and cross-drainage structures under extreme conditions
Climate Change Risks & Infrastructure Resilience	Climate risk types (acute, chronic, transition), adaptation measures, global frameworks (Paris Agreement, NDCs), resilience planning	Integrating climate risk assessment and infrastructure resilience into highway projects
Pavement Condition, Materials & Sub-Soil Investigations	Pavement surveys (NSV, FWD, IRI), subgrade evaluation, alternative materials, bituminous & concrete mix design	Promoting resource-efficient, performance-based pavement solutions
Geotechnical Investigations & Engineering Assessment	Soil/rock properties, liquefaction potential, embankment design, slope stability, foundation systems	Linking geotechnical data to safe, durable structural design
Topography Survey & Data Collection	DGPS, traverse stations, Total Station, levelling, mobile/aerial LiDAR, drone photogrammetry	Accurate base plans for alignment, land acquisition, and quantity estimation
Preconstruction Activities & Statutory Clearances	Land acquisition planning, Environmental Impact Assessment, forest/wildlife/CRZ clearances, social screening, R&R	Early integration of regulatory and social factors to reduce execution risks
Design of Flexible Pavement	Pavement types, load distribution, IRC:37-2018 design approaches, traffic loading, lifecycle cost, overlay design	Durable, reliable, and economically optimized pavement design
Design of Rigid Pavement	IRC:58 and IRC:118 (CRCP) design, IITPAVE software, thin/ultra-thin white topping, composite systems	Emphasizing structural performance and long-term durability
Quality Assurance	Review of inception, alignment, feasibility, DPR reports; consistency checks across documents	Ensuring technical accuracy and implementation readiness
Road Safety Engineering & Allied Measures	Safe System Approach, intersection design, signage, crash barriers, traffic calming, highway lighting, amenities	Embedding safety in highway design and operations
Project Costing & Contract Preparation	Quantity estimation, rate analysis, cost estimation, bid documents, contract models (item-rate, EPC, HAM)	Translating technical designs into commercially viable along with documentation
Economic & Financial Analysis; Innovative Technologies	Economic evaluation (HDM-IV), financial modelling, emerging materials (HiMA mixes)	Linking engineering decisions with investment viability; promoting innovation for durability

KEY INSIGHTS AND OUTCOMES

*

The course **repositioned DPR preparation** as a **multidisciplinary, lifecycle-driven process**, crucial for project success.

*

Strong emphasis was placed on **technical rigor, document control, and traceability** to improve DPR defensibility.

*

Integration of **climate change risk assessment and infrastructure resilience** reflects evolving sector priorities.

*

Use of modern tools such as **3D design, BIM, drone photogrammetry**, and software like **IITPAVE** highlights technology adoption.

*

Addressing **regulatory, social, and environmental clearances upfront** aims to reduce project execution risks.

*

The curriculum balanced **technical design principles with financial and contractual clarity** to ensure project viability.

*

Participant feedback showed **enhanced knowledge, clarity, and confidence** in DPR structuring and application.

*

The program reinforced CEAI Academy's role as a **credible platform for practice-oriented continuing education**, especially in bridge engineering.

*

Active technical engagement and Q&A sessions strengthened understanding of **codal interpretations and real-world applications**.

CONCLUSION

The course addressed key industry challenges and promoted **higher professional standards, accountability for technically robust infrastructure development** in India's highway sector. The comprehensive training program successfully advanced foundational competencies in DPR preparation for highway projects, aligning technical, financial, environmental, and safety aspects within a structured lifecycle framework.

The course's design and delivery positions CEAI Academy as a model for sustained, high-impact professional education in infrastructure engineering.

Soft Skill Training

A full-day Professional Development Workshop on “**The Professional Toolkit: Mastering Communication, Email Etiquette & Interpersonal Mastery**” was held at the CEAI Centre on 20th February 2026.

It was a departure from programmes centred on codes, standards, or calculations. The workshop addressed a capability equally critical to consulting engineering practice: professional communication.

In consulting engineering, technical competence is taken for granted, however, what differentiates professionals, and organisations, is the ability to articulate complex ideas with clarity, manage disagreements constructively, align multidisciplinary teams under pressure, and take ownership beyond defined roles. In an ecosystem involving clients, contractors, regulators, and cross-functional teams, communication failures often cost more than technical errors.

The structured agenda moved progressively from fundamentals to applied scenarios. The morning sessions focused on effective communication. Topics related to verbal, non-verbal, and written communication, along with active listening and questioning techniques, were covered. Participants examined common communication barriers in engineering environments and strategies to overcome them.



The email etiquette module addressed a persistent professional gap. Participants were instructed on how to structure clear, precise, and accountable written communication. Discussions centred on tone, clarity, drafting discipline, and handling difficult

email situations without escalation. In project-driven environments, documentation is both operational and legal; clarity is not optional.

Post-lunch sessions transitioned to interpersonal mastery and workplace dynamics. Rapport-building, empathy, and emotional intelligence were explored not as abstract “soft skills,” but as performance enablers in collaborative engineering settings.

The day concluded with role plays and practical exercises that simulated real-world scenarios, email drafting, conflict conversations, and collaborative problem-solving, followed by structured reflection and Q&A.

What stood out throughout the programme was the seriousness with which participants engaged. The discussions reflected lived workplace realities. There were conversations around site pressures, client expectations, escalation risks, and internal alignment challenges. The session was treated not as a “soft skills” intervention, but as a performance and leadership conversation.

Since the future of engineering leadership lies at the intersection of competence and communication, CEAI Academy reinforces its commitment to strengthening not only technical capability but also professional maturity across the consulting engineering fraternity.



CEAI Academy extends its gratitude to Ms VijayShri Attri for delivering an engaging and thought-provoking workshop that connected communication practice directly to professional credibility and project outcomes.

Campus to Corporate: A Practical Career Readiness Masterclass

As part of the MOU with Maharaja Agrasen Institute of Technology (MAIT), the CEAI Academy conducted a “Campus to Corporate: A Practical Career Readiness Masterclass” at the Maharaja Agrasen Technical Education Society (MATES), for Engineering students, to help bridge the gap between academic learning and professional expectations.

It was a four-hour intensive, in-person workshop, which addressed key aspects of employability including resume building, structured job search strategies, interview preparation, salary negotiation awareness, and understanding workplace dynamics.

Through instructor-led sessions, case simulations, and guided activities, the programme equipped participants with practical tools to present their value effectively to recruiters, navigate the job market strategically, and develop the professional awareness required to succeed in early career roles.

❖ CEAI EVENTS

Webinar: Constructing Integrity – Safeguarding Infrastructure Projects from Resume Fraud

Webinar on “*Constructing Integrity: Safeguarding Infrastructure Projects from Resume Fraud*” was organised on 11 March 2026 as part of its Webinar Series on “*Ethics & Integrity*”. The session focused on understanding the risks associated with resume fraud in infrastructure projects and its impact on quality, ethics, and compliance in the engineering and construction industry.

The webinar was conducted as **Part 1 – Understanding the Risk Landscape**. The session focused on three key aspects:

- Industry perspective on CV fraud
- Impact of fraudulent credentials on project quality and ethics
- Contractual and compliance risks arising from misrepresentation of qualifications and experience

The session speakers were **Mr. Alok Bhowmick**, Managing Director, B&S Engineering Consultants Pvt Ltd and **Mr. Deepak Kumar**, Senior Ethics & Compliance Professional at SYSTRA India.

The webinar was moderated by **Ms. Rasna Kame**, Marketing & Engagement Consultant at SYSTRA India.

The presentation highlighted the growing issue of **resume/CV fraud** in infrastructure and engineering projects, where professionals falsify qualifications, experience, or credentials to secure roles in large projects. While resume discrepancies are common globally but in India the industry reports show that a significant percentage of candidates misrepresent information in their resumes. In infrastructure and donor-funded projects, such fraud can have serious consequences because **key experts’ qualifications directly affect project quality, safety, and funding compliance**.

The presentation also outlined **legal and regulatory implications in India**, including provisions under the **Indian Penal Code (IPC)** related to forgery and the use of fake documents. It further referenced **Government Procurement Rules (GFR 2017)** that allow bid rejection, contract termination, and blacklisting when false declarations are discovered.

The presentation also discussed **Common Fraud Schemes**, such as:

- Substituting key experts after winning a bid
- Using “ghost experts” who are listed but never deployed

These practices create **contractual, financial, and reputational risks** for project owners, consultants, and funding agencies.

Finally, the presentation highlighted **emerging risks from AI-assisted resume fabrication**, predicting a rise in fake or exaggerated candidate profiles in the coming years.

❖ MEMBER NEWS

- Dr Harshavardhan Subbarao, CEAI GC Member was honoured with the S B Joshi Memorial Award. The S B Joshi Memorial Award is one of the most prestigious honours in Indian Bridge and Structural Engineering.
- Mr Alok Bhowmick, CEAI Vice President was selected as the recipient of the second S D Limaye Award for Excellence in Structural Engineering. This prestigious recognition is a testament to outstanding professional contributions, technical expertise, and sustained commitment to excellence in structural engineering.
- Mr Indranil Aich, CEAI Member was elected as a Senior Individual Member of INAE (Indian National Academy of Engineering), the most prestigious autonomous body under the Ministry of Science & Technology.

❖ OTHER NEWS

The 2nd Edition of the *India Rail 2026* Conference was held on 9th and 10th February 2026 at Hotel Le Meridien. CEAI was the Endorsement Partner for the conference. Mr Prashant Kapila, President CEAI made a presentation on “*The Role of Engineers in Developing Public Infrastructure - The Way Forward*”. Mr. Arvinder Brara, GC Member, CEAI and Mr Rajiv Maini, Director, CEAI also attended the conference.



*Mr Prashant Kapila, President CEAI
at India Rail 2026*



*CEAI was Endorsement Partner for the
Conference on India Rail 2026*

❖ FORTHCOMING PROGRAMMES

CEAI Academy's Upcoming Capacity-Building Programmes

Over the next quarter, the CEAI Academy has planned a series of targeted training programmes, workshops, and knowledge sessions designed to strengthen professional competencies across the consulting engineering ecosystem. These initiatives are being organised across multiple regional centres as well as through online platforms, ensuring wider accessibility for professionals, young engineers, and allied stakeholders in the infrastructure sector. The programmes are:

- a) A precursor webinar to a future programme on **Project Management Professional (PMP) Training Programme** scheduled for 14th April 2026. The webinar will give a glimpse into how the programme can help participants solve real life project challenges, and how they can benefit from a PMP certification in their career.
- b) A **Capacity Building Series on Sustainable & Low Carbon Built Environment**, scheduled for 17-18 April 2026 at the PHD Chamber of Commerce and Industry, New Delhi. As sustainability and climate considerations become central to infrastructure planning and design, the

programme will explore approaches to integrating low-carbon strategies into the built environment. It will focus on emerging technologies, regulatory expectations, and practical implementation pathways relevant to consulting engineers and project stakeholders.

- c) **Primavera Training in New Delhi on 24–25 April 2026**, aimed at professionals seeking to strengthen their project design, planning and scheduling capabilities using Primavera tools.
- d) **A one-day workshop on ‘From Tender to Completion: Essential Knowledge for Infrastructure Professionals in North India’**, to be hosted by CEAI Northern Region in **Chandigarh on 8th May 2026**. The workshop will focus on legal frameworks relevant to construction and infrastructure projects. The sessions will cover contractual obligations, dispute resolution mechanisms, and risk mitigation strategies. The program aims to offer valuable insights for professionals engaged in project management and consulting engineering.
- e) **An online Precursor Webinar on AI Training Workshop, being hosted by CEAI Southern Region, on 8th May 2026**, introducing participants to the growing role of artificial intelligence in engineering, project management, and infrastructure planning. The webinar will provide a conceptual overview ahead of a more detailed AI-focused training programme planned later in the year.

Other programmes being planned are as follows:

- a) **May 2026 - CEAI Academy plans FIDIC Training in New Delhi**, focusing on the interpretation and practical application of FIDIC contract frameworks widely used in international infrastructure projects. The training will help professionals understand contractual responsibilities, claims management, and dispute avoidance mechanisms within FIDIC-based projects.
- b) **May 2026 - CEAI Eastern Region will organise an online POSH (Prevention of Sexual**

Harassment) Training aimed at strengthening workplace awareness and compliance with statutory guidelines. The programme will address legal obligations, organisational responsibilities, and practical frameworks for creating safe and respectful professional environments.

- c) **June 2026 - CEAI Academy will hold an extended Project Management Professional (PMP) Training Programme in New Delhi**. Designed as a structured learning series, the programme will support professionals preparing for PMP certification while strengthening project leadership and delivery capabilities.

FIDIC GLOBAL INFRASTRUCTURE CONFERENCE 2026

FIDIC Global Infrastructure Conference 2026 will be hosted in **New Delhi, India** from **13th to 15th September 2026**. As FIDIC’s flagship annual event which has been taking place since 1930, the conference provides a global platform for the infrastructure industry to come together to exchange knowledge, share experience and strengthen collaboration across regions.

New Delhi offers a highly relevant setting for the conference, reflecting India’s growing influence and leadership in global infrastructure development. As one of the world’s fastest-growing major economies, India is at the forefront of large-scale infrastructure delivery, innovation and capacity building, making it an ideal location for the global infrastructure community to meet.

FIDIC’s flagship annual event brings together the full spectrum of the infrastructure industry, including clients, governments, policy makers, consulting engineers, contractors, lawyers, financiers and architects. The conference offers high-level dialogue, knowledge sharing and valuable networking opportunities with peers and partners from across the globe.

Registration is Open for the FIDIC Global Infrastructure Conference 2026!

Join global leaders of the infrastructure sector in New Delhi, India, during 13th to 15th September 2026 for one of the industry's most influential gatherings.

Under the theme *Engineering a Bright Future, Together: Quality Infrastructure for People and Prosperity*, the conference will bring together industry leaders, policymakers, financiers and engineers from over 100 countries to address the most pressing challenges in infrastructure delivery.

Learn more and register <https://lnkd.in/eTdwMPVA>

VIEWPOINT JUNE 2026

The themes for the quarterly issues of CEAI's magazine "ViewPoint" for the balance period of 2026 are given below:

June 2026	Climate Change, Urban Flooding, and Landslides
September 2026	Urban Rejuvenation - A Tech-Enabled Approach
December 2026	Smart Cities or Smart Villages: Where Should India Invest More

The theme of the June 2026 edition of ViewPoint is '*Climate Change, Urban Flooding, and Landslides*' - a subject that needs to be taken cognisance of with a sense of urgency and to reflect on "*What kind of 'Earth' and 'Life' are we leaving for posterity*"?

Human activity has significantly increased greenhouse gas emissions through the rampant use of fossil fuels, large-scale deforestation, unbridled urbanisation and rising pollution levels – all contributing to global warming and increasing unstable weather patterns. These manifest themselves in more intense and unpredictable rainfall.

At the same time, the loss of wetlands and natural water bodies, combined with poorly planned urban growth, has replaced absorbent soil with impervious paved

surfaces. Blocked or inadequate drainage systems further aggravate the problem, preventing rainwater from being absorbed or channelled away effectively and leading to frequent urban flooding.

Similarly, excessive deforestation and unregulated construction in ecologically sensitive regions weaken natural landscapes. The removal of vegetation accelerates soil erosion and destabilises fragile slopes, dislodging soil and rocks and increasing the likelihood of landslides during heavy rainfall.

All Professionals are encouraged to contribute articles on the theme based on their experience/expertise and recommend ways and means to mitigate the damage to the Environment.

Articles (of 1500-3000 words) for the June 2026 edition of ViewPoint need to reach CEAI by 25 May 2026. Articles have to be in MS Word - Times New Roman 12 with single line spacing with before and after 6 pt and normal margin, on A4 size. A recent, clear and bright passport-size photograph on a plain light-coloured background of the author(s) is to be sent along with the article. For details of formatting, please refer to 'Format for Articles for CEAI Viewpoint' on CEAI's website, under 'Publications'. The 'CEAI Conditions of Publication' can also be seen on the website.

Advertisement in ViewPoint

ViewPoint is circulated to all CEAI Members, FIDIC, Ministries of the Government of India, Public and Private Sector Undertakings, Construction Firms, Contractors, Consultants, Foreign Missions, Multilateral Funding Agencies in India, and other organisations related to or dealing with the engineering profession. Thus, all stakeholders partnering in development and progress are its readers.

Support from CEAI members and stakeholders is sought for increasing the number of advertisements, so that ViewPoint gains in its stature as a unique Technical Publication for the fraternity and the public

at large to disseminate information on how Consulting Engineers are helping society improve the quality of

assets created and are doing so sustainably. The rates for advertisements in ViewPoint are given below:

1) ViewPoint Advertisement Rates:

Item	Rate Per issue* (INR)	Discounted rate 10% for 2 consecutive issues* (INR)	Discounted rate 20% for 4 consecutive issues* (INR)
Back Cover	25,000.00	45,000.00	80,000.00
Inside Front Cover	18,000.00	32,400.00	57,600.00
Inside Back Cover	18,000.00	32,400.00	57,600.00
Full Page (Colour)	12,000.00	21,600.00	38,400.00
Full Page (Colour), if a specific page position is required	14,000.00	25,200.00	44,800.00
Full Page (B&W) (Conditions Apply)	8,000.00	14,400.00	25,600.00

Notes: *GST @ 5% or as prescribed will be added to the above rates

2) ViewPoint Sponsor Advertisement:

ViewPoint Sponsor Advertisement per issue for “Theme Specific Solution Providers/ Experts”, the Rate will be Rs. 35,000/-. CEAI will provide the following:

- Mention on the front cover
- Two full-page colour advertisements
- A descriptive article by the Sponsor on the theme (not to exceed 300 words)

NHAI Refines Contractual Safeguards in Standard Bidding Documents

The National Highways Authority of India issued Policy Circular No. 11.84/2026 dated February 13, 2026, amending key provisions on bid security, performance security, and dispute resolution in its standard bidding documents. The circular permits Insurance Surety Bonds as an alternative to bank guarantees and revises the Additional Performance Security (APS) framework for low bids. It also directs disputes below ₹10 crore to institutional arbitration and higher-value disputes to conciliation under the Arbitration and Conciliation Act, 1996, strengthening risk management and dispute resolution in NHAI contracts.

Source: NHAI

Tech Quiz

1. **A fully mechanised composting plant involves**
 - a) mechanized receipt
 - b) mechanized segregation
 - c) mechanized pulverising of refuse
 - d) all of these
2. **Which of the following solid wastes describes the term ‘Municipal Solid Waste’?**
 - a) Toxic
 - b) Hazardous
 - c) Non-toxic
 - d) Non-hazardous
3. **Why is recycled paper banned for use in food containers?**
 - a) Because it creates a lot of spaces
 - b) Because it creates contamination
 - c) Because paper can be used only one time
 - d) Because paper is very thick and can't cover the food containers
4. **The organic material of the solid waste will decompose**
 - a) By the flow of water
 - b) By the soil particles
 - c) By the action of microorganisms
 - d) By oxidation
5. **The burning of solid waste is not recommended because**
 - a) It is very costly
 - b) It requires a lot of space
 - c) It requires modern technologies
 - d) It causes several environmental issues
6. **Find the correct statement**
 - a) The waste from one process becomes the input for another process
 - b) All the processes related to consumption and production produce some kind of waste
 - c) There is no real waste in nature
 - d) All of the above
7. **Which of the following gas is produced from landfill wastes?**
 - a) Biogas
 - b) Natural gas
 - c) Liquified petroleum gas
 - d) All of the above
8. **What is the separation of biodegradable waste from non-biodegradable waste for proper disposal and recycling?**
 - a) Separation
 - b) Segregation
 - c) Removal
 - d) Composting
9. **Which of the following statements is true about zero waste management?**
 - a) Separate collection of each kind of waste
 - b) Segregation of garbage at the source
 - c) Community involvement
 - d) All of the above
10. **Which of the following is the oldest and the most common method used to dump solid wastes?**
 - a) River
 - b) Ocean
 - c) Landfill
 - d) None of the above

The first person to email the correct answers to CEAI info@ceai.org.in will get a congratulatory email and be acknowledged by publishing the person's photograph in the next issue.

Compiled by Rajiv Maini with inputs from Neha Jain

CEAI Answers to Tech Quiz December 2025 issue

1 (b), 2 (b), 3 (a), 4 (c), 5 (d), 6 (b), 7 (c), 8 (d), 9 (c), 10 (a)

TRANSFORMING RAILWAYS

THROUGH EXPERIENCE AND INNOVATION

*India's 1st Private Railway
Engineering Consulting Company*

- Four Decades of Industry Experience
- Proven Success in Timely Delivery of Complex Projects
- Practical Solutions Using Latest Technology
- Strong Commitment to Sustainability
- Comprehensive Services Across Railway Sectors

BARSYL
we innovate



Balaji Railroad Systems Private Limited

"BARSYL Towers", Plot No. 3 Sitaram Nagar, Staff Road, Secunderabad - 500009 Telangana, INDIA.

☎ +91 40 27847804 / 06 ✉ mail@barsyl.in 🌐 www.barsyl.in



With best compliments from

Legacy Law Offices LLP

*Serving the construction and engineering
consultancy industry and aiding:*

PUBLIC PROCUREMENT;
CONTRACT MANAGEMENT; AND
DISPUTE RESOLUTION INCLUDING
ARBITRATION AND LITIGATION.



DELHI

Legacy House
D-18, Nehru Enclave,
Kalkaji, New Delhi – 110019
(India)
Phone: 011 - 41752507,
41752508

CHANDIGARH

Legacy House
#333, Sector 4,
MDC, Panchkula-134114
(India)
Phone: 0172 - 4801333,
4802333

MUMBAI

Office No. 307, 3rd Floor,
NITCO BIZ- Park, Plot No. C-19,
Road No. 16- U, Wagle Estate,
Thane (West),
Maharashtra- 400604, India

CONTACT US



MS. VANDANA RANDHAWA

☎ Mobile - 7597383993



E - vandana.randhawa@legacylawoffices.com



www.legacylawoffices.com



From a modest beginning in 2002, our qualitative services, dynamic approach and strong work ethic have made us scale new heights everyday. Our vision right from the start is to serve society by contributing our stellar services to its **Infrastructure Development**. We have left a remarkable imprint in the **Road and Highway Sector** over the past two decades. To further our efforts in **conserving energy**, we have two of our ventures, Lion Insulation Pvt. Ltd. and Lion Renewable Energy India Pvt. Ltd. working around the clock. Recently we have forayed into **construction** in Urban Sector & also the **Heavy Industries**. To this day and age, Lion Group is humbled and honoured to have its presence in the **rail, water, urban and defence sector**. We expect nothing less than prospering with the nation in the years to come.

2800+
EMPLOYEES
COUNT

200+
COMPLETED
PROJECTS

26+
STATE
PRESENCE

50+
NO. OF
CLIENTS

Our Ventures



Contact



www.liongroup.in



corporate@liogroup.in



0755 2923961-62



Corporate Office: 'Lion Tower' Plot No. 97, Elegant Estate, Bairagarh Chichli,
Near Holy Cross School, Kolar Road, Bhopal-462042 [M.P.]



TATA CONSULTING ENGINEERS
ENGINEERING A BETTER TOMORROW™

ENGINEERING A BETTER TOMORROW

Established in 1962, Tata Consulting Engineers Limited (TCE) is India's leading **Integrated Engineering Consultant** providing **Concept to Commissioning services**. With **12,000+ projects delivered** in **65+ countries**, the Company has recorded a tremendous growth in **revenue of 49%** this year.

The Company is amongst the **top 2 consultants** in its core sectors – **Power, Infrastructure, Hydrocarbons & Chemicals** and **Metals & Mining**. It is powered by its people's **solid knowledge base and technical expertise**, helping it deliver several one-of-its-kind projects.



SECTORS WE SERVE



POWER

Nuclear, Hydroelectric, Renewable, Thermal, Transmission & Distribution, Advanced Facilities



HYDROCARBONS & CHEMICALS

Green & Sustainable Chemicals, Chemicals & Speciality Chemicals, Refineries & Petrochemicals, Agrochemicals & Fertilisers, Advanced Facilities



MINING & METALLURGY

Ferrous Metals, Non-Ferrous Metals, Mineral Beneficiation, Advanced Facilities



INFRASTRUCTURE

Water, Built Environment, Transportation, Sustainable Infrastructure, Advanced Facilities

SERVICES WE OFFER

DESIGN & ENGINEERING

Project Concept Development, Pre-feasibility & Feasibility Reports, Detailed Project Reports, Environmental Study Reports, System Studies, Basic Engineering, Frontend Engineering Design (FEED), OE Services, Detailed Engineering

SUSTAINABILITY AND ENERGY TRANSITION SOLUTIONS

Clean and Renewable Energy, Green Infrastructure, Green Fuels and Chemicals, Green Steel & Cement, Energy Transition Technologies

PROJECT MANAGEMENT & SAFETY

Owner's Engineer & Project Controls, Engineering, Procurement, and Construction Management, Construction Management and Supervision, Project Management Program Management, Inspection and Expediting, Safety and Quality Management, Outage & Opex Management, Procurement Management

DIGITAL & ADVANCED TECHNOLOGIES

Unified 3D Engineering, 4D, 5D Simulation, Building Information Management, Asset Digitisation & Asset Information Management, Industry 4.0 & Asset Performance Management, Product Engineering - Design and Analysis, Turnkey Machine Development



To know more, visit

 www.tataconsultingengineers.com

or send an email to

 tceconnect@tataconsultingengineers.com

Scan Me to
Know More



- **Module I : Practical Use of FIDIC Conditions of Contract**
- **Module II : Management of Claims and Disputes Resolution**
- **Module IV : Contract Management and Administration**



The investment in infrastructure is growing and would continue to grow at an accelerated rate in the near and distant future across the Globe and especially in a developing economy like India. The multilateral financial institutions are pouring in funds and want to be a part of the India growth story. These MDBs invariably use the FIDIC Conditions of Contract which are acclaimed as the Gold Standard of Conditions of Contract Globally.

The FIDIC Conditions of Contract are being used the world over where multi-lateral development banks provide the funding. And in large complex Government projects.

With a number of large and complex projects BOTH on-going and planned in the country, these training courses will bring the participant the necessary detailed knowledge and insights as to the claim management and dispute resolution provisions under the FIDIC Conditions of Contract.

It covers the identification of project risks, their allocation, and the various causes of claim which can emerge over a construction contract and the way FIDIC addresses those. It details the way to handle claims - preparation, submission, assessment, determination under FIDIC Contracts, and how disputes are prevented or otherwise resolved.

Certificate

After successful completion of the training, participants will receive FIDIC Certification.

**The comprehensive program on
FIDIC Contracts led by accredited trainers**

